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RESEARCH PAPER

Assessment of the Ecological Impact of Pollution in the Damanganga River

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Abstract: The Damanganga River faces severe pollution from industrial effluents and sewage, impacting its ecological health. The study aimed to analyze the current water quality status at the proposed conventional barrage site across the river between Silvassa, Vapi and Daman in India. Water samples were collected from three sites along the river during different seasons and analyzed for physicochemical parameters like TDS, COD, BOD, nutrients, fecal coliforms, heavy metals, etc. as per standard methods. Principal component analysis (PCA) was done. GCMS profiling of organics was also carried out. Several parameters exceeded the desired limits. TDS, BOD, fecal coliforms were very high indicating organic pollution and sewage contamination. Dissolved oxygen was deficient at some sites. Cadmium, copper and iron exceeded limits due to industrial releases containing these metals. PCA showed organic pollution as the major degrading factor for water quality followed by industrial contamination. GCMS analysis revealed hazardous organics like petrochemicals, fatty acids, solvents, pesticides and aromatic pollutants at varying levels along the river's course demonstrating pollution from oil spillages, industrial effluents and agricultural runoff. The findings confirm severe deterioration in the Damanganga's water quality from inadequately treated sewage and industrial discharges posing environmental and health risks. Stringent regulations, proper wastewater treatment, runoff control and regular monitoring are vital to improve the river's condition.

Keywords: Damanganga River, water pollution, ecological impact, physicochemical analysis, principal component analysis

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INTRODUCTION

The Damanganga River originates in the Sahyadri Hills, near to the Maharashtra town of Valveri. It then passes through the states of Maharashtra, Gujarat, and the Union Territories before emptying into the Arabian Sea. The main sources of pollution for the river are untreated household sewage and industrial effluents. Industrial facilities like GHCL in Bhilad, Gujarat, and CETP in Vapi, Gujarat, are significant producers of pollution. Through research carried out by groups like CSIR-NEERI and Pollution Control Committees, efforts are being made to evaluate and lessen the ecological impact of pollution on the river [1].

Concerns about the contamination in the Damanganga River have been raised by environmentalists who have found indications of ongoing pollution. The impact of pollution on the aquatic life and water quality of the river is being monitored and evaluated. To mitigate the harm caused by contaminants entering the river, restoration measures are required, according to a number of studies [2], [3].

Due to a mix of man-made and natural forces, the Damanganga and Ganga rivers are severely contaminated [4]. These elements include coal mining operations, untreated household and industrial waste, and sociocultural customs. With high concentrations of total dissolved solids, sulfate, hardness, and iron content together with biological contamination, this pollution has a substantial negative influence on the ecological health of the river [5]. It is clear that quick action is required to reduce pollution and improve the river's water quality. Numerous studies have evaluated the ecological impact of pollution in the Damanganga River. According to these research, wastewater releases, urban and agricultural wastes, and industrial discharges are the main causes of the river's severe contamination [6]. It has been determined that the river is highly polluted, with contamination and pollution indices showing differing levels of pollution at several points along the river[7]. High pollution levels are caused by NH3+, PO43-, SO42-, NO2-, and NO3- pollutants, which are mostly from agricultural runoff and pesticide and fertilizer usage [8]. High levels of organic pollution have also been reported, which suggests that coal mining and related industrial operations have an effect on the river's ecological state[9].These results emphasize how urgently efficient pollution management and ecological health restoration of the Damanganga River are needed.

