# Evaluation of the Physical and Chemical Characteristics of Wastewater Generated from Car Wash Stations in Tikrit City, Iraq

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**Summary:**
This study aimed to evaluate the physical, chemical, and microbiological properties of wastewater from car wash stations in Tikrit, Salah al-Din Governorate, and to determine the level of pollution released from these stations into the environment. The study was conducted from October 2025 to March 2026, and included six sites within the Tikrit district. The results showed that the wastewater from the car wash stations exhibited significant variation in pollutant concentrations. Total hardness ranged from 409–588 mg/L, turbidity from 43–434 NTU, and pH from 6.4–8.9, indicating fluctuations between slightly acidic and alkaline conditions. Dissolved oxygen levels ranged from 6.75 to 8.31 mg/L, while aerobic bacteria levels ranged from 370 to 643, indicating a significant microbial load. Dissolved ions included sulfates from 292 to 510 mg/L and chlorides from 180 to 320 mg/L. The results also showed relatively high concentrations of some heavy metals, with iron ranging from 1.54 to 8.6 mg/L and cadmium from 1.21 to 4.62 mg/L. These are important indicators of wastewater contamination from oils, dirt, detergents, and metal residues generated during car washing operations. Overall, the study suggests that wastewater from car wash stations in Tikrit could be a source of environmental pollution, especially when discharged untreated directly into sewage systems or the surrounding environment. Therefore, the study recommends the necessity of establishing primary treatment units in car wash stations, monitoring the quality of the discharged water periodically, and reducing the discharge of chemical and microbial pollutants in order to preserve the soil, surface and groundwater.

**Keywords: Wastewater, car wash stations, physical and chemical properties, hardness.**

## Introduction:

Water pollution is one of the most prominent environmental challenges facing the world today, particularly in developing countries that are experiencing rapid urban and industrial expansion without effective systems for treating industrial waste. Industrial wastewater pollution is considered one of the most dangerous types of pollution due to its content of complex chemical compounds and toxic substances, most notably heavy metals, which are characterized by their high stability in the environment, lack of biodegradability, as well as their ability to bioaccumulate within living organisms and transfer through food chains, posing a direct threat to human health and the environment (1; 2). Car maintenance and washing workshops are considered significant sources of water pollution, producing large quantities of polluted wastewater containing oils, greases, detergents, suspended solids, in addition to varying concentrations of heavy metals such as lead (Pb), cadmium (Cd), cobalt (Co), zinc(Zn), nickel (Ni), and iron (Fe) (3). These metals result from various processes including corrosion of metal parts, oil leakage, battery waste, painting operations, and the use of various chemicals in maintenance and cleaning. This water is often discharged directly into the surrounding environment without adequate treatment, leading to contamination of soil, surface water, and groundwater (4).

## Materials and Methods:

Sample Collection: The study area included several car wash stations in the Tikrit region of Salah al-Din Governorate. These stations represent active

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environments continuously exposed to the effects of human life, making them suitable sites for studying the environmental, chemical, and physical characteristics of water and soil. Six different locations of car wash stations were selected, distributed in Tikrit city and its suburbs: Al-Qadisiyah district (Plot 500), Al-Qadisiyah district (Balaj Street), Al-Zohour district (Al-Basha Street), Al-Hawli Street, and Civil Defense Street. This selection aims to represent the spatial variation in the nature of human activity and intensity of use. These sites were chosen due to differences in water sources, quantities of detergents and chemicals used, the nature of water discharge, and its impact on the surrounding soil. These sites are characterized by their intense human activity, where various types of detergents and chemical solutions are used, which may contain active compounds affecting the physical and chemical properties of soil and water. The proximity of some of these stations to residential or agricultural areas underscores the importance of assessing their potential environmental impacts. The study area is characterized by a semi-arid to arid climate, with hot, dry summers and cold to mild winters, and significant temperature variations between summer and winter, as well as between day and night. The region is also characterized by low and irregular annual rainfall, affecting the leaching and transport of pollutants in the soil.

**Table (A) Coordinates of car wash stations in Tikrit city within Salah al-Din Governorate using a GPS device.**

| Coordinates | Code | Site Name | NO |
|---|---|---|---|
| **34.65464° N, 43.64785° E** | **P1** | **Al-Khalawi** | **1** |
| **34.59817° N, 43.66311° E** | **P2** | **X Car** | **2** |
| **34.60142° N, 43.66514° E** | **P3** | **Clean Center** | **3** |
| **34.60604° N, 43.68450° E** | **P4** | **Al-Qusour** | **4** |
| **34.64069° N, 43.67473° E** | **P5** | **Al-Taj** | **5** |
| **34.65416° N, 43.65938° E** | **P6** | **JF** | **6** |

**Physical, Chemical, and Biological Tests and Heavy Metals:**

**Total Hardness**

Total water hardness was measured using the Lind method (1979). A 5-10 ml water sample was taken and diluted to 50 ml with distilled water. The pH of the sample was then adjusted to 10 using a buffer solution with 1 ml of ammonia, followed by the addition of an appropriate amount of Eriochrome Black T dry indicator. The sample was titrated with a standard solution of disodium ethylenediaminetetraacetic acid ($Na_2$ EDTA) at a concentration of 0.01 mol/L until the color changed from wine red to blue. The average of two readings per sample was calculated. Total hardness was then calculated based on the volume of titrant consumed using the standard equation (5).

Total Hardness = (V $Na_2$ EDTA × N $Na_2$ EDTA × 1000 × M.W as $CaCO_3$ ) / V Sample

Turbidity

Turbidity was measured immediately upon sample arrival at the laboratory using a turbidity meter manufactured in Portugal, which displays turbidity values in NTU units. Samples were shaken well to ensure homogeneity before measurement, and the measurement cell was filled to the marked line. The cell surface was cleaned with a lint-free cloth to remove fingerprints and impurities, preventing any impact on reading accuracy due to light scattering or air bubble formation and ensuring instrument stability during measurement (6).

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**pH**

pH was measured using a pH meter as the most accurate method in laboratory analysis. The process begins by turning on the device and calibrating it using standard solutions with known values such as 4, 7, 9, or 10. The electrode is washed with distilled water between each solution to ensure calibration accuracy. The sample is then prepared by placing an appropriate amount in a clean glass beaker. The electrode is washed again with distilled water and fully immersed in the sample without touching the bottom of the beaker. The reading is left until it stabilizes on the device, or the sample is gently stirred to obtain a stable reading. After recording the pH value, the electrode is immediately washed with distilled water and stored in its storage solution. Periodic recalibration is necessary to ensure result accuracy, avoiding touching the electrode or leaving it dry for long periods (7).

