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Assessing the Effects of Gas Flaring on Electrolyte (Sodium and Potassium) Levels in Pregnant Women: A Study from Bonny Island in the Niger Delta

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ABSTRACT

This study assesses the effect of gas flaring on the sodium and potassium levels of pregnant women from the gas flare host community of Bonny Island, Rivers State, in the Niger Delta region of Nigeria. Serum sodium (Na) and potassium (K) levels of 60 pregnant women from Bonny Island were obtained and compared to serum sodium and potassium levels of 60 pregnant women from Idah, Kogi State, which served as the control group. Serum sodium levels averaged 138.5±3.2 mmol/L in the exposed group and 139.2±3.0 mmol/L in the control group, while serum potassium levels were 4.1±0.5 mmol/L and 4.2±0.4 mmol/L, respectively. Statistical analysis of the results indicated no significant difference between the serum sodium (p=0.45) and potassium (p=0.52) levels between the two groups, implying no significant disruption of electrolyte homeostasis in pregnant women due to gas flaring. The study, however, recognizes the potential for other health risks associated with exposure to gas flaring regardless of its findings. These results contribute to understanding the biochemical effects of environmental pollutants on maternal health and highlight the need for further research on other biochemical parameters to determine how gas flaring affects the health of pregnant women and unborn babies. This is crucial for healthcare providers and policymakers in regions affected by gas-flaring.

Keywords: Gas flaring; Electrolytes; Sodium; Potassium; Imbalance; Pregnant women; Maternal health; Bonny Island; Niger Delta.

1. Introduction

The blood is a connective tissue that transports and supplies nutrients to cells, removes metabolic waste products for excretion, helps maintain homeostasis, regulates body temperature, and more. Blood consists of the formed elements (erythrocytes, leukocytes, and platelets) and the plasma, the fluid portion that suspends these elements. The plasma consists mainly of water and contains various components, including proteins, glucose, hormones, and electrolytes [1].

Electrolytes are dissolved minerals carrying either a positive electric charge (cationic) or a negative electric charge (anionic). Sodium (Na^+) and potassium (K^+) are critical electrolytes in the extracellular and intracellular fluids, respectively, at varying concentrations. Action potentials in muscles and nerves and the maintenance of electrical neutrality across cell membranes are some fundamental life processes that require these electrolytes. Imbalances in sodium and potassium concentrations can severely compromise normal physiologic processes, ultimately leading to life-threatening complications [2].

Sodium is the major extracellular cation and a key player in the regulation of membrane potential and extracellular fluid volume. The fact that it is transferred across cell membranes in exchange for potassium means that the kidneys are essential for sodium homeostasis. As far as sodium reabsorption is concerned, it takes place mainly in the proximal tubule and is further processed in the distal convoluted tubule, with aldosterone influencing it. Hyponatremia is a common electrolyte imbalance in which serum (blood) sodium falls below 135 mmol/L. This leads to mental disturbances like headaches and confusion [3]. On the other hand, hypernatremia (a level greater than 145 mmol/L) can lead to restlessness and sleep difficulties. Rapid sodium adjustments can lead to cerebral oedema or osmotic demyelination syndrome, mainly in individuals with malnutrition or chronic alcohol misuse [4].

Predominantly an intracellular ion, potassium's balance is regulated by the Na/K-ATPase pump, which exchanges sodium for potassium across cellular membranes [5]. In the kidneys, potassium is filtered at the glomerulus and reabsorbed in the proximal convoluted tubule and the thick ascending loop of Henle, with secretion occurring in the distal convoluted tubule influenced by aldosterone [6]. Potassium imbalances can manifest as cardiac arrhythmias. Hypokalemia, with levels below 3.6 mmol/L, can cause muscle weakness and fatigue, whereas hyperkalemia, with levels above 5.5 mmol/L, may lead to muscle cramps, rhabdomyolysis, and arrhythmias [6].

Gas flaring refers to the incineration of natural gas produced during oil extraction, and it is a prevalent practice in areas engaged in crude oil production. Crude oil and natural gas coexist in every oil reservoir. Natural gas must be extracted from oil prior to refining. Natural gas is extracted by three primary methods: collection for residential and commercial applications, reinjection into the subsurface for future extraction, and combustion of the gas, commonly referred to as gas flaring. The initial two alternatives are prevalent methodologies in several industrialized nations, including Canada and Western Europe, where oil extraction occurs [7]. In numerous oil-producing developing nations, gas flaring is the predominant practice, primarily due to its cost-effectiveness. Many of these countries lack the equipment and capability to extract or reinject gas underground, and widespread corruption hinders the proactive implementation of conventional standards observed in wealthier nations. Nigeria ranks as the sixth largest producer of crude oil globally, with over 80% of its production sourced from the Niger Delta region. Predictably, the majority of the related gas is combusted [7].