The industrial and domestic wastes of Silvassa, Daman, Kachigaon, and Vapi town discharge pollutants into the Damanganga River, which flows downstream from Vapi and into the sea. The BOD value measured at the Central Pollution Control Board's (CPCB) monitoring site downstream of Kachigaon reached a maximum of 30 mg per liter, per the report. According to a study report by the Machhimar Adhikar Rahstriya Abhiyan (ADAR), the town of Vapi's groundwater has a mercury content approximately 96 times higher than WHO guidelines, and the town's dissolved oxygen level is extremely low at 0.1 mg/L due to industrial effluents from the town. Direct dumping of untreated wastewater into the Kolak and Daman Ganga Rivers occurs[10]. As a result, fish life has been negatively impacted by contamination of the sea up to a five nautical mile radius. Due to the Sarigam Industrial Association's effluent disposal pipeline, around 1000 small-scale and artisanal fishermen in four to five villages were reportedly impacted by the Common Effluent Treatment's malfunction. The Sahyadri Hills, which are close to Valveri village in the Nasik district of Maharashtra, are the source of the Damanganga River. Along with its tributaries, the river travels approximately 131.30 km from east to west before emptying into the Arabian Sea. It passes through mountainous regions of Maharashtra, Gujarat, and the Union Territories (UT) of Dadra & Nagar Haveli (DNH) and Daman & Diu (DD) (Figure 1). The main source of water is the Madhuban Dam, which was built in the Gujarat state upstream of the river. The river travels approximately 41.56 kilometers from Madhuban Dam to its confluence with the Arabian Sea. Along the river's course are large, medium, and small-scale companies found in the Dadra & Nagar Haveli, Vapi (Gujarat), and Daman industrial clusters. Additionally, the catchment area's domestic wastewater is dumped into the river.

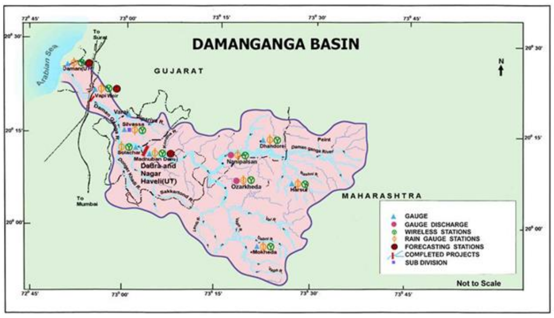

Figure 1. Map of Damanganga River Basin

The purpose of the research was to evaluate the Damanganga River's ecological health in order to build the planned conventional barrier that would span the river between Silvasa, Vapi, and Daman. It is critical to show how well it interacts with the river's natural processes and how successful it is in enhancing the ecological health of the waterway. The purpose of the research was to determine the river's present state of water quality at the suggested location.

MATERIALS AND METHODS

Sample Collection

At the chosen 3 locations in Silvasa (20°13'02"N 73°00'35"E), Vapi (20°20'34"N 72°54'21"E) and Daman (20°22'31"N 72°52'41"E), sampling was done in a three different seasons. The main source of pollution at Site Silvasa DG1 is the outflow from GHCL, a large chemical manufacturing unit and 6 km DG3 Daman stretch is contaminated by a number of sources, including the now-ceasing discharge from Khemani Distilleries and smaller, untreated industrial effluents. The 28 km DG2 Vapi area is heavily impacted by the discharge from the CETP, which treats wastewater from over 500 Vapi-based industrial units. The subsurface level was sampled using a bottle sampler that had an opening mechanism set to the appropriate depth. An aliquot was moved to the sampling bottles for analysis after they had been well washed with sampled water. For collection, bottles labeled with dissolved oxygen (DO) and biochemical oxygen demand(BOD) were utilized. As soon as the samples were collected for the titrimetric determination, they were fixed for the DO determination. The remaining samples were shipped to the Bioscience Department's laboratory at VNSGU, Surat, for examination. They were all stored in ice-filled containers. The 23rd edition of APHA (2017) was used to determine all other chosen criteria[11].

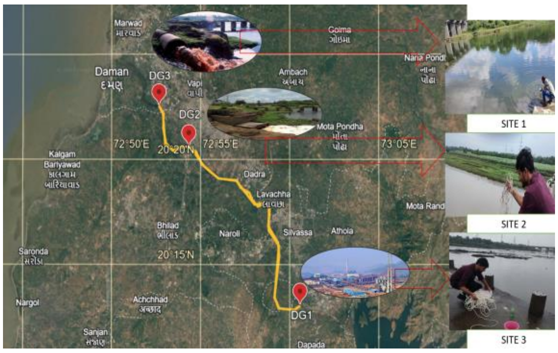

Figure 1 Sample collection sites in Damanganga River

In accordance with the method, the water samples were examined for the necessary physico-chemical characteristics to assess the ecological health of the Damanganga River.

