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Article

Risk Assessment of Gas Station

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Abstract: Objective: The report provides an analysis and assessment of gasoline concentration released at different gas stations using various analytical methods. **Methods:** The analysis incorporates trend analysis, frequency analysis, basic statistics, and interactions affecting the analysis, all conducted using MINITAB. **Results:** The research highlights the increasing concern over benzene gas emissions, which are considered a significant factor contributing to health diseases and are associated with cancer. The investigations show that benzene, an organic compound, is in high demand and is increasing rapidly because of the increasing production of automobiles and industrial usage. Benzene concentrations measured at gas stations were between 0.143 mg/m³ and 0.536 mg/m³ with an average of 0.106 mg/m³. A key factor in the increasing dangers associated with the release of C6H6 from various sources of C6H6 is the increasing production volume, estimated at 50 million metric tons per year. **Conclusion:** The data analysis results align with existing literature, showing that excessive benzene emissions can alter air quality and pose health risks. The primary focus of this study was to test and analyze existing data from previous studies using different analytical approaches to assess their impact on environmental health.

Keywords: gasoline; risk; analysis; benzene; effect; emission; production; release

1. Introduction

Air pollution has become one of the most urgent global environmental crises, significantly influencing the health of human beings and natural systems (WHO, 2019). As industrialization and urbanization grow, transportation networks widen, resulting in an increase in harmful pollutants like volatile organic compounds (VOCs), such as benzene (EPA, 2016). It is well-known that benzene, a carcinogen, regularly escapes from gas stations, industrial operations, and vehicle exhaust (CDC, 2022). This poses serious dangers to both public health and environmental quality (ATSDR, 2007). According to the World Health Organization, air pollution is responsible for approximately 7 million premature deaths each year, making monitoring and mitigation measures imperative (WHO, 2014). People in the Middle East have long adapted to extreme heat, dust storms, little rainfall, and harsh geography. The Industrial Revolution, which began in the late 18th century and ushered in an era of mass production and elevated emissions, laid the foundation for modern pollution. However, by the mid-20th century, environmental degradation intensified due to accelerated industrial activity. As a result, air pollution has evolved into a global ecological crisis. Today, many regions experience high levels of particulate matter, and as industrialization continues, gas emissions have drastically increased (American Cancer Society, 2023). It is well understood that air pollution contributes significantly to various health complications and reduced environmental productivity. The purpose of this research is to evaluate VOC emissions in gas stations and investigate their impacts on human health—focusing primarily on benzene.

$$2\ C_6H_6\,(l) + 15\ O_2\,(g) \dashrightarrow 12\ CO_2\,(g) + 6\ H_2O\,(g) \quad (1)$$

The complete combustion of benzene (C_6H_6) in an oxygen-rich environment is represented by this equation. Burning benzoene emits carbon dioxide (CO_2) and water vapor (H_2O) through a reaction with oxygen (O_2). This process, which plays an important role when it comes to air pollution, greenhouse gas emissions, and climate change, is found in power plants, industrial facilities, and automobile engines (Bittner et al., 1983). Benzene is emitted from gas stations, industrial refineries, and vehicle exhaust. Benzene vapours are found to escape from fuel storage tanks, refuelling activities, and exhaust emissions, and they are a major source of air pollution (Edokpolo et al., 2015). It was also noted that gas stations are continuous sources of volatile organic compounds (VOCs). Benzene emissions in urban environments are largely due to automobile exhaust. Elevated benzene levels have been documented in studies of the levels of these gases in residential buildings near gas stations, suggesting a persistent source of pollution that will remain until additional measures are in place to eradicate it. Recent studies reinforce that long exposure to benzene, even under low concentrations, represents an important risk factor for increased dispersal of hematologic malignancies and immuno-system suppression (Khalade et al., 2010). Furthermore, recent epidemiological studies have also confirmed a direct correlation between occupational benzene exposure and the development of acute myeloid leukaemia (Rothman et al., 1997). Public health concerns related to benzene emissions from transportation and industrial activities continue to be of concern in urban and semi-urban environments. This knowledge highlights the importance of more stringent regulatory measures to limit workers and communities residing around gas stations from being exposed to benzene. The studies show that gas stations continuously emit vapours, distributing organic materials and increasing VOC concentrations in the ambient environment. In addition, it was identified gas evaporation as a major source of high toluene concentrations, particularly in gas stations where fuel storage and dispensing processes lead to benzene and toluene emissions:

1. Loading and breathing of fuel storage tank
2. Dispersing petrol into the vehicle fuel tank (refueling)

Also, emissions occur from vehicle operation and hot-soak, spills, and leaks from connectors and components.

The focus of this study is to evaluate the impacts of benzene emissions from gas stations on human health and environmental safety, over time, benzene exposure also results in anemia and immune system disorders because it reduces red blood cell and white blood cell production.

Since its physical features may vary depending on the vapor pressure, causing harmful, toxic gases, benzene is a substance that is chemical. Several chronic as well as acute illnesses and negative health effects have been connected to human exposure to benzene. Long-term exposure to benzene can cause humans' bone marrow to produce less red and white blood cells, which can lead to aplastic anemia and a decrease in birth weight (Synder, 2012).

Group 1, which comprises compounds or physical elements carcinogenic for humans that cause acute amyloid leukaemia and could raise the risk of leukaemia-related death, includes benzene, according to the classification scheme created by the International Agency for Research on Cancer (IARC). Because acceptable amounts of benzene are unknown and depend on other characteristics, like absorption susceptibility, extra attention must be made to the extent and duration of benzene exposure (Chiavarini et al., 2024).