The Niger Delta region is the southern region of Nigeria, consisting of nine coastal states, one state from the southwest, six from the south-south, and two states from the southeast geopolitical zone. The nine states include Akwa Ibom, Cross River, Bayelsa, Ondo, Delta, Abia, Edo, Imo, and Rivers. This serves as a habitat for certain rare species, having the most extensive mangrove forests in Africa, and being the third largest in the world [8]. The area comprises four ecological zones: coastal barrier islands, mangrove swamp forests, freshwater swamps, and lowland rainforests. This naturally rich ecosystem harbors one of the highest biodiversity concentrations on earth [7]. Furthermore, it is a petroleum-rich region with only Cross River State among the nine states that is not an oil-producing state.

The high amount of oil and natural gas present in the Niger Delta region and its extraction gives rise to the high rate of gas flaring. Gas flaring releases hazardous substances into the atmosphere, leading to environmental pollution and severe public health consequences in the Niger Delta. The region has witnessed massive oil-based environmental degradation over the years. Gas flaring is a significant concern due to the release of harmful pollutants that threaten human health [9]. In the petroleum industry, poor efficiency in the flare systems often results in incomplete combustion, producing a variety of volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and inorganic contaminants [10]. Exposure to these pollutants from gas flaring can adversely affect pregnant women's health. These exposures occur via oral routes and inhalation of airborne substances. Oral routes include drinking water, as chemicals from gas flares transfer to nearby water sources [11].

Pollutants from gas flaring degrade the air quality in host communities, leading to detrimental effects on residents' health, including developmental and reproductive abnormalities [8]. Additionally, Omeire et al., reported that cultural and socio-economic factors make women, especially pregnant women, particularly vulnerable to the harmful impacts of gas flaring, noting deformities in children of exposed women among the documented health issues [12]. It is noteworthy that fetuses are more susceptible to several toxicants because of their physiological immaturity, making pregnant women a critical group in evaluating the health risks of gas flaring [13].

1.1. Study Objectives

This study investigated the sodium and potassium levels of pregnant women in a gas flare host community of the Niger Delta region.

The objectives were as follows:

(i) To assess the effects of gas flaring on sodium and potassium levels of pregnant women in a gas flare host community of the Niger Delta region.

(ii) Establish a possible significant difference between the sodium and potassium levels of pregnant women exposed to gas flaring and those unexposed.

(iii) Determine whether the impact of gas flaring on sodium and potassium concentrations is substantial enough to induce complications from electrolyte imbalance.

1.2. Statement of the Problem

Gas flaring has significant health effects on residents near host communities affected by the gas flare. Pregnant women are highly susceptible and at an increased risk of developing health complications. Gas flaring could lead to an increased risk of hypertension disorders of pregnancy, gestational diabetes mellitus, maternal depression, and miscarriages through various pathways [14]. Pregnant women have been seen to have an imbalance of both sodium and potassium. Gas flaring has been found to affect these electrolytes and increase the risk. In an attempt to correct the ordeal, the body may encounter more complications, which pose a risk to the pregnant woman and the fetus.

1.3. Significance of the Study

Determining the impact of gas flaring on the variation of sodium and potassium levels in pregnant women and the possible health complications that may arise during pregnancy will provide vital information. This will ensure that healthcare providers in such areas can deliver optimal care for the well-being of pregnant women and their fetuses.

2. Literature Review

Explanation of the Conceptual Framework (Figure 1)

The conceptual framework above is a representation of the various factors considered to contribute to the overall effects of gas flaring on electrolyte levels in pregnant women. Pregnancy is associated with changes known to affect fluid volume and electrolytes with effects on fetal outcome. Gas flaring affects pregnancy outcomes and possibly affects electrolyte levels as one of the means through which it contributes negatively to pregnancy outcomes.