**Dissolved Oxygen (DO)**

Dissolved oxygen concentration in water was measured using a modified version of the Winkler-Azide method. 250 ml oxygen bottles were filled with water extracted directly from car wash wastewater. The sample was fixed in the field by adding 2 ml of manganese sulfate solution, followed by 2 ml of alkaline potassium iodide solution. The sample was then shaken well to ensure chemical mixing. After 10 minutes, 2 ml of concentrated sulfuric acid was added to dissolve the resulting precipitate. A 100 ml volume of the sample was then titrated with 0.025 M sodium thiosulfate solution, adding a few drops of starch solution as a color indicator. The average of two readings per sample was used, and results were expressed in mg/L of dissolved oxygen (8).

**Biochemical Oxygen Demand ($BOD_5$ )**

BOD was calculated using the indirect method of dissolved oxygen measurement, where dark Winkler bottles were placed in an incubator at 25°C for five days. After the incubation period, the final dissolved oxygen concentration (DO) was determined and compared to the initial DO concentration measured at the beginning of the experiment. The difference between the two values represents the BOD, expressed in mg/L (8).

**Total Aerobic Bacterial Count**

The total number of viable aerobic bacteria was estimated using the pour plate method. The water sample was shaken well about 25 times to ensure homogeneity, then a series of serial dilutions up to $10^{-2}$ was performed using 0.85% physiological saline solution. 1 ml of each dilution and the original sample was transferred using a sterile pipette to sterile Petri dishes. Warm nutrient agar medium (45-50°C) was poured over the agar. Dishes were gently swirled in a figure-eight motion to ensure even sample distribution, and the medium was left to solidify. Dishes were then incubated inverted at 37°C for 24 hours. After incubation, colonies were counted using a standard colony counter, and plates containing 30-300 colonies were considered. The total viable aerobic bacterial count was calculated by multiplying the number of colonies by the reciprocal of the appropriate dilution, and results were expressed in CFU/100 ml (9).

**Sulfate ($SO_4^{2-}$ )**

Sulfate ion concentration was determined using the turbidimetric method. A water sample volume between 0.5 and 1 ml was taken and diluted to 100 ml with distilled water. Then, 5 ml of conditioning solution was added, and the sample was mixed mechanically at constant speed using a magnetic stirrer to ensure homogeneity. Barium chloride crystals were then added, and stirring continued for an additional

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minute to form a barium sulfate precipitate, whose turbidity is directly proportional to the sulfate concentration in the sample. Concentrations were then read and compared to a standard curve to determine the final concentration. Appropriate dilution was performed if necessary to avoid exceeding the acceptable range of the method. Results were expressed in mg/L (10).

**Chloride Ion ($Cl^-$ )**

Chloride ion was measured by taking 5-10 ml of the water sample and diluting it to 25 ml with distilled water. A standard solution of silver nitrate (0.24 M) was added to 1 ml of potassium dichromate solution until the reaction ceased (appearance of a reddish-brown color). The average of two readings was calculated. The same steps were performed on 25 ml of distilled water free of chemicals, and results were expressed in mg/L (11).

**Heavy Metals**

Water samples were digested for total heavy metal estimation by taking a known sample volume between 100 and 250 ml, shaking samples containing sediment to ensure homogeneity, then adding 5 ml of concentrated nitric acid ($HNO_3$ ), followed by 1-2 ml of perchloric acid ($HClO_4$ ) or hydrochloric acid (HCl) according to the protocol used for analyzing organic compounds and metal complexes. Samples were then heated using a water bath or electric heater (hot plate) at 85-95°C until the volume decreased to about 25 ml and became clear or nearly clear, without allowing them to dry. They were then left to cool and diluted to a known final volume (50 or 100 ml) using deionized distilled water. This was followed by filtering the samples using metal-free filter paper (Whatman 42). Finally, they were analyzed using Atomic Absorption Spectrometry (AAS) or other spectrometric techniques such as Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) orInductively Coupled Plasma Mass Spectrometry (ICP-MS) to estimate heavy metal concentrations (9).

## Results and Discussion

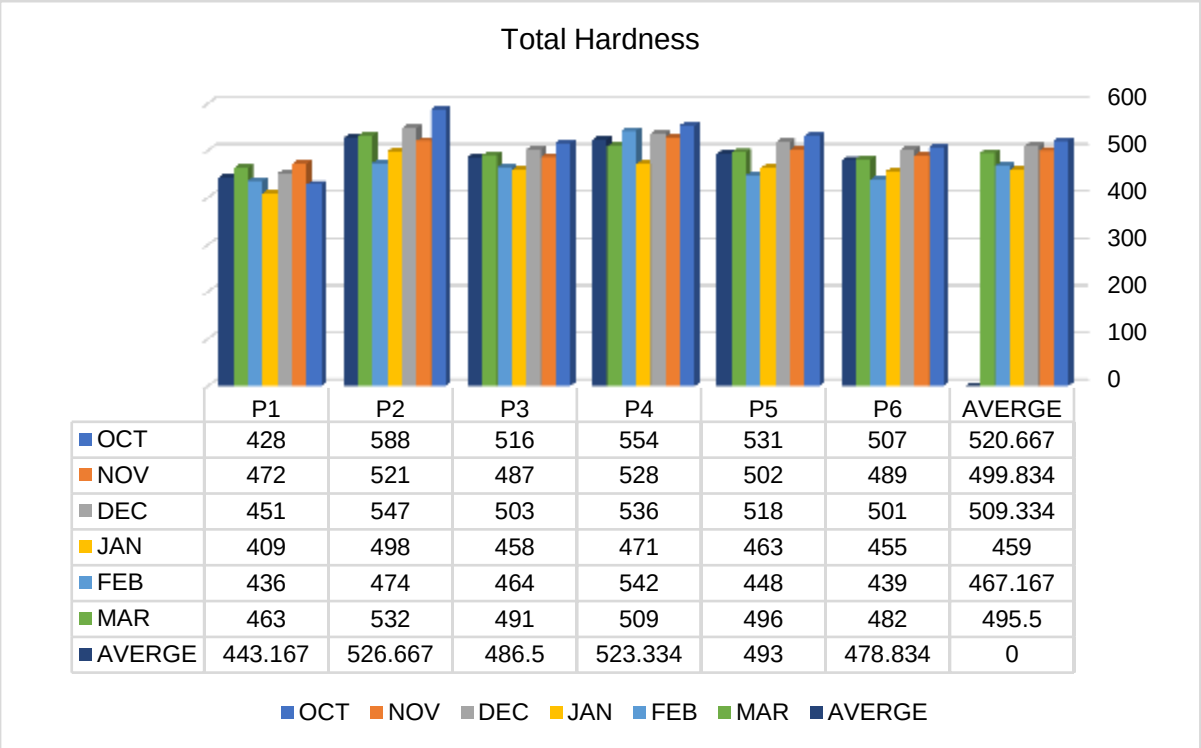
### Physical, Chemical, and Biological Properties and Heavy Metals