It is listed as an AGGIH suspect human carcinogen with the following properties:

Mw: 78.1
Boiling Point: 176 F
Solubility in Water: 1.79 g/L @ 76 F
Vapor Pressure: 3.2 Pisa @ 100F
Flash Point: 12.2 F
Autoignition Temperature: 1042 F
Research Octane Number (RON): 106

It is a toxic chemical that has been connected to cancer. Section 112 of the Clean Air Act appointed it as a dangerous air pollutant. In the United States, mobile sources account for 85% of benzoene emissions, with exhaust generating 70% and evaporative emissions for 14%, according to a record Environmental Protection Agency (EPA) source inventory (U.S. EPA, 2006).

The second series of measurements for the evaporation of benzene exposure for particular worker classes considers the ACGIH-proposed threshold limit value (TLV) of 0.3 mg/m^3, which a substitute an existing value of 32 mg/m^3 as shown in Table 1.

Table 1. The threshold limit value (TLV).

Threshold Limit Value (TLV/TWA)	30 mg/m^3 (10ppm)
Permissible exposure Limit (PEL)	30 mg/m^3 (10ppm)
Short-term Exposure (STEL)	75 mg/m^3 (25ppm)
LD50 (Oral-rat)	4894 mg/kg
LD50 (Oral-mouse)	4700 mg/kg
LD50 (IPR-rat)	2.9 mg/kg

LC50 (IBHL-mouse-7H)	9980 ppm

For an eight-hour shift, a maximum acceptable peak over the acceptance ceiling concentration is 50 ppm for 10 minutes.

$(PEL)_{Ceiling}$ = 25 ppm for eight hours. Migraines, weakness, nausea, vomiting, disorientation, narcosis, asphyxia, and depression of the central nervous system are among the conditions caused by 50–150 ppm for five hours. Inhalation of vapor can result in lung inflammation, pulmonary edema, or severe irritation of respiratory burns.

Skin and eyes may become affected by liquid. Dermatitis can be caused on by prolonged skin contact. Keeping eye contact can cause a short-term corneal damage (CDC, 2005).

2. Environmental Exposures

A substantial amount of exposure to benzene occurs by respiration due to its high volatility. The upper atmosphere degrades it quickly. Rain may remove a small amount due to its water solubility, affecting soil and surface channels of water. However, It either breaks down or volatilizes back to air by microbial organisms thus it is not retained in surface water or soil.

2.1. Source of Exposure

There are several man-made sources of benzoene emission levels. Evaporative losses, refueling emissions, and vehicle exhaust are the main sources of environmental benzene (EPA, 2017). Both partially burnt benzene and benzene generated during combustion in the motor by the toluene and xylene dealkylation make up the combination of benzene seen in the exhaust of an automobile (EPA, 2006). Air emissions from wastewater treatment facilities and fumigating emissions from the manufacture and processing of industrial intermediates activities are the main ways that it enters the environment from industrial sources (AGI, 2016). There are natural sources of benzene emissions, including forest fires and volcanoes. However, due to its widespread use and high emissions of benzene, emissions from vehicles are a major source of pollution and benzene emissions that require regulatory attention (CDC, 2023). Oil refineries, for instance, 2. Benzene production and processing facilities, 3. Cooking plants, 4. Fossil fuel combustion at rest: energy generation, 5. Platforms offshore, 6. Traffic on the roads, 7. Distribution of petroleum: evaporative losses, 8. Service stations, 9. Fossil fuel combustion: heating in homes and businesses, 10. Treatment plant for wastewater (WWTP), 11. Laboratory solvents and reagents in labs, 12. Waste management: landfills, 13. Natural sources, 14. Tobacco smoke in the environment (ETS) (ATSDR, 2007). Although the use of benzene has been progressively reducing over the last 20 years, exposure to benzene still constitutes an environmental health stress due to the relatively elevated concentrations such as gas filling stations.

2.1.1. The Aim of Review

A review of benzene emissions from gas stations and automobile exhaust emissions has been written, and their impacts on human health have been evaluated. In this chapter, the objective is to provide a quantitative summary of the exposure situation that arises from fueling station sources of benzene C_6H_6 across different stations in the Middle East (ME).

However, this report will be written based on previous data collected from other reports.

Figure 1 shows the movement of the benzene concentration in different stations with different concentrations, which is increasing dramatically from 0.143 mg/m^3 to approximately 0.536 mg/m^3. This proves that there is no clear standard to follow and applied to the different stations to limit benzene emission by all stations.

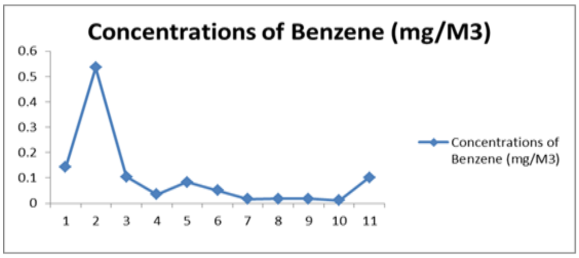

Figure 1. Benzene Concentration in Several Stations.

2.2. Risk for Workers Exposure to Benzene

It is known that benzene causes cancer in people. The existing Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 1 ppm and exposure at Leaking Underground Storage Tank (LUST) locations were evaluated. The last inhalation reference concentration of benzene is 0.03 mg/m^3, according to the EPA's documented exposure (RFCs) and Reference Doses for Chronic Oral Exposures (RFDs) at the Integral Risk Information System (IRIS) (U.S. EPA, 2002). According to a survey of the pertinent literature, the absorption efficiencies for oral and inhalation modes of exposure are 100% and 50%, respectively. The concentration and duration of benzene exposure determine its harmful effects on human health as shown in Table 2.