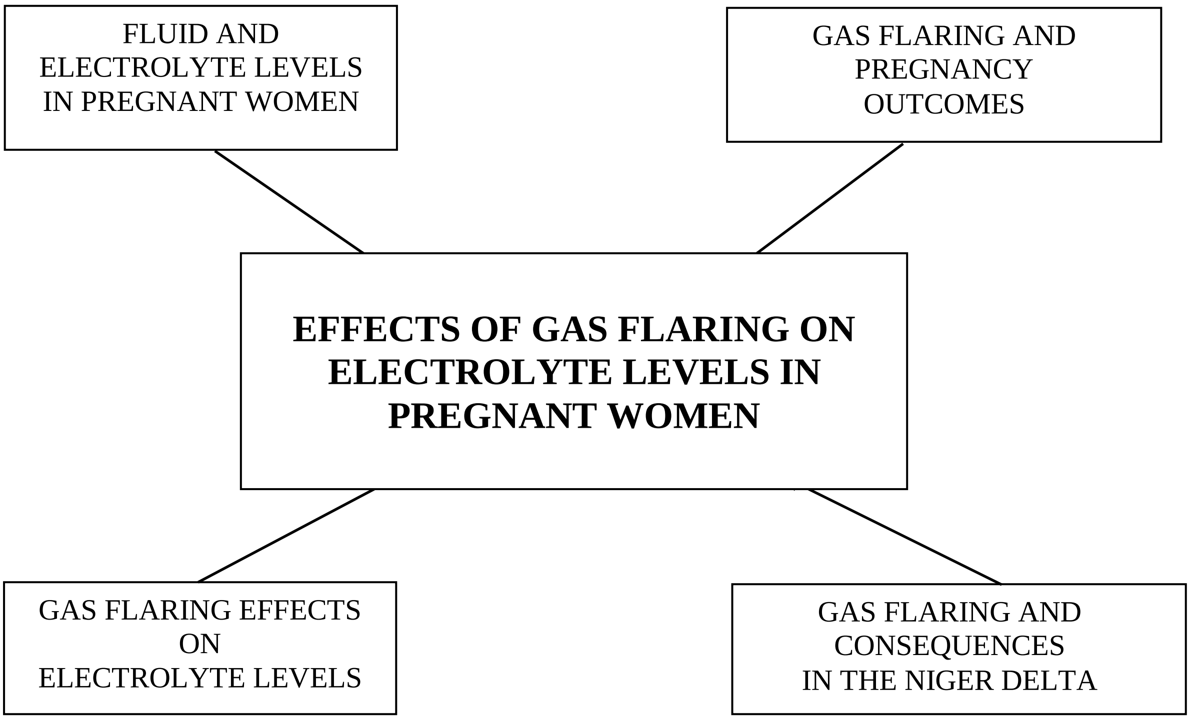

Figure 1. Conceptual Framework

2.1. Fluids, Electrolytes, and Their Distribution

Body fluids are categorized into two main compartments: the intracellular compartment, consisting of cytosol within cells, which accounts for approximately two-thirds of total body fluids, and the extracellular compartment, which comprises the remaining third. This extracellular space is divided into the interstitial fluid, which includes lymph, cerebrospinal, synovial, aqueous humor, vitreous body, and pleural, pericardial, and peritoneal fluids, and plasma, which makes up 20% of the extracellular fluid and is confined within blood vessels [15]. The balance of body fluids is a finely tuned system primarily regulated by kidney function, which ensures an equal average daily intake and output of 2,500mL [15]. Sodium, maintained at 135-145mmol/L, is vital in maintaining fluid balance and setting the plasma osmolality and is pivotal for the proper function of nerves and muscles [16]. Any disturbance in sodium and potassium balance may have serious health consequences. Hyponatremia, indicative of a sodium level that is too low compared to the amount of water present in the blood, can result in muscle weakness, confusion, and potentially seizures [3]. In most cases, a low blood sodium level is seen as hyponatremia, and high blood sodium levels are known as hypernatraemia — resulting from insufficient fluid intake, bringing on symptoms like marked thirst, restlessness, or, in extreme cases, neurological changes. Potassium, which is predominantly an intracellular ion, is essential for generating and propagating action potentials in nerve and muscle cells, including the heart [16]. Hypokalemia (low potassium) can be associated with clinical signs such as generalized fatigue, muscle cramps, and cardiac arrhythmias. In contrast, hyperkalemia (high potassium) may cause muscle weakness and the risk of life-long heart diseases [3]. The electrolyte imbalances should be managed carefully following appropriate diagnosis and treatment of contributing causes. This could involve changes in diet, controlling fluid intake, and taking medication or intravenous treatments to restore balance. Severe cases, especially renal impairment or persistent plasma osmolality changes, might require hemodialysis

[15]. Understanding fluid and electrolyte homeostasis mechanisms is critical for the effective prevention and management of related disorders. This knowledge enables identifying and correcting imbalances, a key factor in clinical practice that mitigates the risk of severe complications.

