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Assessment of Seasonal Variation in Volatile Organic Compound Levels in Water Bodies of Shahdol District, Madhya Pradesh

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Abstract: *VOCs are organic chemicals that possess high vapour pressure at ordinary room temperature, posing significant environmental and health risks. They are released by a variety of construction components and consumer goods that are used indoors, including adhesives, floor coverings, paints, sanitation products, etc. These VOCs mix with water bodies and contaminate them. There is a need to examine VOC levels in various water bodies. In the present work, concentration and presence of VOCs were examined across four distinct seasons, revealing critical patterns and trends. The result showed benzene, ethylbenzene, xylene, toluene, and chloroform as the main VOCs in all of the sampling sites. The findings demonstrate the relationship between human activities, seasonal changes, and VOC levels in the aquatic environment of Shahdol district, providing essential insights for policymakers and environmentalists.*

Key Words: *Volatile Organic Compounds, Seasonal Variation, Water Quality, Water Bodies, Environmental Risk.*

1. INTRODUCTION :

Volatile Organic Compounds (VOCs) form a significant part of environmental research due to their substantial influence on atmospheric chemistry, human health, and aquatic ecosystems. Volatile Organic Compounds (VOCs) are a group of organic chemicals that have a high vapor pressure under normal room temperature conditions. This characteristic means they can easily evaporate into the atmosphere from their solid or liquid state [1]. Common sources of VOCs include vehicle exhaust, industrial emissions, solvents, paints, and even some natural processes such as vegetation emissions [2]. From an environmental perspective, VOCs play a pivotal role in atmospheric reactions, leading to the formation of ground-level ozone and secondary organic aerosols, both of which have severe implications for air quality and human health [3]. Ground-level ozone, which is formed through a series of photochemical reactions involving VOCs and nitrogen oxides, is a major component of smog and is harmful to respiratory health, ecosystems, and can reduce agricultural yields [4]. The Environmental Protection Agency has classified VOCs into different categories based on their sources, reactivity, and potential harm, with some being regulated due to their role in ozone formation [5]. Volatile organic compounds (VOCs) are vaporised at environmental air pressure. These are carbon compounds and major components of air pollution. These air pollutants showed negative effect on plants [6].

Some VOCs are directly hazardous to human health. Compounds like benzene, toluene, ethylbenzene, and xylene (BTEX) are known carcinogens and can contaminate drinking water resources, posing direct consumption risks. VOCs in water bodies can have dire ecological impacts. Acute toxic effects on aquatic life are observed with high VOC concentrations, affecting everything from microbial communities to fish [7]. Beyond direct toxicity, some VOCs can bioaccumulate, leading to long-term effects in aquatic food webs [8]. Hence, it is essential to monitor and manage VOC emissions and their concentrations in the environment. The current study was the assessment of various types of VOCs in selected water bodies of shahdol district. The study also represented the effect of various season on VOCs of water bodies.

2. METHODOLOGY

2.1 Site Selection and Description

Shahdol is a district in Madhya Pradesh, India. Geographically, it is distinguished by a variety of rivers, undulating hills, and dense forests which maintain a wealth of wildlife. The region experiences a tropical climate with distinct wet and dry seasons [9]. Water bodies or Sites were selected based on proximity to industrial zones, accessibility, and their significance to local communities. Three primary water bodies in Shahdol were chosen. The first site was Lake Banas mentioned as Site A, located close to the central industrial zone of Shahdol and receives runoff from surrounding areas. The Second Site was Site B, River Sone. This river flows adjacent to a major highway and several small-scale industries in Shahdol. The third site was reservoir Mukundpur Situated in a more pristine area, away from the dense industrial zones, mentioned as Site C. This reservoir serves as a control site with expected minimal VOC concentrations due to its location and protected status.

2.2 Sampling Techniques

During the study bi-weekly sampling over a one-year period to capture seasonal variations. Two different kinds of sampling methods were applied. The first one was grab sampling, in which water samples were collected from the surface at predetermined points for each water body. The second technique was integrated sampling, using a weighted bottle to collect samples at different depths, providing a more holistic sample from the entire water column. Collected samples were stored in 40ml VOC vials with Teflon-lined septa, ensuring no contamination and minimal VOC loss due to evaporation.

2.3 Methods for detecting and quantifying VOCs

Solid-phase microextraction (SPME) was used to extract VOCs from water samples. After the extraction, two types of methods were used for quantification and identification of VOCs. The first one was Gas Chromatography-Mass Spectrometry (GC-MS), which is the standard method for VOC detection and quantification. The extracted samples were injected into a GC-MS, where VOCs were separated and identified based on their mass-to-charge ratios. The second method was calibration curves for all potential VOCs, created using standard solutions. This ensured accurate quantification of VOC concentrations in each sample. To assure the analysis, we quantify the VOCs from selected sampling sites by a three-time replication experiment. The study was conducted during the summer, monsoon, and winter seasons of Shahdol district. Each season provides a different context for VOC presence and movement. Statistical analysis- The present study was indicated about the amount of volatile compound from three different sites in different weather. The observed data was statistically analysed by ANOVA. After applying ANOVA, the P-value of sampling Site 1 between collected samples was 5.14E-32, for sampling site 2 it was 2E-27, and for sampling site 3 it was 1.85E-22. Which was less than 0.05, represented that the observed data was significant.