Heavy Metal Analysis

Polythene bottles, pre-cleaned, are employed for the collection of water samples. A 250ml portion is taken from each sampling site for subsequent heavy metals analysis. Subsequently, 10ml of HNO_3 and 10ml of HCl are added to the samples, and the mixture undergoes digestion on a hot plate at 115 °C within a fume hood for approximately 1–2 hours, resulting in a final volume of 20ml. The digested water samples are then allowed to cool for around 20 minutes and filtered through Whatman No. 40 filter paper. The filtrates are washed with 30ml of distilled water, collected, and then brought to a volume in a 100-ml volumetric flask using distilled water. Using certified reference materials (CRM 700) and duplicates for control and quality assurance, an acetylene flame atomic absorption spectrophotometer (Agilent AAS 240FS) was utilized to analyze heavy metals in each batch of water samples and reagent blanks [12].

Extraction of wastewater and GC-MS analysis

The liquid-liquid extraction process was used to extract wastewater samples (500 mL) using 20 ml of n-hexane (HPLC grade, SRL, India) and dichloromethane (DCM) (HPLC grade, SRL, India) (APHA, 2017). Samples of homogenized wastewater were shaken briskly three times in a separatory funnel, with 20 milliliters of HPLC-grade n-hexane used each time. After the solvent and water phases were separated, the solvent layer was collected in a 100 mL container with an amber color. Acidic and basic fractions were obtained in the case of DCM by extracting water samples at pH values greater than 2 and lower than 11, respectively. After the extracts were dried out completely, they were reconstituted in two milliliters of the appropriate solvents, put into GC vials, and subjected to GC-MS (Nexis GC-2030), auto sampler, and ion trap mass spectrometer analysis. The carrier gas containing helium had a head pressure of 8.7 psi. A Bruker-glass liner was used to make the injection of the sample (injection volume 1μL) in split mode with a split ratio of 10[13]. The NIST MS search v2.0 library (National Institute of Standards and Technology) was utilized to identify the compounds based on their mass spectra.

RESULTS AND DISCUSSION

Physicochemical Analysis

The physicochemical parameters of water samples collected from three sites from the Damanganga. River was analyzed during winter, summer and monsoon seasons. The parameters tested as per Table 2 included pH, total dissolved solids (TDS), chemical oxygen demand (COD), dissolved oxygen (DO), biochemical oxygen demand (BOD), ammoniacal nitrogen (NH_3-N), nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N), total Kjeldahl nitrogen (TKN), fluoride, fecal coliforms, and heavy metals such as lead, cadmium, chromium, nickel, copper, iron, zinc and cobalt. The pH values ranged from 7.58 to 8.62, indicating slightly alkaline water. The TDS exceeded the permissible limit of 500 mg/L at all sites during all seasons, with the highest TDS of 1172 mg/L recorded at site DG2 during winter. High TDS indicates the presence of elevated amounts of ionic substances in the river water. COD levels were also found to breach the standard of 150mg/L at sites DG2 and DG3, implying high organic pollution from domestic and industrial effluents discharged into the river. DO levels were below the desired level of 5mg/L at sites DG1 and DG2 in winter, when the water suffers from oxygen deficit due to reduced mixing and dilution of pollutants. BOD exceeded the standard of 3mg/L during all seasons at the three sites, with the maximum BOD of 76mg/L obtained at site DG2 in summer. Elevated BOD indicates substantial organic pollution and depletion of dissolved oxygen needed for aquatic life Among nitrogen compounds, ammoniacal nitrogen and TKN were present at high concentrations compared to prescribed limits at all sites. Nitrate nitrogen was within the norm of 10 mg/L. The nutrients ammoniacal nitrogen, nitrite and nitrate nitrogen chiefly originates from domestic sewage, industrial effluents and agricultural runoff in the catchment area of the river.