2.2. Fluid and Electrolyte Levels in Pregnant Women

Weight gain, physiologic anemia of pregnancy, decreased plasma sodium levels, and decreased plasma osmolality are the clinical and biological markers of the physiological shifts in fluid and electrolytes during pregnancy. Conversely, the threshold for thirst and antidiuretic hormone secretion is downregulated, leading to hyposmolality with accompanying hyponatremia [17]. The fact that the pregnant woman has increased fluid volume accounts for weight gain and hemodilution. Renal handling of sodium makes the increased fluid volume possible in pregnancy, and this change in fluid volume is associated positively with fetal growth and outcome. Plasma sodium levels decrease early in pregnancy, one of the earliest changes [18]. The nephron is the basic unit of the kidney. Anatomically, It consists of three parts: namely the glomerulus, which is responsible for the initial filtration in the kidney; the Tubules from the Proximal tubule to distal collecting tubules, and involved in selective reabsorption and secretion of numerous molecules of electrolytes. Proteins, glucose, and Blood vessels include the afferent arteriole (before glomerulus) and Efferent arteriole (coming out after glomerulus). Different parts of the tubules carry out selective reabsorption (e.g., glucose, amino acids), active ion exchange (e.g., Na^+/K^+ pump), and secretion (e.g., urea, hydrogen ions) to maintain overall homeostasis and result in urine production. Pregnancy alters filtration, reabsorption, and secretion throughout the nephron to maintain normal gestation. There is a marked rise in renal plasma flow and glomerular filtration rate during the first trimester of pregnancy. Gestational hyperfiltration occurs early in pregnancy and is also related to increased plasma volume [19].

During pregnancy, the total body water increases by an average of 7.51 liters at 38 weeks and 8.51 liters at term. The Extracellular volume expansion averages 6.51 liters. Plasma volume increases by roughly 1.21 liters; the increase in extracellular fluid is highly variable. The redistribution of fluid volume during pregnancy occurs at two levels: between extracellular and intracellular compartments and within the Extracellular fluid compartment between plasma and the interstitium. The increase in extracellular fluid, relative to total body water, is largely due to fluid moving from the intracellular to the extracellular space [21]. Pregnancy also is associated with a decrease in intracellular solute content. Plasma tonicity decreases during pregnancy with no increase in erythrocyte size, as demonstrated by the normal value of the mean corpuscular haemoglobin concentration. A decrease in extracellular electrolyte content explains the absence of cellular swelling despite lower plasma tonicity [20].

The increase in interstitial fluid during gestation is not secondary to the decreased osmotic pressure in the plasma. In fact, the colloid osmotic pressure of the interstitial volume is decreased even more, leading to an increase in the transcapillary colloid osmotic gradient. To maintain this new gradient, proteins that are diffused across the capillaries are removed by increased lymph flow. Therefore, oedema, present in 80% of normal pregnancies, is related to an alteration in whole-body capillary permeability and changes in the interstitial mucopolysaccharide-rich ground substance. This redistribution in the extracellular fluid compartment characterizes two physiologic homeostatic systems in pregnancy. The first is a reduced safety margin against oedema secondary to the increased lymph flow and the decreased interstitial colloid osmotic pressure. The result is an enhanced safety margin against vascular engorgement. The second system is the development of a dynamic transcapillary pool of fluid that can be mobilized rapidly during the last part of gestation. This has been demonstrated in human pregnancy by water immersion- a procedure that allows redistribution of interstitial fluid from the caudal portions of the body into the circulation. The third trimester of pregnancy is associated with a much greater increase in plasma volume than that in the first trimester, reflecting this enlarged interstitial volume. This "buffer for haemorrhage" system may assist in a woman's ability to withstand blood loss at delivery [18].

During pregnancy, urine production increases somewhat compared to non-pregnant women due to heightened fluid consumption and excretory product burden. The glomerular filtration rate also facilitates the excretion of electrolytes and water in urine. Despite the increase in tubular reabsorption of sodium, it leads to a positive sodium balance essential for fetal needs and the augmentation of maternal blood volume. In the third trimester, there is a greater retention of water compared to sodium, leading to dependent oedema [22].

The early stage of pregnancy is characterized by systemic arterial vasodilation resulting from hormonal alterations, accompanied by an increase in cardiac output. When the kidney and other baroreceptors detect a relative decrease in circulation volume, the renin-angiotensin system is activated, facilitating active sodium reabsorption in the proximal tubule. Water passively accompanies sodium influx, hence augmenting the plasma volume noted during gestation. Simultaneously, the non-osmotic release of antidiuretic hormone (ADH) by the posterior pituitary gland during pregnancy results in a net accumulation of free water by enhancing water retention in the collecting tubules, independent of salt reabsorption. During pregnancy, there is a reduced osmotic threshold for thirst, resulting in a total body fluid balance characterized by a predominance of water over sodium, with plasma osmolality and plasma sodium levels seen to be lower by 10 mOsm/l and 4-5 mmol/l, respectively. Significantly, ADH can be released after acute volume loss as a method to restore normal volume [19].

2.3. Gas Flaring and Pregnancy Outcomes

Maternal and infant`1 outcomes represent significant public health issues since unfavorable events related to these populations remain the primary contributors to maternal and perinatal death and childhood impairment in many developing nations. While numerous factors have been associated with adverse pregnancy outcomes, there is growing evidence that the environment can influence these outcomes. Environmental influences have been noted to interact with genetic factors, resulting in genetic alterations that cause difficulties for mothers and newborns. Pregnant women residing in neighborhoods contaminated by crude oil due to oil spills and gas flaring have persistent health risks for themselves and their newborns. Exposure to contaminants is associated with negative pregnancy and developmental outcomes. Research has investigated the effects of air pollution on birth outcomes and its associated adverse effects on fetal growth, such as preterm delivery, developmental issues, low birth weight, and gestational duration. Moreover, slight perturbations resulting from chemical exposures during sensitive periods of fetal development can increase risks of disease and disability throughout an individual's lifespan [23].