Benzene inhalation risk associated with cancer was estimated for a few stations selected at random from prior research papers conducted on the Middle East Region and compared to U.S. EPA criteria in order to ascertain the harmful effects of benzene.

3. Risk Assessment

To assess the risk associated with the gas released from gas stations, several scenarios were studied. To investigate the worst-case scenario, illustrating some scenarios achieved as follows;

3.1 First Scenario

The scenario was performed using a software program, and data used as

Table 2. Cancer Risk Factors for Benzene Inhalation.

Ref.	**Dose(mg/kg/d)**	**Dose(mg*10^6)**	**$(mg/m^3)^{-1}$**	**$(mg/kg/d)^{-1}$**
Rinsky - 1987	22.8	5.1	3.5	0.0024
Rinsky - 1987	22.8	0.1	4.6	0.0032
Wong - 1987	1.37	0.24	32	0.022
Wong - 1987	1.37	0.24	19	0.013
Wong - 1987	1.37	0.24	35	0.024

1. Body Weigh a male adult worker: **70 kg**
2. Exposure time: **7 days per week, 50 weeks per year for 20 years.**
3. The workers breathe deep two hrs**. (1.5 m^3 air per hour)** and
4. In the other six hrs. **1 m^3 air per hr**.
5. Potency factor of Benzene for Inhalation: **$0.029(mg/kg/day)^{-1}$**, based on occupational epidemiology studies from EPA Reference.
6. Benzene Absorption rate (of Inhalation): **50 %**
7. Average Benzene Concentration Rate of Station: **0.1 mg/m^3**

Risk Calculations

There are some assumptions were made

- Assume exposure for 300 days/year for 30 years
- Assume 70 kg body weight and exposure for 365 days/year over 20 years.

Daily Intake Rate = ($1.5\ m^3/hr \times 2$ hrs) + ($1\ m^3/hr \times 6$ hrs) = $3\ m^3 + 6\ m^3 = 9\ m^3$ per shift.

Fraction of Lifetime Exposed = 30/70 = 0.43

Total Dose = $9\ m^3/day \times 7$ days/week $\times$ 43 weeks/year $\times$ 30 years $\times$ 0.1 $mg/m^3 \times$ 50% = 4,064 mg

Chronic Daily Intake = 4,064 mg/(70 kg $\times$ 70 yrs $\times$ 300 days/yr) = 2.76×10^{-3} mg/kg/day (0.00276 mg/kg/day)

Risk = CDI $\times$ PF = $2.76\times10^{-3} \times 0.029 = 8.00\times10^{-5}$"

Where: CDI: Chronic Daily Intake, PF: Potency factor of Benzene for inhalation. Thus, the risk for the workers and people living near the stations is 1.6 people per 10000 people **(High)**, which shows that the inhalation reference concentration of benzene is 1ppm or 3.19 mg/m^3

EPA-RFC Calculation

Total Dose = 675 mg

Chronic daily Intake = 0.000377

Risk = 0.0000011

The simulation data described gas emission concentration, which is higher than the threshold level. Risk, in other words, must not exceed **1.1 per 100000** people.

3.1.1. Emission on Road

Private vehicles are the most used form of transport worldwide, especially in developing countries. Especially in rapidly expanding developing nations, the rise in per capita wealth is most likely to be accompanied by the rise in car ownership. From 2008 to 2050, the number of motor vehicles is expected to increase tenfold nationwide.

3.1.2. Health Effects

As vehicle emissions contribute to environmental pollution that impacts human health along the road and raise the risk of fatalities in the impacted population, it is vital to assess the risk related to vehicle emissions. Further, 90% of environmental pollution in the Arab world is produced by automobile emissions, which accounts for the vast majority of gas emissions in Arab nations (El-Raey, 2006). The objective of this part of the report is to estimate the vehicle emissions (Latent Cancer Fatalities per Km (LCF/Km)) and its potential fatal carcinogenic risk to human health. Transportation is accountable for 26% of global gas emissions, according to IEA data. In addition, transportation accounts for almost half of the net increase since 1990, making it the source of GHGs with the fastest rate of growth. The automobile industry is one of the major contributors to carbon dioxide emissions, with cars accounting for 18% of around the world emissions, according to the IEA (International Energy Agency, 2021). To lessen the detrimental impacts of gas emissions on air quality, human health, and atmospheric temperature, emission reduction is necessary.

3.2. Second Scenario

Most of the total gas emissions in the Middle East, particularly (in the Arab Region) are due to transportation activities (UNECE, 2013), this scenario will show expected annual cancer deaths based on the following equation and recorded data, which are collected from different sources as shown in Table 3.

To estimate the number of cancer deaths caused by benzene exposure, we use the following equation:

$$(Exp * RF * POP) / 70 = LCFs / yr \tag{2}$$

Exp = Annual average air concentration of benzene (mg/m^3)

Table 3. Risk factor characteristics for workers.