All sites showed fluoride levels above the limit of 1 mg/L in some seasons, which can adversely affect dental and skeletal health of consumers using this water. Fecal coliform counts were also extremely high, breaching the stipulated levels by several folds at the three locations. This represents serious fecal contamination from human and animal waste discharges into the river.

Heavy metal analysis revealed concentrations of lead, chromium, nickel and cobalt to be within permissible limits at all sites. However, cadmium exceeded the standard of 0.003mg/L at sites DG1 and DG2 in all seasons. Copper surpassed the limit of 0.05 mg/L at site DG2 in winter. Iron was detected above the desirable limit of 0.3mg/L at sites DG1 and DG2 in summer and DG3 in monsoon. The presence of heavy metals is linked to industrial pollution from nearby clusters.

Principal Component Analysis

At the three sample locations along the Damanganga River, principal component analysis (PCA) was used to determine the primary physicochemical characteristics influencing water quality [14]. 51.4% of the variation in the first two principal components (PC1 and PC2) in Figure 3 can be explained by the PCA biplot. Strong positive loadings for pH, TDS, COD, BOD, ammoniacal nitrogen, nitrite nitrogen, nitrate nitrogen, TKN, and fecal coliforms are present in PC1, which explains 27.9% of the variation. This element stands for sewage and organic pollution in the river water. All three sites had positive PC1 values, but site DG2 has the highest score, suggesting that organic and microbiological characteristics are substantially contaminated. Strong positive relationships are shown with fluoride, lead, cadmium, chromium, nickel, copper, iron, zinc, and cobalt. PC2 accounts for 23.5% of the variability in the data. This element denotes the presence of heavy metal and inorganic pollution in the river. Because of its closeness to industrial clusters that discharge metal-rich effluents into the river, Site DG1 has the lowest PC2 score, indicating comparatively lower quantities of heavy metals than the other two sites.

Analysis of GC MS

Water samples from Damanganga River site 1 were subjected to GCMS analysis, which identified the presence of many organic substances from different groups, such as fatty acids, alcohols, ketones, hydrocarbons, and synthetic chemicals (Figure 4). The samples contained petrochemical chemicals such as aromatics including dodecane, hexadecane, benzene, and alkylbenzenes, as well as alkanes. Their existence suggests that there may have been unintentional spills, storage tank leaks, or the disposal of petroleum products into drains that are connected to rivers, among other causes of oil or gasoline pollution. It is well recognized that petrochemicals are harmful to aquatic life [15]. The samples include a variety of fatty acids, including hexanoic, octanoic, nonanoic, tetradecanoic, and hexadecanoic acids. These acids may have come from natural sources, but they may also have entered the river from industrial and household discharges that included grease, soap, and food waste. Numerous industrial compounds and common organic solvents, such as ketones and alcohols, were found. Chemicals such as 3-octanone and 2,4-dimethyl-1-heptene, as well as chlorinated solvents such as butanenitrile and 4,4,4-trichloro-, are representative of pollutants released by industrial sources alongside the river. These substances are dangerous contaminants of water. The samples also included pesticide compounds including N-neopentyloxycarbonyl and D-alanine. Their presence indicates that pesticide residues from agricultural runoff are making their way into the river through surface drainage. Certain aromatic compounds, such as 3,5-bis(1,1-dimethylethyl) and phenol, are harmful organic pollutants that are released from industrial wastewater systems. Overall, in Damanganga River site 1, the GCMS study found significant pollution from both natural and man-made sources, including sewage, industrial effluents, urban runoff, and agricultural pesticides.