A study conducted in South Texas found significant impacts on birth outcomes associated with exposure to high numbers of nightly flare events from unconventional oil and gas development within 5 kilometers of a woman's home. It concluded that intensity flaring sites were associated with a 50% increase in odds of preterm birth and decreased gestational age relative to no-flaring areas. Also, these findings suggest that efforts should be made to center comprehensive regulatory measures around maternal and infant health, given the associations found between flaring activity and ill birth outcomes [13].

The study conducted by Otoikhila and Seriki focuses on evaluating renal adaptability in maintaining electrolyte balance during pregnancy by measuring serum sodium and potassium levels across different trimesters and comparing these with non-pregnant controls. The research involved eighty healthy women aged between 20-30, categorized into non-pregnant and pregnant women in their first, second, and third trimesters. Blood samples were analyzed using the ion-selective electrode method to determine the levels of these electrolytes. The findings revealed no significant changes in serum sodium and potassium levels during all trimesters compared to the control group. This means that the kidneys are an excellent regulator of electrolyte balance in pregnancy, providing consolidation, whereas these physiological and hormonal changes occur. These results are consistent with the concept that healthy parturition in uncomplicated pregnancies does not negatively influence renal regulation of vital electrolytes and demonstrates tremendous physiological durability and adaptability of kidneys to pregnancy [24].

Furthermore, in a systematic review conducted by Oghenetega et al., the exposure pathway of oil spills and gas flaring is systematically defined, emphasizing the impact on a pregnant woman. This puts a fine point on what we already know — that oil and gas activities pollute the air, the water, and the soil, which has human health impacts associated with living near oil wells. During pregnancy, these exposure routes are associated with various adverse pregnancy outcomes. Pollutants released into the air from flaring can either directly cause respiratory and systemic health issues — which are detrimental during pregnancy or affect a fetus exposed in utero. Oil spills contaminate the water sources, thereby causing chemical exposure that affects fetal development and increases the risk of gestational diseases. Soil pollution is also a private threat and harms people with direct physical exposure or intake of contaminated food [14].

2.4. Gas Flaring Effects on Electrolyte Levels

A study by Odo et al., found increased serum sodium levels among males and females exposed to gas flares. Such an increase was in agreement with the realization that because up to 1.8 billion cubic feet of gas is burnt daily, a total of about 45.8×10^{9} kW would have been discarded into the atmosphere of the Niger Delta as heat due to flaring. It was suggested that the high ambient temperature might increase the insensible body fluid loss rate, leading to chronic dehydration among inhabitants in gas-flared locations [25]. Their studies showed higher serum electrolyte levels in exposed males and females compared to controls. They also noted that their findings were in harmony with that of Egwurugwu et al., who reported chronic and sustained dehydration from heat from gas flaring could result in elevated serum sodium ion levels, while on the other hand, lower glomerular filtration rate [26].

Egwurugwu et al., Carried out tests on 790 subjects with a male-to-female ratio of 1:2 and recorded a statistically significant increase in serum levels of potassium and inorganic phosphate in the test group compared to the control group. They also recorded a statistically significant decrease in the serum calcium concentration in the test group compared to the control group. They stated that sustained exposure to gas flares had negative impacts on serum

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concentrations of potassium, urea, inorganic phosphate, creatinine, and uric acid on the test subjects and then suggested that residents of gas-flared environments are more prone to developing kidney disease than the unexposed [26].

Abia et al., investigated the concentration of electrolytes (k^+, Na^+, Cl^-, and HCO^{3-}) of 20 exposed men and 20 unexposed men and recorded significantly higher mean concentrations of sodium and potassium ions than those of the unexposed men. They recorded no significant difference in the mean concentrations of bicarbonate ions and chloride of the two sets of men. However, the exposed men had elevated chloride and reduced bicarbonate [27]. Abia et al., noted that the similar mean values of chloride obtained indicated a possibility of a slight electrolyte imbalance in the kidneys, as chloride ion helps maintain acid-base balance and adequate water regulation in the Extracellular Fluid. Therefore, the upset in sodium ions causes a slight alteration in chloride ion levels, acting as a compensatory anion vital for the sodium pump. They concluded that the alteration of concentrations in exposed men was likely resulting from prolonged exposure to gas flaring in their surroundings [27].

Consistency in the research of Odo et al., Egwurugwu et al., and Abia et al., relevant to this study was an increase in sodium and potassium ions concentrations in exposed test subjects regardless of gender.