EPA Clean Air Act Risk Range	Risk Factor Characteristics	Risk Factors for Workers
The least health-protective end of the range	1 case in 10,000 people	1*10E-4
Midpoint of range	1 case in 100,000 people	1*10E-5
Most health-protective end-of-the-range	1 case in 1,000,000 people	1*10E-6

Risk Factor (cancer risk per mg/m^3 exposure based on EPA data) RF = 4.4E-7 to 1.6E/6 $mg/m^{3.}$ EPA Risk Factor range for benzene exhaust in cancer deaths per person exposed in lifetime to 1 mg/m^3**. (1.6E-6 mg/m^3)** (U.S. EPA, 2000).

Population (total number of exposed individuals) POP = Entire rural or urban population for the year and

70 = Years per lifetime.

Annual Latent Cancer Fatalities Annual (LCF) = Total annual rural or urban vehicle emissions attributed to cancer deaths * Annual Vehicle Emissions/Total Annual Vehicle Emissions).

Assumption:

This example will be applied to gas Emission in the Middle East based on the following data:

Concentration of Particulate matter PM (mg/m^3) =89 in 2015 (WHO, 2022)

RF =1.6E-6 mg/m^3

POP = 1,438.5 million.

(89 * 1.6E-6 * 1438.5) / 70 = 2.93E-3 (0.00293) LCFs / yr.

In addition, the risk for the people living in that region is around three people per 1000 people. However, the number of industrial areas has increased sharply, and there weren't enough studies on the effect of industrial production on environmental health.

3.3. Third Scenario

Saudi Arabia has recently increased the number of industrial cities, which increased production. It is among the largest producers of oil countries in the world. However, special emphasis must be placed on the environmental health of the entire environment, including humans, animals, and forests. The following example shows the vehicle emissions per kilometer in K.S.A:

Evaporative emissions limit = 6.0 grams per test (SHED)

Standard Limit = 2 Gram/test

By using the following Equation:

$$\text{Gram/Km} = \frac{\text{diurnal g/test} + \text{N*(hot soak Kg/test)}}{\text{Average Km driven /day}}$$

where N = is the average number of trips per day.

Assumptions

Number of trips = 5

Hot-soak (kg/test) = 0.6

Average Km driven/day = 40

Vehicle emission in Saudi Arabia (g/Km) = 0.45 g/Km

There were 750,000 cars were purchased in 2013 in Saudi Arabia, therefore;

Total amount of car emissions in 2013 = 337,500 g/km or 337.5 kg/km of total vehicles' exhaust was released.

It is highly recommended that Saudi Arabian Transportation Authority has to take an urgent reaction to the air quality in the future by applying restricted environmental rules and share it with the public and institutions.

3.4. Fourth Scenario

This scenario will evaluate the amount of benzene produced for fueling the vehicles and its total heat emitted and contributed to global warming.

As illustrated in Figure 2 the energy is obtained from the combustion of gasoline by the conversion or reaction of benzene with oxygen to give carbon dioxide and water as follows:

$$2C_6H_6 + 15O_2 \rightarrow 12CO_2 + 6H_2O \qquad \Delta H = -6534 \text{ KJ}$$

6534 is obtained by combusting two moles of benzene. Fuel combustion is essential to internal combustion engines, and the result of the combustion process is great heat production, as well as carbon dioxide. In addition, one barrel of crude oil (42 Gallons) produced 19 gallons of gasoline or approximately 72 Liters. To calculate the amount of heat produced from one barrel of crude oil, the following assumptions are applied. In 2013, there were about 750,000 cars on the road in the Kingdom of Saudi Arabia.

The average volume of filling a car's tank = 50 L

Average Distance = 300 Km

Benzene Mw = 78.11 g = 22.4L

The density of gasoline is 0.70-0.80 g/L

Mass (Kg) = Volume (m^3) * Density (Kg/m^3)

Mass = 0.80 g/L * 50L

Mass = 40 g

For 750,000 cars = 750,000 * 40 g = 30,000,000 g = 30,000 Kg OR (3 Exp 3 Kg)

Number of moles = 30,000,000 / 78 = 348,615 moles

To convert the amount of gasoline consumed by cars to heat generated and emitted to the atmosphere, by using equation 3

$$= (6534\text{KJ}/\ 156\text{g}) * 348{,}615 \text{ g} = 14{,}601{,}605 \text{ KJ of gasoline}$$

Which is a high and that will be added to the natural heat and increase the global temperature.

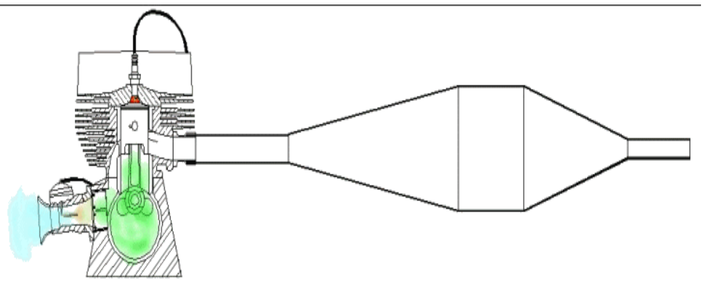

Figure 2. Internal Combustion engine.

3.5. Fifth Scenario

Calculation of the effect of gas-released concentrations of the vehicles on the roads by using the Pasquill-Gifford Model as shown in Figure 3.
Assumption

1. Wind Direction

As shown in Table 4 assuming the wind is blowing perpendicular to the direction of travel by 100 m and by using the Pasquill-Gifford Dispersion Coefficients Equation, at any given point, the following air concentration is obtained:

$$C_{air}=\sqrt{(2Q/\pi\sigma zu)}_{EXP}(-h^2/2\sigma_z^2) \quad (3)$$

The Briggs horizontal dispersion coefficient for a Gaussian plume is given as:

$$\sigma z = \partial \times (1 + b \times)^c \quad (4)$$

x = 100 m, 200 m
where x is the downwind distance from the released point, and a,b, and c are constants depending on the stability class.