**Total Hardness**

Total hardness values shown in Table 1 ranged between 409 and 588 mg/L. The highest value was recorded at Station 2 during October, and the lowest at Station 1 during January, indicating a relative increase in water hardness due to elevated levels of calcium and magnesium ions and mineral salts. Statistically, significant differences were found between stations (Sig = 0.000), with the highest mean recorded at Station 2 (526.667 mg/L) and the lowest at Station 1 (443.167 mg/L), showing clear spatial variation in salt concentrations. Significant differences were also found between months (Sig = 0.034), with the highest mean recorded in October (520.667 mg/L) and the lowest in January (459 mg/L). This variation is attributed to seasonal effects such as evaporation and dilution due to rainfall. Results also showed a strong correlation between total hardness and calcium and magnesium hardness, confirming that increased hardness is primarily associated with increased dissolved calcium and magnesium ions. These results are consistent with studies (12) on the impact of mineral salts and human activities on car wash wastewater.

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Table No. 1 Shows total hardness values (mg/L) for the stations during the study period.



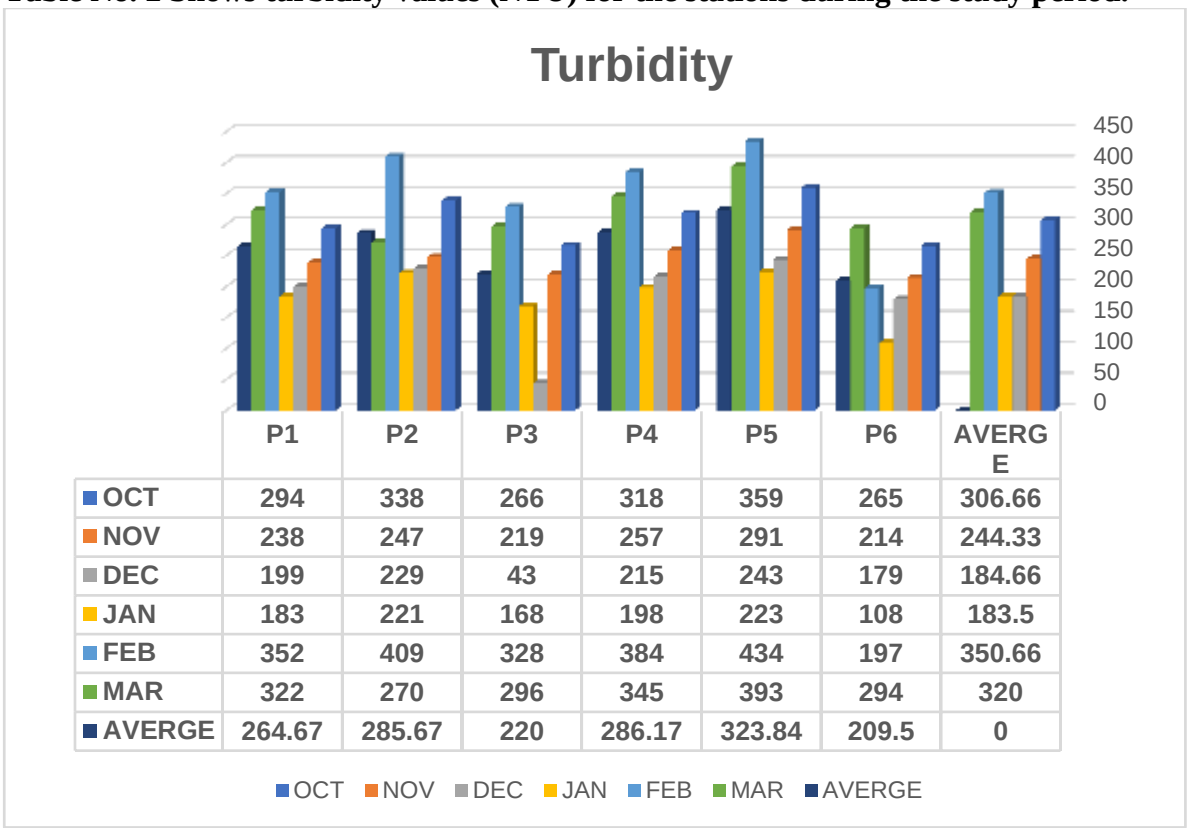

| | P1 | P2 | P3 | P4 | P5 | P6 | AVERGE |
|---|---|---|---|---|---|---|---|
| OCT | 428 | 588 | 516 | 554 | 531 | 507 | 520.667 |
| NOV | 472 | 521 | 487 | 528 | 502 | 489 | 499.834 |
| DEC | 451 | 547 | 503 | 536 | 518 | 501 | 509.334 |
| JAN | 409 | 498 | 458 | 471 | 463 | 455 | 459 |
| FEB | 436 | 474 | 464 | 542 | 448 | 439 | 467.167 |
| MAR | 463 | 532 | 491 | 509 | 496 | 482 | 495.5 |
| AVERGE | 443.167 | 526.667 | 486.5 | 523.334 | 493 | 478.834 | 0 |

Turbidity

The turbidity measurement results shown in Table (2) revealed a clear variation between stations and months, with values ranging between 43 and 434 Nephelometric Turbidity Units (NTU). The highest value was recorded at Station 5 during February, and the lowest at Station 3 during December. This variation is attributed to differences in the amount of suspended solids, surface runoff, and sediment disturbance. Statistically, no significant differences were observed between stations in turbidity values (Sig = 0.144), despite the varying means. The highest mean was recorded at Station 4 (286.17 NTU), and the lowest at Station 6 (209.5 NTU). However, highly significant differences were observed between months (Sig = 0.000), with the highest mean recorded in February (350.66 NTU) and the lowest in January (183.5 NTU), reflecting the impact of seasonal variations. Pearson's correlation coefficient also showed a strong positive correlation between turbidity and aerobic bacteria (r = 0.849), indicating that high turbidity is associated with an increase in organic matter and suspended particles that support bacterial growth. The results of this study were higher than those of (19) and lower than those of (13).