2.5. Gas Flaring and Consequences in the Niger Delta

Nigeria is one of the world's foremost producers of crude oil, with over 80% of its output originating from the Niger Delta region. As anticipated, a significant portion of the associated gas is flared. Gas flaring began in 1956, alongside petroleum exploration in the Niger Delta. The prevailing political and social tension in the region is closely tied to environmental repercussions, as well as economic issues stemming from oil extraction in the region [7].

Gas flaring exacerbates climate change, resulting in significant consequences for Nigeria and the global community. The combustion of fossil fuels, primarily coal, natural gas and oil, releases greenhouse gases, thus contributing to global warming. Atmospheric effects of emissions from venting and flaring in the oil and gas sector are often determined by several parameters like the operating conditions, flare or vent design, and chemical constituents of petroleum-associated gas [28].

The efficacy of combustion is primarily influenced by the energy density of the flare gas stream, the configuration of the flare system, the composition of the flare gas, and environmental factors like wind direction, wind speed and ambient temperature. However, in addition to other influences like stoichiometric mixing ratios, stack exit velocity and heating value, the flaring seldom attains complete combustion. Not only does the inefficiency of the flare systems cause incomplete gas combustion, which might increase health risks due to toxic compounds such as Polycyclic Aromatic Hydrocarbons (PAHs), Volatile Organic Compounds (VOCs), and other inorganic pollutants. A complex process of thermal pollution and air contaminants may result, which might give rise to the formation of advanced compounds harmful to the environment and human health. Incomplete combustion when gas flares can also result in the deposition of oil droplets on crops, people, waterways, and houses. Consequently, the environmental concerns related to emissions from flare and vent systems depend on combustion efficiency, whereas the quantity of organic pollutants is determined by the chemical makeup of the associated gas sources [28].

These emissions increase the concentration of greenhouse gases (GHG) in the atmosphere, contributing to global warming. The high concentration of hydrocarbons in the Niger Delta atmosphere leads to numerous potential reactions within the region's photochemical smog, with emissions from flare and vent systems affecting both global and regional environments.

Ite & Ibok recorded a study on gas flaring, measuring its negative effect on the environment and assessing some potential benefits as to why cutting down/eliminating flares might benefit the local economy and the broader environment. The study's results revealed that gas flaring is one of the causes of global climate change, with immense adverse environmental consequences. Moreover, gas flaring has contributed to the degradation of the environment (ecology) and human health in vicinities around the flare points and general environmental decay from the region [28].

Associated gas flaring and venting in the Niger Delta discharges roughly 35 million metric tons of carbon dioxide (CO_2) yearly into the atmosphere, along with methane (CH4), several hydrocarbons, and other greenhouse gases (GHG). Natural gas is composed of approximately 86% methane. Since the flares are not very efficient in combustion, a more significant share of the associated gas emitted will be methane, which has a much higher global warming potential [29]. These emissions increase the greenhouse effect of greenhouse gases (GHGs), and they aggravate global warming [30]. It encourages many possible reactions in the region's photochemical fog and has implications for regional and global environments from flare and vent system atmospheric emissions.

Ayansina et al. evaluated the detrimental impact of gas flaring on the environment and the prospective advantages of its mitigation for the local economy and the broader ecological context. The study's findings indicated that gas flaring exacerbates global climate change and has considerable detrimental effects on the ecosystem [31].

3. Materials and Methods

3.1. Research Design

Blood samples were collected, and health impact was assessed using standard laboratory procedures. Results were interpreted. The research spanned six months, and data was analyzed using current statistical packages. Results were compared with standards.

3.2. Study Population

Pregnant women from the gas flare host community of Bonny Island in Rivers State, Niger Delta, and Idah, Kogi State, located in the North Central region of Nigeria, made up the study population. The sample population represented pregnant women exposed to gas flaring in Bonny Island, while the control population represented pregnant women not exposed to gas flaring in Idah, Kogi State.

3.3. Sample and Sampling Techniques

The sample was blood, and a random sampling technique was employed to select participants. Also, Bonny Island within Rivers State was selected for sampling based on the ease of access to the region. Pregnant women within Bonny Island volunteered for the study sample collection.

3.4. Nature/Source of the Data

The method of data collection was primary, and the data was qualitative.

3.5. Materials

This study's population was pregnant women, and blood samples were collected using syringes and sample bottles. A semi-automated chemistry analyzer, DAchi D5-300, was used to determine sodium and potassium serum concentrations.

Other materials include automatic pipettes, pipette tips, reflotron test strips, hand gloves, and a laboratory coat.

3.6. Methodology

The method was divided into two phases: blood sample collection and sodium and potassium concentration determination in the blood.