Assuming a ground-level release, h = 0, and substituting Eq. 2 into Eq.1 for σ_z, equation 1 gives the following equation:

$$C = \sqrt{\frac{2Q}{\pi}} aux(1+bx)^c \quad (5)$$

Assuming the Distance from the nearest area to the farthest distance =
D_1 = 1000 m, D_2 =200 m

$$C = \sqrt{\frac{2Q}{\pi}} aux[-\frac{1\left(\frac{y2}{\sigma 2}\right)}{2}] \quad (6)$$

Gas Concentration released by vehicles' Exhausts

Table 4. Wind speed versus stability class.

Wind Speed	**Stability Class**	**Q^*_m (g/s)**	**X (m)**	**σ_y (m)**	**σ_z (m)**	**C (g/m^3)**
2	A	100	100 200	21.89 43.56	20 40	1.07×10^{-6} 6.58×10^{-4}
4	B	100	100 200	15.92 31.68	12 24	1.15×10^{-10} 7.14×10^{-5}
6	D	100	100 200	7.96 15.84	5.59 10.52	6.38×10^{-36} 7.10×10^{-11}

These values are based on theoretical assumptions; they might be different from reality. Therefore, an accurate study will be needed to compare them and make a correct decision. A: Extremely Unstable, B: Moderately Unstable, D: Neutrally Stable, and F: Moderately Stable. Based on the result shown in the table, the concentrations of gas released by the vehicle exhaust on the road depend on the following conditions:

- Stability class
- Wind speed and direction
- Dispersion Coefficients, which are a function of atmospheric conditions and the distance from the released point

When the day is unstable (class A) but the wind speed is slightly slow at 2 m/s, the effect of the gas concentration is higher than that when it is at a stable condition, but the velocity of the wind is 6 m/s, the wind has a strong effect on the gas concentration. It is recommended that choosing the station site or location is important, but also the consideration of the wind direction and speed have to be taken into account.

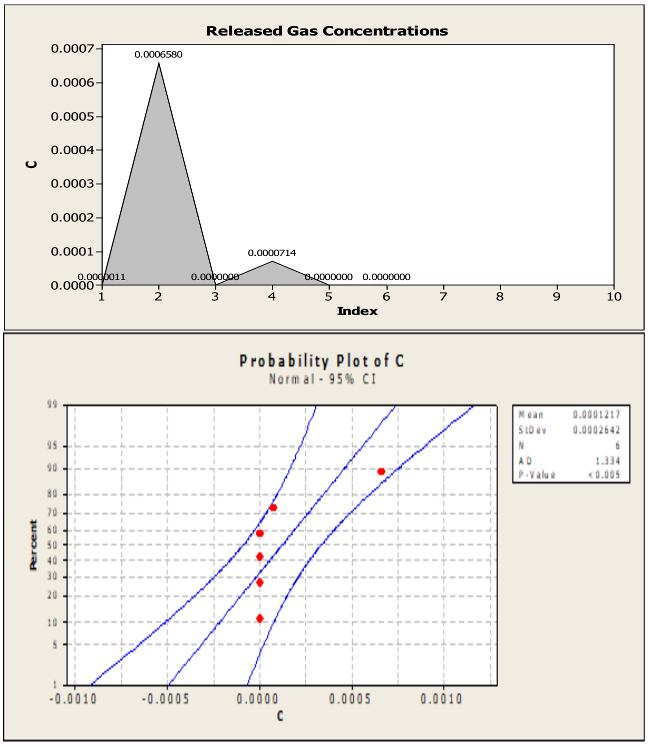

Figure 3. Gas release and Probability versus Concentration.

Using Minitab helps to evaluate the process of the released gas and investigate the vital factors that might have a real impact on the process of the gas release.

Although the wind direction has a strong effect on the gas released by cars on the road, the program shows that there are no serious effects on human health since the *p*-value is < 0.005. The fluctuation of dots shows the instability of gas concentrations from the exhaust, but still, they are inside the limit.

4. Methodology

Experimental studies usually produce cancer risk factors in excess risk units (mg/m^3) or excessive risk units (mg/kg/day). Epidemiologic or animal experiments are both viable. The first step is to determine the additional risk and associated human dose from an experimental investigation in obtaining a risk factor. The exposed group's response frequency adjusted for the response in the control group is known as excess risk. The following factors determine the comparable human dose from an epidemiological or animal study: Pharmacokinetics; exposure concentration; body weight (or surface area); daily intake of tainted food, water, or air; exposure duration; observation time since the previous exposure; lifetime; and latent period.

4.1. Experimental Planning

The method of experimentation utilized to examine and assess the effects on both people and their interactions will be the main topic of the next section. implementing multiple techniques to manage noise in an experiment and arrive at a wise choice for the chemical process. The following procedures must be followed in order to develop an experiment utilizing the engineering method:

1. Response Components
2. The elements
3. The use of randomization
4. Replication and Repetition

The following graphs were generated by Minitab and showed the variation of the benzene concentrations through different numbers of stations. The graph constructed the concentration levels with uncontrolled values by fluctuating from 0.143 to 0.536. The study was conducted using Minitab since.

it possesses a great deal of power in handling environmental data in terms of the analysis of trends and variations of benzene concentrations. While traditional spreadsheet-based analysis suffices for air quality data, Minitab provides advanced tools for regression analysis, probability distributions, and hypothesis testing, which are important for analysis of the air quality data as shown in Table 5. Furthermore, Minitab's graphical tools, such as probability plots and control charts, may be used to view the trends of benzene exposure over time. The complexity of VOC emissions and their health implications make it possible to apply a more refined statistical approach to the detection of potential risks from benzene inhalation using Minitab. Indeed, Minitab can be used for trend analysis but could make further contributions to the design of predictive models of benzene dispersion patterns by attaching machine learning techniques.