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Table 1 Analysis of Sampling Sites DG1, DG2 and DG3 from Damanganga River

River Code Parameters	DG1 Winter	DG1 Summer	DG1 Monsoon	G2 Winter	DG2 Summer	DG2 Monsoon	DG3 Winter	DG3 Summer	DG3 Monsoon	Permissible Limits
pH	7.67	7.71	7.65	8.1	8.62	7.95	7.64	7.68	7.58	**6.5-8.5**
TDS	874	548	541	1172	958	1074	648	741	592	**500 mg/l**
COD	70	80	110	260	350	182	130	120	344	**150 mg/l**
DO	5.6	5.63	5.47	3.5	8.41	5.63	4.94	6.1	8.51	**>5 mg/l**
BOD	14	16	22	53	76	22	26	24	63	**<3 mg/l**
NH_3N	13.2	14	15.1	14.5	17.4	12	14.8	13.5	16.5	**<30mg/l**
NO_2N	0.3	1.4	0.4	0.2	1	0.9	1.3	1.4	1.6	**<0.3mg/l**
NO_3N	2.4	1.9	2.8	3.8	1.7	1.8	1.6	1.6	0.2	**<0.7mg/l**
TKN	0.84	1.12	0.84	1.2	1.01	0.94	1.07	1.19	1.02	**25mg/l**
FLUORIDE	0.25	0.21	0.16	0.84	0.882	0.42	0.18	0.11	0.84	**1mg/l**
FC	120	130	170	240	220	240	350	1600	170	**200**
LEAD	-0.09	-0.11	-0.07	0.11	-0.13	-0.08	-0.11	-0.11	-0.08	**0.01mg/l**
CADMIUM	-0.604	-0.595	-0.601	-0.596	-0.593	-0.607	-0.602	-0.598	-0.605	**0.003mg/l**
CHROMIUM	-0.075	-0.09	-0.071	-0.072	-0.077	-0.053	-0.046	-0.091	-0.036	**0.05mg/l**
NICKEL	-0.03	-0.016	-0.041	-0.055	-0.049	-0.097	-0.075	-0.048	-0.056	**0.02mg/l**
COPPER	-0.052	-0.084	-0.071	0.837	-0.085	-0.055	-0.054	-0.077	0.126	**0.05mg/l**
IRON	0.682	1.387	11.5	0.171	2.103	1.19	1.218	0.58	2.706	**0.3mg/l**
ZINC	0.043	0.038	0.018	0.011	0.01	0.027	0.013	0.036	0.048	**3mg/l**
COBALT	-0.029	-0.052	-0.087	-0.056	-0.021	-0.034	-0.084	-0.029	-0.047	**0.004mg/l**

These chemicals' existence in Damanganga River site 1 suggests that the river is contaminated by sewage, industrial waste, and agricultural runoff, among other things. a few of these.