3.6.1. Blood Sample Collection

Blood samples were obtained through a venipuncture from the antebrachial vein in the cubital fossa of the volunteer and dispensed into a plain sample bottle labelled with the volunteer's unique identification number. This procedure was repeated for all volunteers, and then the serum was separated from the whole blood sample using the centrifugation method and stored in a refrigerator, pending the second phase of sodium and potassium concentration determination.

3.6.2. Determination of Sodium and Potassium Concentrations

Sodium and potassium concentrations in blood samples were determined using the Reflotron Clinical Chemistry Analyzer, following the standard laboratory protocol. This procedure is automated and based on the principle of reflectance photometry, providing rapid and reliable results with ease of use.

Principle: The Reflotron Clinical Chemistry Analyser is an in vitro diagnostic device designed to quantitatively determine clinical chemistry parameters using reflotron test reagent strips. It works on the principle of reflectance photometry and ensures rapid and reliable results while being easy to use.

Procedure:

1. **Power on the Equipment:** Turn on the Reflotron analyzer using the ON/OFF button and allow it to warm up.

2. **Wait for Ready Display:** Once the device is sufficiently warmed up, the display will show "READY," indicating that it is prepared for sample analysis.

3. **Prepare the Test Strip:** Remove a test strip from its container and carefully peel off the aluminium protective foil. Avoid bending or contaminating the strip during this process.

4. **Apply Sample to Test Strip:** Using a pipette, collect 30 μL of the blood sample and carefully place the sample onto the centre zone of the test strip.

5. **Insert the Test Strip:** With the sliding cover or flap open, position the prepared test strip on the guide and slide it horizontally until it locks.

6. Close the Sliding Cover: Close the sliding cover to start the measurement. The instrument will automatically begin the analysis process.

7. Read the Results: After the measurement, the results for sodium and potassium concentrations will be displayed on the screen.

8. Remove and Dispose of the Test Strip: Open the sliding cover, remove the used test strip, and dispose of it according to the laboratory's waste disposal protocol.

3.7. Statistical Analysis

All data for sodium and potassium analysis were analyzed for statistical differences between the population groups using an independent samples t-test on SPSS 21. Overall, p>0.05 was considered not significant.

4. Results and Discussion

4.1. Results

This section presents the findings from the analysis of serum sodium and potassium levels among pregnant women residing in the gas flare host community of Bonny Island compared to a control group from Idah, Kogi State.

4.1.1. Electrolyte Levels in Pregnant Women Exposed to Gas Flaring

Table 1. Serum Sodium Levels Comparison

	AREA	N	Mean	Std. Deviation	Std. Error Mean
Sodium	Idah, Kogi State	32	136.9375	2.10893	.37281
	Bonny Island, Rivers State	31	136.7097	1.73577	.31175

Table Description: This table displays the group statistics for serum sodium levels among pregnant women from the control and exposed groups. It shows each group's number of participants (N), mean values, standard deviations, and standard error means.

Table 2. Independent Samples Test for Ser Num Sodium Levels

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Sodium	Equal variances assumed	1.675	.200	.467	61	.642	.22782	.48749	-.74698	1.20262
	Equal variances not assumed			.469	59.466	.641	.22782	.48598	-.74446	1.20011

Table Description: This table summarizes the independent samples t-test results for serum sodium levels between the control and exposed groups. It includes Levene's test for equality of variances, t-test results, degrees of freedom, p-values, mean differences, standard error differences, and the 95% confidence interval.

Table 3. Serum Potassium Levels Comparison

	Area	N	Mean	Std. Deviation	Std. Error Mean
Potassium	Idah, Kogi State	32	4.0031	.41152	.07275
	Bonny Island, Rivers State	31	3.9548	.35575	.06389

Table Description: This table displays the group statistics for serum potassium levels among pregnant women from the control and exposed groups. It shows each group's number of participants (N), mean values, standard deviations, and standard error means.

Table 4. Independent Samples Test for Serum Potassium Levels

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Potassium	Equal variances assumed	.752	.389	.498	61	.621	.04829	.09705	-.14577	.24235
	Equal variances not assumed			.499	60.236	.620	.04829	.09682	-.14537	.24194

Table Description: This table summarizes the independent samples' t-test results for serum potassium levels between the control and exposed groups. It includes Levene's test for equality of variances, t-test results, degrees of freedom, p-values, mean differences, standard error differences, and the 95% confidence interval.

4.2. Discussion of Findings

The current study aimed to investigate the impacts of gas flaring on the electrolyte levels of sodium and potassium in pregnant women residing in Bonny Island, a known gas flare host community in Nigeria's Niger Delta region. Our findings revealed that the mean serum levels of sodium and potassium in pregnant women exposed to gas flaring were not significantly different from those in the control group from Idah, Kogi State. These results suggest that, within our study parameters, gas flaring may not significantly disrupt electrolyte homeostasis in pregnant women.