3. RESULT AND DISCUSSION

The present study documented a yield of VOCs from sampling water bodies. After the observations, we found benzene, ethylbenzene, xylene, toluene, and chloroform as the main VOCs in all of the sampling sites. Shahdol has seen significant coal mining activities over the decades, which form the backbone of its economy. Apart from coal mines, there are smaller industries related to agriculture, wood products, and some light manufacturing [10]. The coal mines and associated activities potentially contribute to VOC emissions, directly and indirectly, with coal storage, transport, and combustion being significant sources [11]. Natural sources, like vegetation emissions, play a significant role in VOC emissions in forested areas [12].

The VOCs concentration data across the different seasons is summarized in Tables 1 and Chart 1. The highest amount of benzene, 14.66, toluene, 20.33, ethylbenzene, 9.33, xylene 28.33 and chloroform, 5.33, was recorded in the monsoon from sampling site A. The data collected from the sampling site B, showed that amount of benzene, 9.33, toluene, 11.66, ethylbenzene, 6, xylene 14.66 and chloroform, 5.33 in the monsoon season. which was highest comparative to all study seasons. The maximum amount of benzene, 1.66, toluene, 1, ethylbenzene, 0.53, xylene 2.56 and chloroform, 0.16, was recorded in the monsoon from sampling site A. Overall, higher levels of VOCs were detected during the monsoon season compared to summer, autumn and winter for all three water bodies - Lake Banas, River Sone and Reservoir Mukundpur. Of all the selected sapling sites, the amount of xylene, 28.33 was found to be the highest in the monsoon season while the amount of chloroform was found to be the lowest, 1.03 in the winter season among the VOCs found in sampling site A.

The data collected from sampling site B represented that the maximum amount of xylenes, 14.66 in the monsoon season and chloroform was found to be the lowest, 0.63 in the winter season among the VOCs found in sampling site B. Among the VOCs detected at sampling site C, the amount of xylene, 2.56 was found to be the maximum during the monsoon season and the amount of chloroform, 0.02 to be the lowest during the winter season. In the summer season, moderate levels of VOCs were found across the VOCs and sampling sites. Site A showed the maximum concentrations likely due to proximity to industrial zones. Site C was very low VOCs owing to its pristine nature. Water bodies, including lakes, rivers, and reservoirs, serve as vital resources for drinking water, agriculture, industrial activities, and recreation. However, they are also vulnerable to contamination by VOCs from various sources, including industrial discharge, urban runoff, and atmospheric deposition [13]. Table 2 (a) represented the Percentage prevalence of VOC types by season. Resulted that aromatic VOCs like benzene and toluene are most prevalent across seasons. Chlorinated VOCs contribute more during monsoon, potentially from increased runoff carrying industrial effluents. Table 2 (b) showed VOC levels positively correlate with temperature and rainfall, indicating seasonal impacts on concentrations. Rainfall shows the highest correlation, reflecting the increased runoff during monsoons.

Studying VOCs in water bodies is also crucial for understanding their transport, transformation, and fate in the aquatic environment. Different water bodies have varied VOC concentrations depending on local sources, meteorological conditions, and water flow dynamics [14]. VOCs can undergo various processes in water, such as biodegradation, volatilization, and sorption, which influence their residence time and potential impacts [15]. Understanding VOC levels in water bodies can serve as an indicator of anthropogenic influence and a tool for water resource management. For regions relying heavily on surface water as a drinking source, regular VOC monitoring can ensure public health safety [16].

4. CONCLUSION:

The monsoon season saw a noticeable spike in VOC concentrations, can be attributed to increased agricultural and urban runoff introducing more contaminants into the water bodies. A declining trend in VOC levels was observed moving from the monsoon to autumn season. The reduced rainfall limited additional runoff, allowing concentrations to decrease across the board. The winter season had the lowest VOC concentrations out of all seasons, with many VOCs being close to the detection limits. Colder temperatures and an absence of rainfall minimized new inputs and likely increased volatilization rates. Aromatic VOCs like benzene, toluene, ethylbenzene and xylenes were the most prevalent compound types detected. Their proportions increased in the winter season when concentrations of chlorinated VOCs decreased sharply. This indicates aromatics constitute a major portion of background VOC contamination. The strong positive correlation of VOC levels with rainfall points to runoff from agricultural fields, industries, roads as a major driver of increased monsoon concentrations in Lake Banas and River Sone. Additionally, proximity to urban canters and coal mining are likely factors for heightened VOC levels at those sites. The monsoon VOC levels observed in Lake Banas and River Sone exceeded safe limits for drinking water and aquatic biota. Exposure to elevated levels can have toxic effects on fish and other aquatic organisms. Additionally, there are risks to human health from contamination of crucial water resources, especially those relied on for drinking water supply.