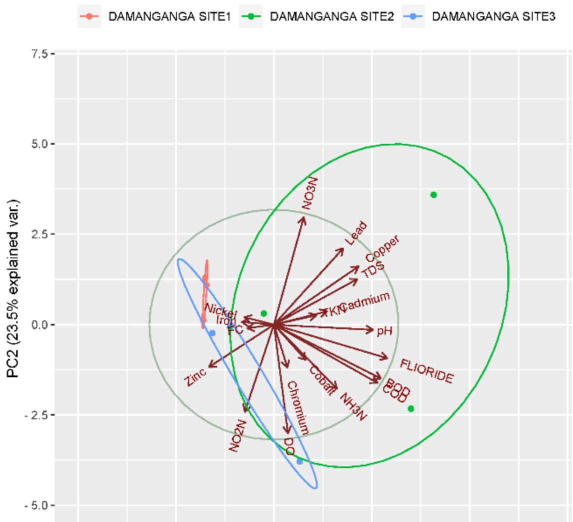

Figure 2 Principal Component Analysis of Sample DG1, DG2 and DG3

Water samples from Damanganga River site 2 were subjected to GCMS analysis, which identified the presence of several organic substances, including fatty acids, alcohols, ketones, and many aliphatic and aromatic hydrocarbons (Figure 5). Multiple alkanes, such as octane, nonane, dodecane, and hexadecane, when detected, point to petrochemical pollution from sources related to oil and gasoline. This shows that surrounding industrial sites may be the source of pollution due to activities like fuel and solvent leaks from storage tanks and pipes. The different fatty acids and alcohols that have been discovered are probably the result of both natural and man-made sources, such as home sewage and food processing enterprises that release wastewater into the river. Typical industrial solvents like the ketone 3-octanone and the aromatic hydrocarbon benzene are present in industrial effluent that has been contaminated by companies along the river. Certain molecules that have been found, such as phenol and benzene, are considered priority environmental pollutants because they are hazardous, persistent, and bioaccumulative. The health of aquatic ecosystems and people who drink river water are seriously threatened by their existence.Water samples from Damanganga River site 3 were subjected to GCMS analysis, which identified the presence of several organic substances, alcohols, fatty acids, aromatic compounds, and many aliphatic hydrocarbons (Figure 6). The samples contained many alkanes, including heneicosane, dodecane, hexadecane, and octadecane. Their existence suggests that petroleum-based products like diesel and gasoline have contaminated the area. These petrochemicals most likely originate from car emissions and gasoline storage facility leaks close to the river. Industrial solvents often employ a variety of alcohols, such as 1-octanol, 2-hexyl-1-decanol, and 2-isopropyl-5-methyl-1-heptanol. Their finding indicates that adjacent firms and industrial clusters are discharging these chemicals into the river through wastewater discharges. Hexanoic and octanoic acids are examples of fatty acids that can come from both natural and man-made sources, such as sewage and food processing wastes. The hazardous water contaminant benzene, an aromatic hydrocarbon, is most frequently the result of industrial activity. Compounds such as oxaspiro compounds, butanenitrile, and derivatives of phenol are signs of leaks from chemical production facilities and other enterprises near the river. Several of these are organic pollutants that are persistent and have negative ecological effects.