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**Table No. 2 Shows turbidity values (NTU) for the stations during the study period.**



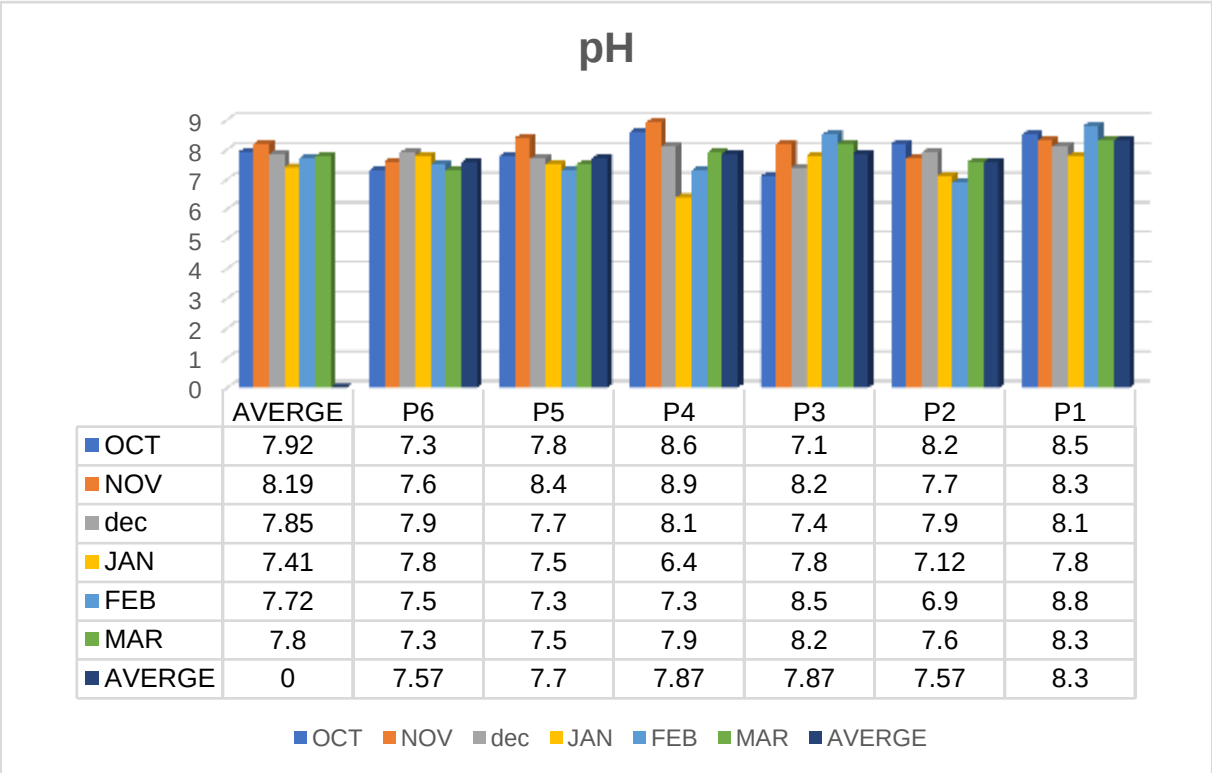

| | P1 | P2 | P3 | P4 | P5 | P6 | AVERGE |
|---|---|---|---|---|---|---|---|
| OCT | 294 | 338 | 266 | 318 | 359 | 265 | 306.66 |
| NOV | 238 | 247 | 219 | 257 | 291 | 214 | 244.33 |
| DEC | 199 | 229 | 43 | 215 | 243 | 179 | 184.66 |
| JAN | 183 | 221 | 168 | 198 | 223 | 108 | 183.5 |
| FEB | 352 | 409 | 328 | 384 | 434 | 197 | 350.66 |
| MAR | 322 | 270 | 296 | 345 | 393 | 294 | 320 |
| AVERGE | 264.67 | 285.67 | 220 | 286.17 | 323.84 | 209.5 | 0 |

**pH**

The results shown in Table 3 indicate that pH values ranged between 6.4 and 8.9, with the highest value recorded at Station 4 during November and the lowest at the same station during January. These values suggest that the water from the car wash stations ranged from neutral to slightly alkaline, which may be attributed to the effects of detergents and alkaline substances, in addition to rainwater and organic matter. Statistically, no significant differences were observed between stations in pH values (Sig = 0.187), with the highest mean of 8.3 recorded at Station 1 and the lowest mean of 7.57 recorded at Stations 2 and 6. Similarly, no statistically significant differences were recorded between months (Sig = 0.269), with the highest mean of 8.19 recorded in November and the lowest in January (7.41), indicating relative stability in the acid-base balance of the water. Pearson's correlation results also showed that the correlation between pH and most variables was weak and not statistically significant, with only weak positive correlations with some factors at the 0.05 level, indicating a limited effect of certain chemical and biological properties. The results of this study were higher than those of (14) and lower than those of (15).

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**Table No. 3 Shows pH values for the stations during the study period.**