Table 5. Process Analysis of the Release gas.

Analysis of Variance
Source P DF Seq SS Adj SS Adj MS F
Regression 1 746.675 746.675 746.675 145.920 0.0002694
y 1 746.675 746.675 746.675 145.920 0.0002694
Error 4 20.468 20.468 5.117
Total 5 767.143

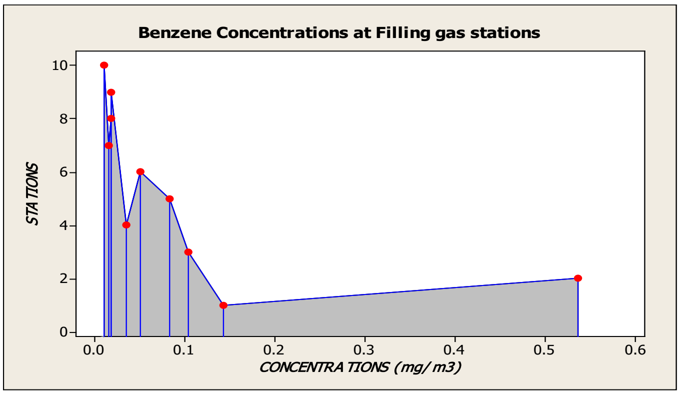

Figure 4. Benzene Concentrations by Minitab.

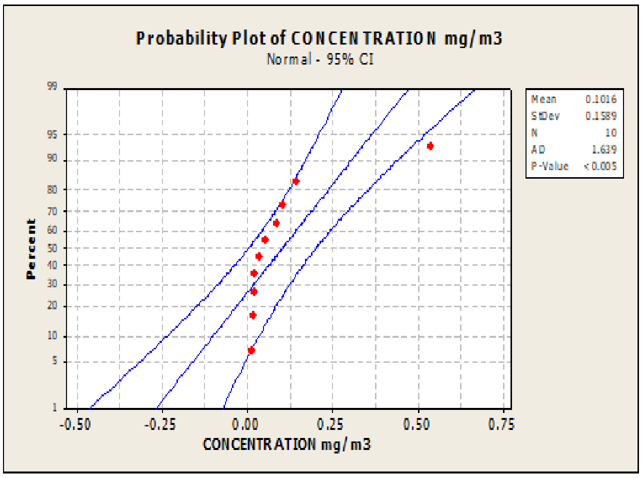

Figure 5. Probability Plot of Benzene Concentration.

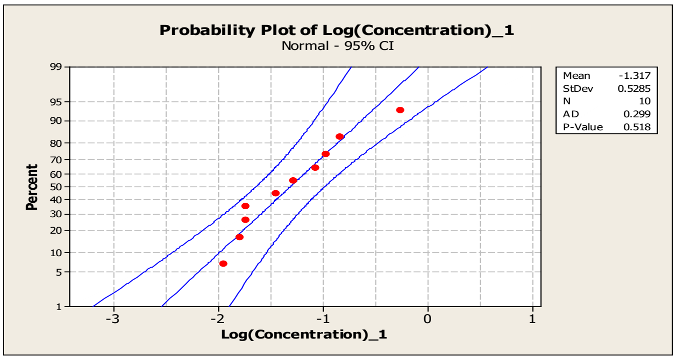

Figure 6. Probability Plot of Benzene Concentration.

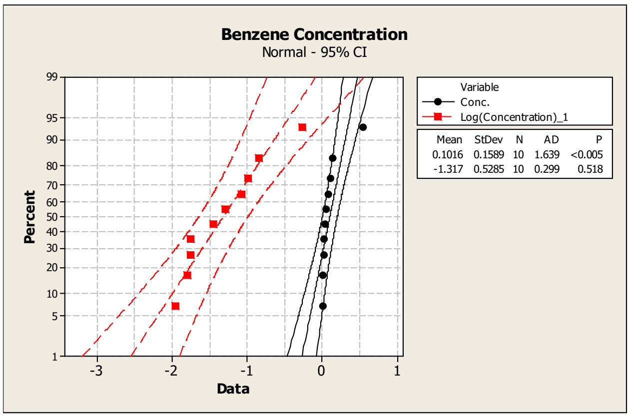

Figure 7. Benzene Concentrations with Normal Confidence Interval.

4.2. Data Analysis

Part 1:

To perform the analysis,

1. Copy all data on the Excel sheet to Minitab and use the Minitab calculator to create a new column, which is the log of the concentration level (Calculator), filling the fields as desired and in expression use: LOGTEN ('Concentration') (reference level).
2. A new column, which has the log value of concentration level, will be created as shown in Figure 5 and Figure 6. Thus, we can now draw the QQ plots to demonstrate that the log value is better distributed.

We now obtain a new column that has the log value of the concentration. (Graph|Probability

Plot|Multiple…) as shown in Figure 4.

The above graphs show that the log concentration level (reference Level) is more bounded as it has no points outside the limits and is better distributed as it is closer to a straight line than the concentration level as shown in Figure 7.