5. ACKNOWLEDGEMENT

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Table 1. Quantitative data of VOCs from selected sampling sites in different seasons.

Sampling Sites	VOCs (µg/L)	Summer	Monsoon	Autumn	Winter
Site 1 (Lake Banas)	Benzene	10.33333	14.66667	7.666667	4.666667
	Toluene	7.333333	20.33333	9	4.333333
	Ethylbenzene	5.666667	9.333333	4.666667	3.666667
	Xylenes	14.66667	28.33333	11.33333	6.333333
	Chloroform	2.666667	5.333333	1.7	1.033333
Site 2 (River Sone)	Benzene	7	9.333333	5.666667	3.333333
	Toluene	6.666667	11.66667	8.333333	3.333333
	Ethylbenzene	4	6	1.666667	1.333333
	Xylenes	9.233333	14.66667	7.333333	3.9
	Chloroform	1.7	3	0.966667	0.633333
Site 3 (Mukundpur)	Benzene	1.233333	1.666667	1	0.733333
	Toluene	0.566667	1	0.866667	0.3
	Ethylbenzene	0.233333	0.533333	0.133333	0.133333
	Xylenes	1.733333	2.566667	0.866667	0.833333
	Chloroform	0.133333	0.166667	0.056667	0.02

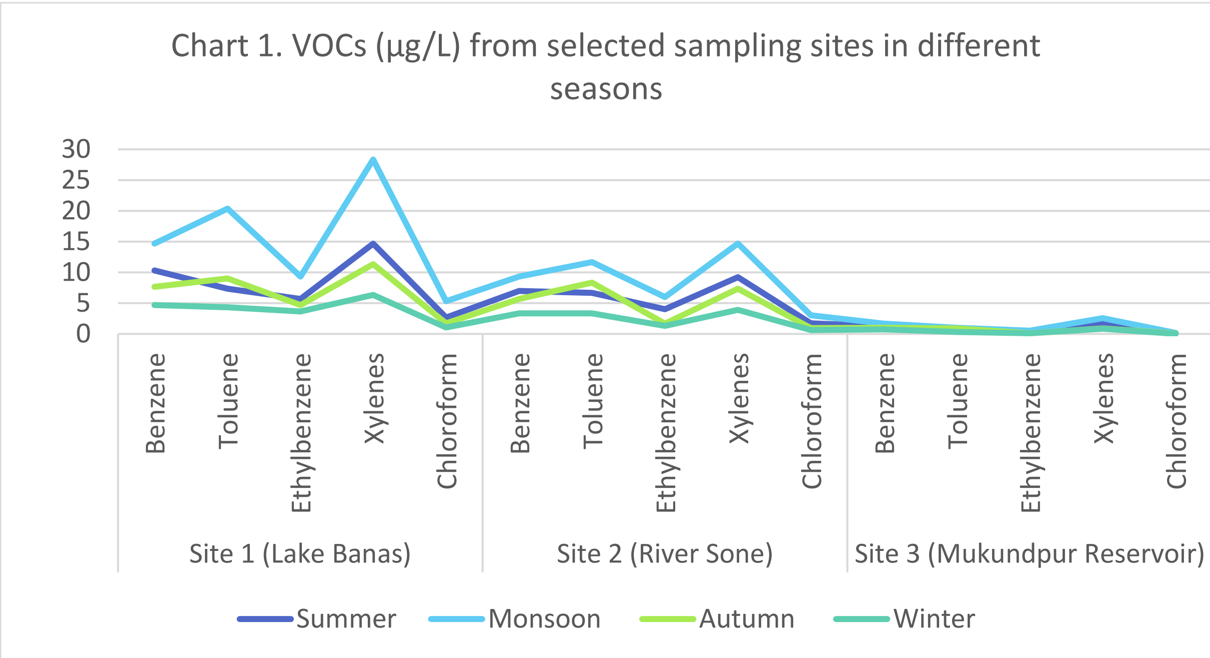

Chart 1. VOCs (µg/L) from selected sampling sites in different seasons

Table 2 (a) and Table 2 (b): Percentage prevalence of VOC types by season and Correlation of VOC levels with meteorological data

VOC Type	Summer	Monsoon	Autumn	Winter
Aromatics	50	55	60	70
Chlorinated Hydrocarbons	10	15	5	2
Other	40	30	35	28

Parameter	Correlation Coefficient
Temperature	0.7
Rainfall	0.85
Wind Speed	0.5
Solar Radiation	0.6

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