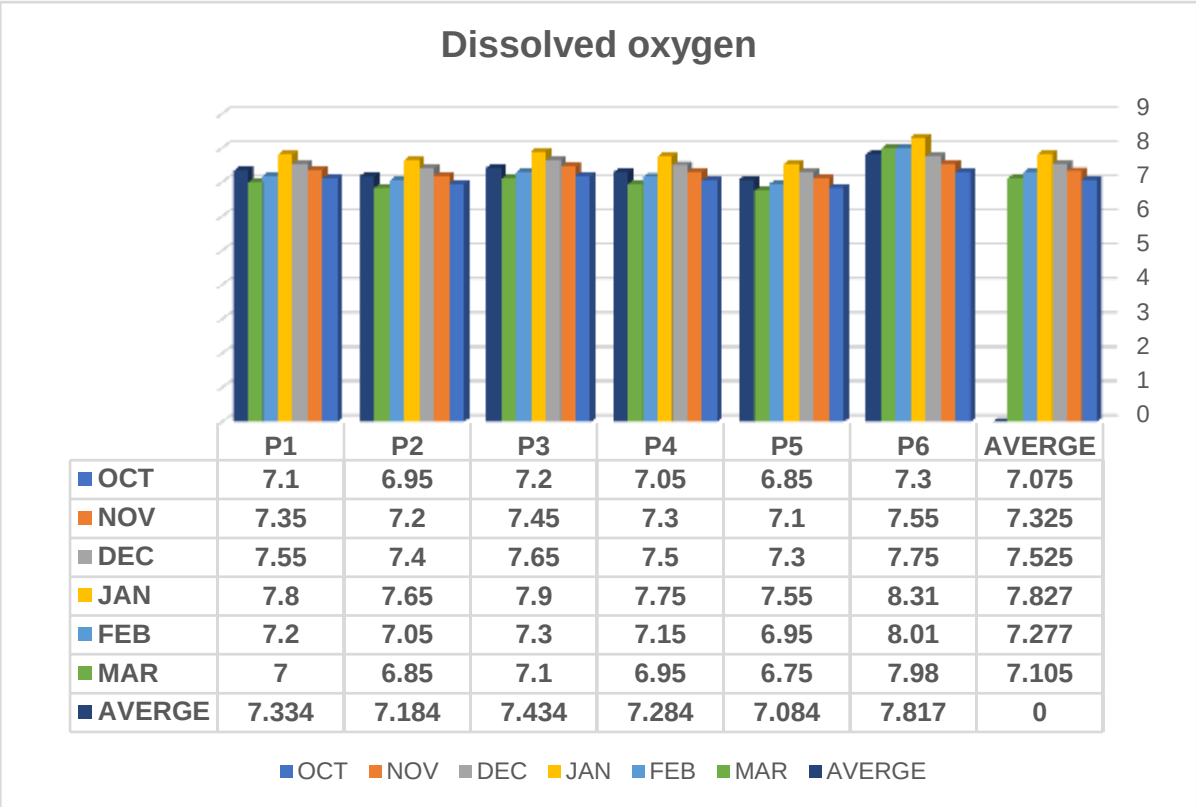

| | AVERGE | P6 | P5 | P4 | P3 | P2 | P1 |
|---|---|---|---|---|---|---|---|
| OCT | 7.92 | 7.3 | 7.8 | 8.6 | 7.1 | 8.2 | 8.5 |
| NOV | 8.19 | 7.6 | 8.4 | 8.9 | 8.2 | 7.7 | 8.3 |
| dec | 7.85 | 7.9 | 7.7 | 8.1 | 7.4 | 7.9 | 8.1 |
| JAN | 7.41 | 7.8 | 7.5 | 6.4 | 7.8 | 7.12 | 7.8 |
| FEB | 7.72 | 7.5 | 7.3 | 7.3 | 8.5 | 6.9 | 8.8 |
| MAR | 7.8 | 7.3 | 7.5 | 7.9 | 8.2 | 7.6 | 8.3 |
| AVERGE | 0 | 7.57 | 7.7 | 7.87 | 7.87 | 7.57 | 8.3 |

**Dissolved Oxygen (DO)**

The results shown in Table 4 indicate that dissolved oxygen values ranged between 6.75 and 8.31 mg/L. The highest value was recorded at Station 6 during January, and the lowest at Station 5 during March. The increase in dissolved oxygen during winter is attributed to lower temperatures and the increased capacity of water to retain oxygen, while its decrease is associated with higher temperatures, increased organic load, and microbial activity. Statistically, significant differences were found between stations in dissolved oxygen values (Sig = 0.006). The highest mean was recorded at Station 6 (7.8167 mg/L) and the lowest at Station 5 (7.084 mg/L), indicating differences in environmental conditions between stations. Significant differences were observed between months (Sig = 0.001), with the highest mean recorded in January (7.82 mg/L) and the lowest in October (7.07 mg/L). Correlation results showed strong negative relationships between dissolved oxygen and electrical conductivity, total dissolved solids, sodium chloride, sulfates, and aerobic bacteria, indicating that increased salinity, organic load, and microbial activity lead to decreased dissolved oxygen. The results of this study were lower than those of (17) and higher than those of (16).

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**Table No. 4 Shows dissolved oxygen values (mg/L) for the stations during the study period.**



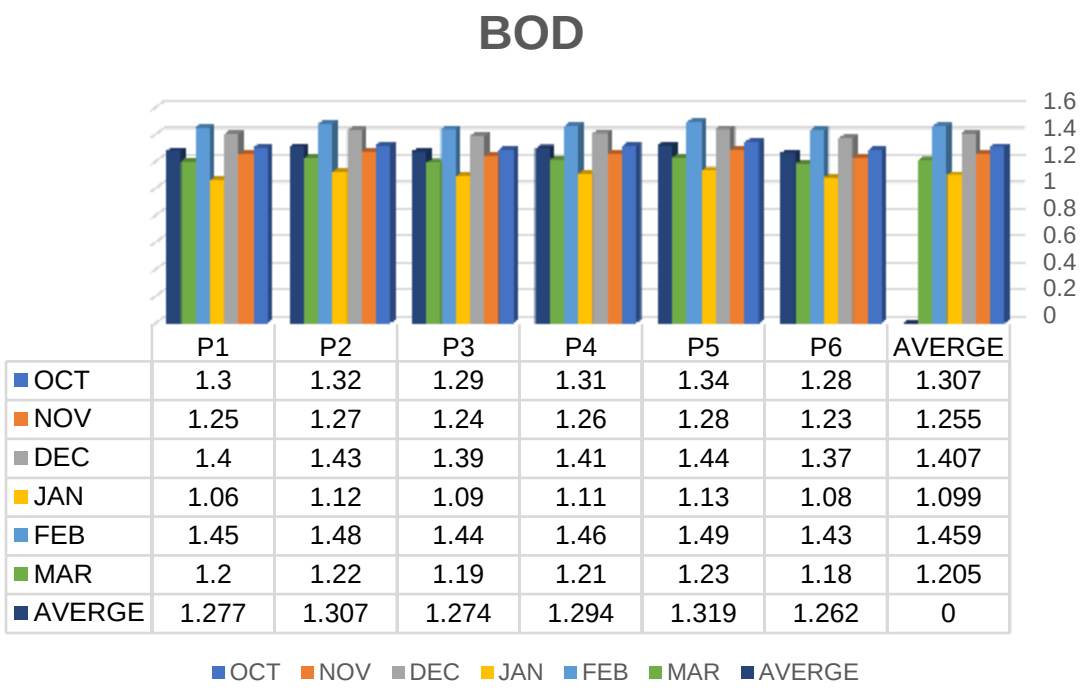

| | P1 | P2 | P3 | P4 | P5 | P6 | AVERGE |
|---|---|---|---|---|---|---|---|
| OCT | 7.1 | 6.95 | 7.2 | 7.05 | 6.85 | 7.3 | 7.075 |
| NOV | 7.35 | 7.2 | 7.45 | 7.3 | 7.1 | 7.55 | 7.325 |
| DEC | 7.55 | 7.4 | 7.65 | 7.5 | 7.3 | 7.75 | 7.525 |
| JAN | 7.8 | 7.65 | 7.9 | 7.75 | 7.55 | 8.31 | 7.827 |
| FEB | 7.2 | 7.05 | 7.3 | 7.15 | 6.95 | 8.01 | 7.277 |
| MAR | 7 | 6.85 | 7.1 | 6.95 | 6.75 | 7.98 | 7.105 |
| AVERGE | 7.334 | 7.184 | 7.434 | 7.284 | 7.084 | 7.817 | 0 |