To obtain the mean and standard deviation of each as well as standard errors of means, we use (Stat| Basic statistics| Display Descriptive Statistics). Therefore, the following results will be created:

Descriptive Statistics

The analysis of benzene concentrations at different stations led to descriptive statistical calculations that summarized the data. The benzene measurements showed a mean of 0.102 mg/m³ with a standard deviation of 0.159 mg/m³ across all stations, according to Table 6. The air quality measurements spanned between 0.011 mg/m³ as the lowest value and 0.536 mg/m³ as the highest value at different gas stations. The data distribution statistics provide vital information about benzene exposure levels which will be crucial for determining human health risks. The benzene concentration distribution among stations becomes more evident through the data presentation in Figure 8.

Table 6. Concentration mg/m^3.

Variable	N	Mean	SE Mean	St Dev	Min	Max
Concentration mg/m^3	**10**	**0.102**	**0.050**	**0.159**	**0.011**	**0.536**

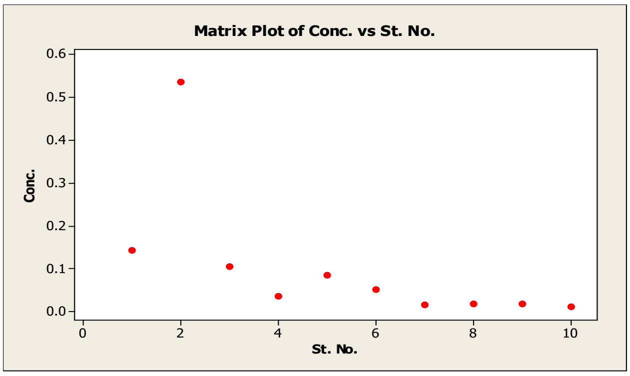

Figure 8. Benzene Concentrations Distribution.

5. Results and Discussion

Several experiments were carried out in the chemistry lab to comprehend the reaction mechanism. These experiments were conducted by other researchers for all benzene concentrations of different gasoline stations. At the end of the experiment, the measurement of risk was calculated for each experiment. Unlike the previous studies that used traditional statistical methods, this research proposes a refined method using Minitab software for trend analysis. Advanced statistical tools are provided by Minitab to enhance accuracy in determining benzene concentration variations and determining exposure risks. The application of this approach improves precision in environmental risk assessment and provides a stronger basis for evaluation than the previous methods. As shown in Figure 9, the normal probability plot demonstrates the distribution pattern of benzene concentration data, while Figure 10 shows the concentration distribution, highlighting the spread and variance among different gas stations.

5.1. Design of Experiment (DOE)

The experimental design to examine and assess the individual and interaction effects will be the primary focus . Employing several strategies to manage noise in an experiment and arrive at a wise choice for the chemical process, as indicated in Table 7. In order to use engineering methods to design an experiment, the following steps are required:

4 Response Variables
5 Factors
6 Randomization
7 Repetition and Replication

Measured variables that are the focus of characterization or optimization are known as response variables (Y's). The most challenging aspect of experiment design, however, will be determining the response. In order to resolve this problem, several questions have to be addressed such as:

- How will the results be analyzed?
- How good is the measurement system?
- What are the baseline mean and standard deviation?

2. Factors:

They are variables that are controlled or varied systematically during the experiment. The two steps are important to designing the experiment and evaluating or investigating the factors that affect the process.

The purpose of using an experimental design is to deal with different factors and make a good decision for an optimal production process. Before starting the design of the experiment DOE, a pre-experimental plan is recommended.

5.2. Experimental Design Procedures

5.2.1. Planning

Pre-experimental planning must be completed before the computer program is launched. Your problem will determine how much preparation is needed before starting any experiments. You must ascertain, for instance, which processing conditions and influencing factors are involved. Therefore, thorough preparation can aid in preventing issues that might arise when the experimental strategy is being carried out.

5.2.2. Processing Characterization (Screening)

There are various variables that could have an impact in many manufacturing and process development applications. Through the identification of the critical factors influencing product quality, screening lowers the number of variables. This reduction makes it possible to concentrate on the most crucial factors. The best or ideal environment for these aspects may also be suggested by screening. After that, you can define the curvature's nature and find its best values by using optimization techniques.
Screening test by running a relatively small number of tests to isolate the most important factors.

5.2.3. Optimization

The optimization technique aids in defining the curvature's nature and identifying the ideal parameters. The process objectives determine the ideal values for the experimental factors.

5.2.4. Randomization

It can be done in many ways

A. Run the treatment combination in random order

B. Assign experimental units to the treatment combinations randomly

The advantage of randomization is to average out the effect of the extraneous factors (called noise) that may be present but were not controlled or measured during the experiment as shown in Table 8.

C. Spread the effects of the noise across all runs

D. These extraneous factors (noise) cause unexplained variation in the response variable (Yield).

Table 7. Randomization method.

Run Order	Std order	Concentration
1	6	0.051
2	3	0.104
3	1	0.143
4	8	0.018
5	10	0.011
6	5	0.084
7	9	0.018
8	4	0.035
9	7	0.016

10	2	0.536

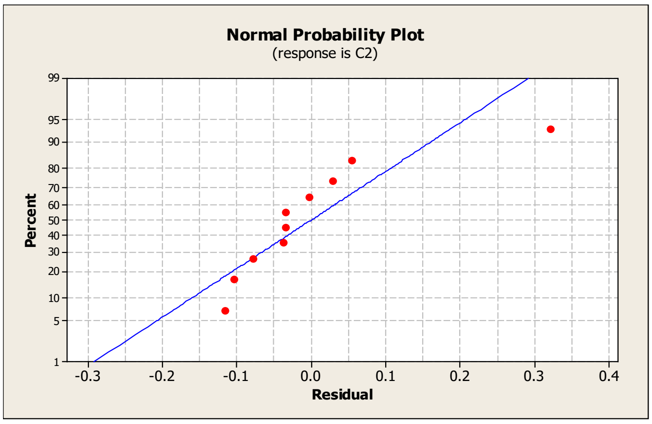

Figure 9. Normal Probability Plot.