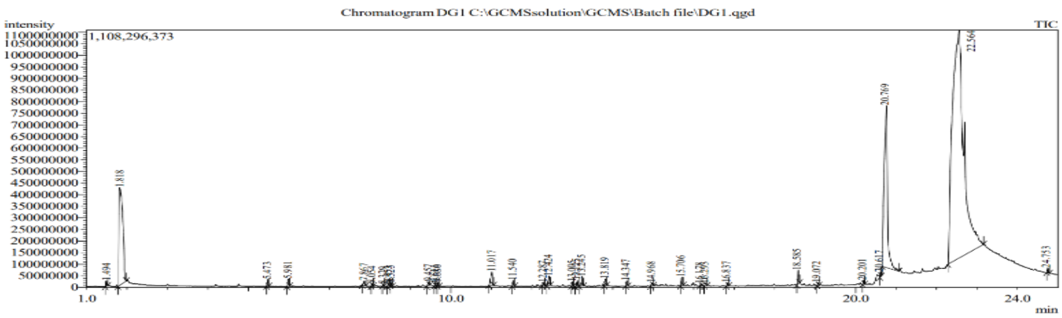

Figure 3 Chromatogram Peak Analysis of DG1

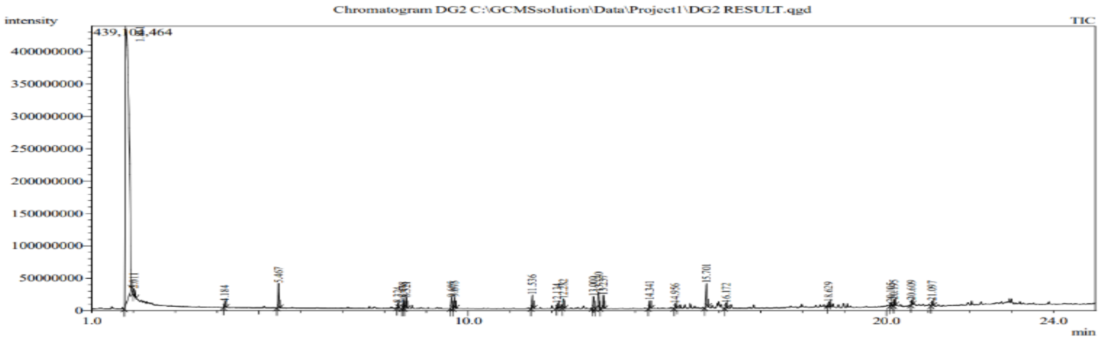

Figure 4 Chromatogram Peak Analysis of DG2

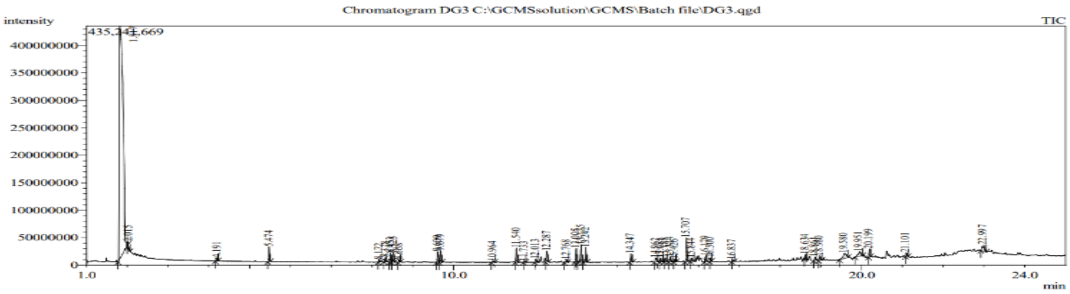

Figure 5 Chromatogram Peak Analysis of DG3

The PCA results show that the primary cause of deteriorating the water quality at all sites of the Damanganga River is organic pollution, specifically from sewage and household garbage, as reflected by PC1. The river's water quality is also being negatively impacted by industrial pollution from adjacent industrial estates and clusters, particularly in regard to heavy metals at sites DG2 and DG3, as shown in PC2. To improve the river's water quality state, effective controls must be put in place for both industrial and residential pollution sources [16]. An evaluation of the organic pollutants found in the water of the Damanganga River at three separate locations along its course was given by the GCMS study. Throughout the sites, a wide range of substances were found, including hydrocarbons, fatty acids, alcohols, ketones, and synthetic chemicals. All test sites included petrochemicals, including both aromatic and aliphatic hydrocarbons, suggesting widespread petroleum contamination in the river, most likely via emissions, leaks, and urban runoff. Extremely high levels at Site 2 indicated significant pollution from adjacent industrial zones. Solvents, plasticizers, and pesticide residues found in various locations also indicate the presence of these chemicals in agricultural runoff and industrial effluent. In instance, Site 1 displayed pesticide fingerprints from drainage from farms. At each of the three locations, different amounts of alcohols and fatty acids were visible. Elevated concentrations indicate increased loads from home and food industrial wastewater discharges along the river flow, even if some natural origin is expected. Hazards to human health and the environment are present for toxic priority pollutants such as benzene, chlorinated chemicals, and phenol derivatives [17]. Their discovery attests to the industrial pollution caused by manufacturing processes and the insufficient processing of industrial wastewaters.

CONCLUSION

In the current study, water samples from three locations along the Damanganga River were subjected to physicochemical examination, principal component analysis, and GCMS profiling at various times of the year. All locations had significant levels of organic and microbiological contamination, according to the data, which also showed that fecal coliforms, nutrients, TDS, COD, and BOD were all over recommended values. At several locations, low quantities of dissolved oxygen were discovered [18]. Because of industrial pollution, trace elements such as iron, copper, and cadmium were also found to be present in excess of allowable limits. Sewage contamination and organic pollution were found by PCA to be the main factors lowering the river's water quality. Along the river's path, GCMS analysis verified the widespread presence of dangerous organic substances such as pesticides, fatty acids, solvents, petrochemicals, and aromatic pollutants.

Overall, our research indicates that the discharge of industrial effluents and poorly treated sewage has caused a considerable decline in the water quality of the Damanganga. This is seriously endangering human health and the environment. To enhance the state of the river ecology, strict laws, appropriate wastewater treatment, runoff management, and routine water monitoring are desperately needed. The study offers essential baseline data that will direct corrective actions and further investigation.

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