**Biochemical Oxygen Demand ($BOD_5$ )**

The results shown in Table 5 indicate that Biochemical Oxygen Demand (BOD) values ranged between 1.08 and 1.51 mg/L, with the highest value recorded at Site 5 during February and the lowest at Site 1 during January. These relatively low values indicate a limited organic load in car wash wastewater. Statistically, no significant differences were observed between stations in BOD values (Sig = 0.975), with means ranging between 1.262 and 1.407 mg/L, demonstrating similarity in spatial organic loads. However, highly significant differences were observed between months (Sig = 0.000), with higher values during certain periods. This may be associated with increased bacterial activity and decomposition of organic matter. Correlation results also showed a statistically significant positive relationship between BOD and COD (r = 0.563), indicating an association between biodegradable organic matter and chemically oxidizable organic matter. Overall, BOD values were relatively low, indicating the absence of high levels of organic pollution, although a clear temporal effect was observed. The results of the current study were lower than those of (19) and higher than those of (18).

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**Table No. 5 Shows Biochemical Oxygen Demand ($BOD_5$ ) values (mg/L) for the stations during the study period.**



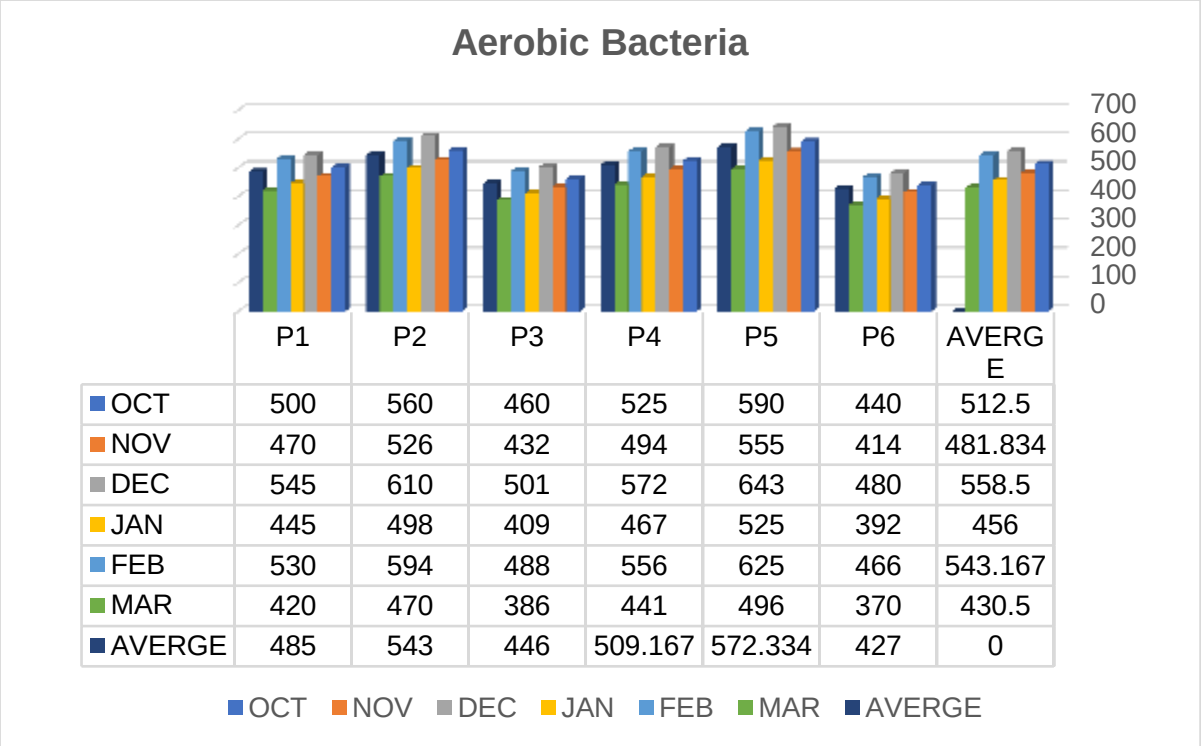

| | P1 | P2 | P3 | P4 | P5 | P6 | AVERGE |
|---|---|---|---|---|---|---|---|
| OCT | 1.3 | 1.32 | 1.29 | 1.31 | 1.34 | 1.28 | 1.307 |
| NOV | 1.25 | 1.27 | 1.24 | 1.26 | 1.28 | 1.23 | 1.255 |
| DEC | 1.4 | 1.43 | 1.39 | 1.41 | 1.44 | 1.37 | 1.407 |
| JAN | 1.06 | 1.12 | 1.09 | 1.11 | 1.13 | 1.08 | 1.099 |
| FEB | 1.45 | 1.48 | 1.44 | 1.46 | 1.49 | 1.43 | 1.459 |
| MAR | 1.2 | 1.22 | 1.19 | 1.21 | 1.23 | 1.18 | 1.205 |
| AVERGE | 1.277 | 1.307 | 1.274 | 1.294 | 1.319 | 1.262 | 0 |

**Total Number of Aerobic Bacteria**

The counts of aerobic bacteria, as shown in Table 6, ranged between 370 and 643 CFU/100 ml, with the highest value recorded at Station 5 during March and the lowest at Station 6 during January. This is attributed to variations in organic load and environmental conditions favorable for bacterial growth, such as temperature and nutrient availability. Statistically, significant differences were found between stations (Sig = 0.000), with Station 5 recording the highest mean (572,333 CFU/100 ml) and Station 6 the lowest mean (427,000 CFU/100 ml), indicating that Station 5 was the most affected by microbial activity. Statistically significant differences were also found between months (Sig = 0.003), likely associated with higher temperatures and increased organic decomposition during warmer months. Correlation analysis revealed a statistically significant positive relationship between nitrates and aerobic bacteria (r = 0.442), reflecting the contribution of microbial activity to the nitrogen cycle. The results of the current study were higher than those of (25) and lower than those of (20).

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Table No. 6 Shows the total count of aerobic bacteria (CFU/100 ml) for the stations during the study period.