The effect of different factors can be calculated by applying the following equation:

$$\text{Effect} = \left(\frac{+Y}{n}\right) - \left(\frac{-Y}{n}\right) = \left(\frac{+Y}{n}\right) - \left(\frac{-Y}{n}\right)$$

Table 8. One-Sample T: CONCENTRATION mg/m^3.

Variable	N	Mean	StDev.	SE Mean	95% CI	P
Concentration mg/m^3	10	0.1016	0.1589	0.0502	(-0.0121,0.2153)	0..057

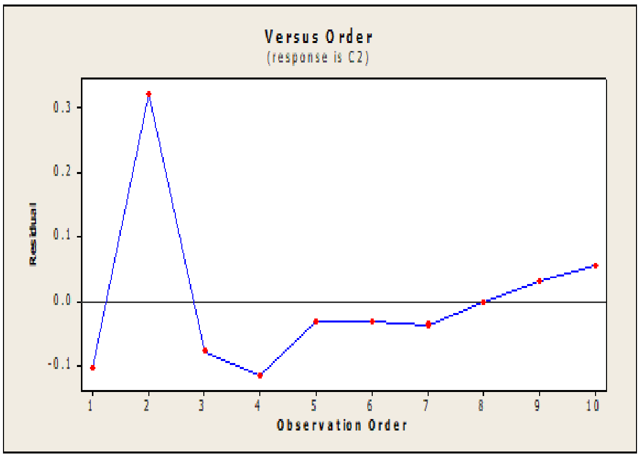

Figure 10. Benzene Concentrations Distribution.

6. Evaluation

The mechanism of gas release from filling gas stations was studied. The data was obtained from the sources. It was found that at about an average of 0.1016 mg/m^{3,} benzene concentration was released into the atmosphere.

The novelty of the study is mainly at the methodological level, where new data are used to reanalyze previous studies using a different analytical approach. The purpose of this methodological refinement is to assess the effect of gas station benzene emissions on environmental and human health. The results of the study exceed the p-value threshold, and therefore, a definitive conclusion about benzene's significant health effects cannot be made. The main reason for this is that there are limitations such as insufficient information, experimental errors, and unknown variables. The temperature fluctuations and time variations are important factors that contribute to the benzene concentration and its effect on human health. Furthermore, designing the experiment by DOE is a good way for evaluation, which saves time and money.

7. Summary

It discusses important aspects and a new approach to analyzing benzene concentration using Minitab software. Benzene concentrations measured were from 0.143 mg/m^3 to 0.536 mg/m^3, with an average of 0.106 mg/m^3. The Chronic Daily Intake (CDI) calculated was 2.76×10^{-3} mg/kg/day, and the estimated cancer risk was 8.00×10^{-5}, which was greater than the U.S. EPA's acceptable threshold of 1×10^{-6}. They suggest that urgent action is needed to improve emission control policies from both local and national levels, tougher monitoring of levels of benzene exposure in urban areas, and evaluating the level of different values based on pod data collected from different sources. A lack of information such as temperature and time makes it hard to make a better decision on these given data. However, it gives a basic idea of the level of concentration regardless of other factors. Accurate and more concentration values for each station are needed to evaluate the effect of the benzene emission concentration, and a better decision can be made.

The analysis of experimental design showed that based on these data, benzene concentrations have exceeded the limited level however, there is no serious effect or huge impact can be seen on human health. Furthermore, personal protection equipment should be worn by site workers to prevent any undetected or unexpected risk.

Finally, although the studies need to be improved, policies and strategies to reduce gas emissions are being employed. These include restraining vehicle usage, managing traffic congestion, and reducing energy usage. Based on these strategies, IPCC (2007, P.336) suggests four sets of measures to reduce emissions associated with vehicles

1. Increasing and improving the efficiency of fuel energy
2. Reducing emissions of gases from vehicles' exhausts.
3. Taxation and Pricing
4. Fuel economy
5. Transport Demand Management.

The analysis of experimental design shows that based on the collected data, benzene concentrations have exceeded the limited level and lead to an effect on human health. For personal protection, equipment should be worn by site workers. The author recommended that improving the yield of data and introducing different methods of analysis would result in a good assessment of such a case. However, the report also investigates the fact that the gas emission of benzene has limitations.

Some of the limitations include: 1) Prediction and Uncertainty of the gas release limitation are becoming an issue. 2) Increasing the number of processes and energy consumption leads to high spending for benzene production, causing a release problem.

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Nomenclature

Symbol	Definition
C_6H_6	Benzene
CO_2	Carbon Dioxide
H_2O	Water Vapor
VOCs	Volatile Organic Compounds
WHO	World Health Organization
EPA	Environmental Protection Agency
ppm	Parts per million
mg/m^3	Milligrams per cubic meter
LCF	Latent Cancer Fatalities
CDI	Chronic Daily Intake
PF	Potency Factor
EXP	Exposure Concentration
RF	Risk Factor
POP	Population

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