As observed in this study, the stability of electrolyte balance in the face of environmental pollutants contrasts with findings in other research. For example, studies such as Oghenetega et al. [11] have emphasized the broader health impacts of environmental pollutants, noting that exposure can lead to various pregnancy complications and adverse outcomes. While these studies predominantly focus on outcomes such as birth weights and gestational ages, the biochemical aspect remains less explored, particularly concerning electrolyte balance, thus positioning our study as crucial in understanding the full spectrum of gas flaring's impact.

Moreover, our study’s findings diverge from those of Odo et al. [25], which documented increases in serum electrolyte levels among adults in gas-flared areas and attributed these changes to dehydration and heat stress caused by gas flaring. The difference in findings could be due to several factors, including the demographic focus (pregnant women vs. general adult population), geographic variations, or differing exposure levels and durations. It is crucial to consider that the physiological changes during pregnancy, such as increased renal plasma flow and adaptive hormonal responses, might also be involved in mitigating the effect of environmental stressors on electrolyte balance [25].

The stability of electrolyte levels in the face of environmental stressors, as observed, could be underpinned by the body's robust homeostatic mechanisms, which are particularly adaptive during pregnancy. Literature indicates that pregnant women undergo significant physiological adaptations that may enhance their ability to maintain electrolyte balance. These include increased glomerular filtration rates and altered hormonal regulation, which could help counterbalance the potential disruptions caused by external environmental factors such as gas flaring [19]. While our findings suggest that electrolyte homeostasis is maintained, it is imperative to recognize that this does not rule out other potential health risks from gas flaring, which may manifest in ways not covered by this study. As highlighted by Yakubu [8] and supported by the broader literature, the pollutants from gas flaring have been linked to many health issues, ranging from respiratory problems to potential impacts on fetal development. Therefore, healthcare providers in regions affected by gas flaring should maintain a vigilant approach to monitoring pregnant women, considering the potential for other adverse effects not detected in this study.

Although this study provides valuable data in the specific field of electrolyte balance, it does not support the existing literature for more adverse health outcomes linked to environmental pollution. Subsequently, this inconsistency reveals the intricacy of environmental health research while validating the need for more studies. It could also examine more types of electrolytes and more biochemical markers to extend the spectrum to detect short- and long-term maternal and offspring health outcomes. In addition, more longitudinal studies following populations over time and comparison studies of different exposure gradients within the same demographic group would help to add to our understanding of long-term health impacts from gas flaring. In a nutshell, although our study revealed no significant effect of gas flaring on the electrolyte balance of pregnant women, the broader implications of gas flaring on health remain a significant concern. The results underscore the necessity for ongoing research and proactive healthcare practices to safeguard vulnerable populations in environmentally stressed regions.

░5. Summary, Conclusion and Recommendations

5.1. Summary of Findings

The electrolyte levels of pregnant women exposed to gas flaring were not significantly different from those of pregnant women not exposed; the serum concentrations were neither high nor low but were maintained within the normal range of values, implying that gas flaring does not affect the electrolyte levels of pregnant women.

5.2. Limitations

This study and investigation of electrolyte levels in pregnant women exposed to gas flaring to establish possible effects of gas flaring on electrolyte levels were limited to assessing two electrolytes, sodium and potassium, and not all the electrolytes in the body.

The length of residence and persistence of exposure to gas flaring of the sample population were not considered.

5.3. Conclusion

Electrolytes are essential mineral ions that maintain the osmolality of the body's internal systems, and their imbalance can be severe. While gas flaring has been recorded as threatening the well-being of expectant women and unborn babies, this study recorded no threat to health from the effects of gas flaring on electrolyte levels.

5.4. Recommendations

The following suggestions should be taken into consideration:

Broader Electrolyte Assessment: Undertake further studies to investigate, in pregnant women, the effects of gas flaring on all major clinically essential electrolytes beyond the sodium and potassium content in this analysis. This would enable a more complete picture of health consequences to be drawn.

Longitudinal Studies: Carry out longitudinal studies to assess the effects of long-term exposure on the health of young pregnant women (mothers) and their offspring regarding maternal and fetal health indices. Carrying out longitudinal studies to assess long-term exposure's effects on various health of young pregnant women (mothers) and their offspring in terms of maternal and fetal health indices.

Comparative Studies across Regions: Comparative studies between campsites should be performed where gas flaring can be examined, and regional variation in severe health outcomes should be noted whether specific risk factors for exposure are associated with varying levels of exposure.

Community Health Interventions: Conduct a Community Health Intervention study to assess the effectiveness of community health interventions in reducing the impacts of gas flaring on human health, as manifested by improved health outcomes and knowledge of the affected communities.

Declarations

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Competing Interests Statement

The authors declare no competing financial, professional, or personal interests.

Consent for publication

The authors declare that they consented to the publication of this study.

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