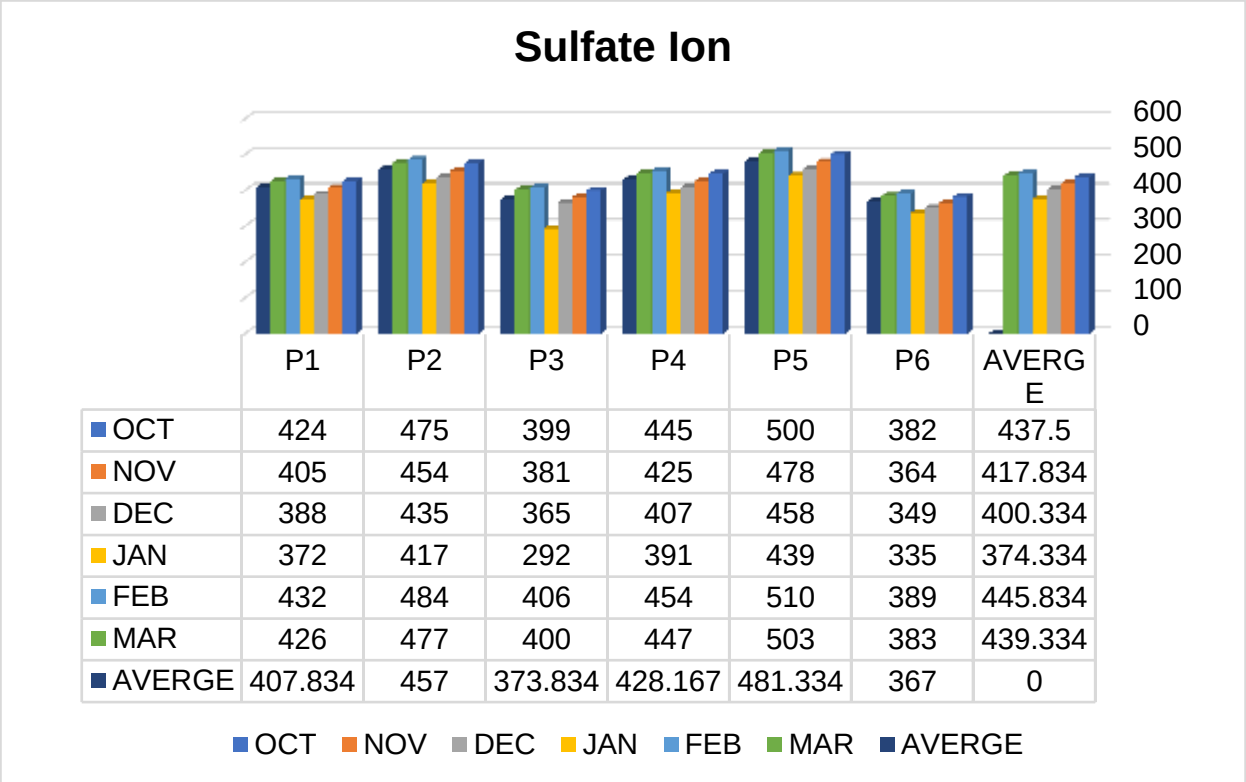

| | P1 | P2 | P3 | P4 | P5 | P6 | AVERGE |
|---|---|---|---|---|---|---|---|
| OCT | 500 | 560 | 460 | 525 | 590 | 440 | 512.5 |
| NOV | 470 | 526 | 432 | 494 | 555 | 414 | 481.834 |
| DEC | 545 | 610 | 501 | 572 | 643 | 480 | 558.5 |
| JAN | 445 | 498 | 409 | 467 | 525 | 392 | 456 |
| FEB | 530 | 594 | 488 | 556 | 625 | 466 | 543.167 |
| MAR | 420 | 470 | 386 | 441 | 496 | 370 | 430.5 |
| AVERGE | 485 | 543 | 446 | 509.167 | 572.334 | 427 | 0 |

**Sulfate Ion ($SO_4^{2-}$)**

Sulfate concentrations shown in Table 7 ranged between 292 and 510 mg/L, with the highest value recorded at Station 5 during February and the lowest at Station 3 during January. This variation is attributed to differences in local sources, such as soil type, drainage, detergent residues, and chemicals from car washes. Statistically, significant differences were found between stations (Sig = 0.000), with Station 5 recording the highest mean (481.333 mg/L) and Station 6 the lowest mean (367.000 mg/L), indicating clear spatial variation. In contrast, no statistically significant differences were observed between months (Sig = 0.086), suggesting relative stability in sulfate sources over time. The results also showed a very strong positive correlation between sulfate and electrical conductivity (r = 0.974), indicating the role of sulfate in increasing dissolved salts and salinity. The results of the current study were higher than those of (21) and lower than those of (22).

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**Table No. 7 Shows sulfate ion ($SO_4^{2-}$) values (mg/L) for the stations during the study period.**



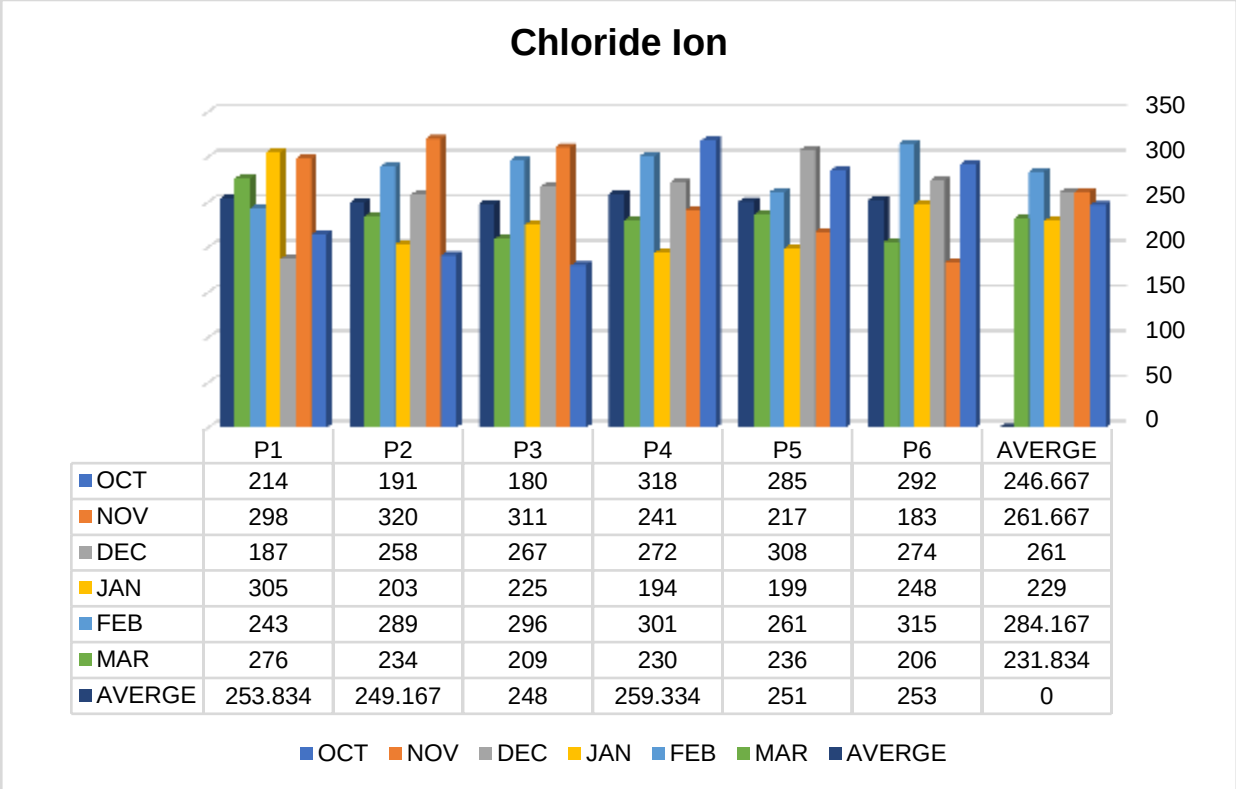

| | P1 | P2 | P3 | P4 | P5 | P6 | AVERGE |
|---|---|---|---|---|---|---|---|
| OCT | 424 | 475 | 399 | 445 | 500 | 382 | 437.5 |
| NOV | 405 | 454 | 381 | 425 | 478 | 364 | 417.834 |
| DEC | 388 | 435 | 365 | 407 | 458 | 349 | 400.334 |
| JAN | 372 | 417 | 292 | 391 | 439 | 335 | 374.334 |
| FEB | 432 | 484 | 406 | 454 | 510 | 389 | 445.834 |
| MAR | 426 | 477 | 400 | 447 | 503 | 383 | 439.334 |
| AVERGE | 407.834 | 457 | 373.834 | 428.167 | 481.334 | 367 | 0 |

**Chloride Ion ($Cl^-$)**

Chloride concentrations shown in Table 8 ranged between 180 and 320 mg/L, with the highest value recorded at Station 2 during November and the lowest at Station 3 during October. These values indicate moderate concentrations likely resulting from dissolved salts, detergent residues, and dust particles adhering to vehicles. Statistically, no significant differences were observed between stations (Sig = 0.999) nor between months (Sig = 0.260), indicating the stability of chloride concentrations spatially and temporally throughout the study period. Chloride is one of the major ions associated with salinity, total dissolved solids, and electrical conductivity. The results of this study were higher than those of (21) and lower than those of (19).

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Table No. 8 Shows chloride ion ($Cl^-$) values (mg/L) for the stations during the study period.



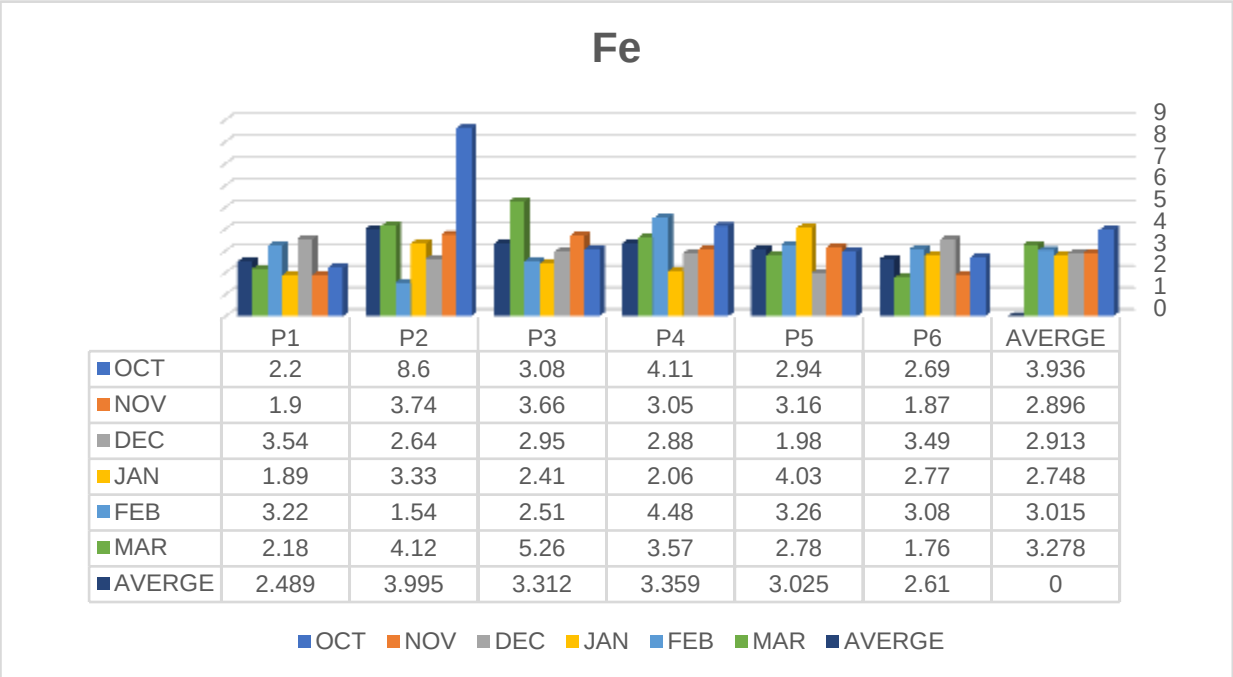

| | P1 | P2 | P3 | P4 | P5 | P6 | AVERGE |
|---|---|---|---|---|---|---|---|
| OCT | 214 | 191 | 180 | 318 | 285 | 292 | 246.667 |
| NOV | 298 | 320 | 311 | 241 | 217 | 183 | 261.667 |
| DEC | 187 | 258 | 267 | 272 | 308 | 274 | 261 |
| JAN | 305 | 203 | 225 | 194 | 199 | 248 | 229 |
| FEB | 243 | 289 | 296 | 301 | 261 | 315 | 284.167 |
| MAR | 276 | 234 | 209 | 230 | 236 | 206 | 231.834 |
| AVERGE | 253.834 | 249.167 | 248 | 259.334 | 251 | 253 | 0 |

**Iron (Fe)**

Iron concentrations, as shown in Table 9, ranged between 1.54 and 8.6 mg/L. The highest value was recorded at Station 2 during October, and the lowest at the same station during February. This variation is attributed to differences in the amount of sediment and dust, corrosion of metal parts, or the transport of iron with suspended solids from car washes. Statistically, no significant differences were observed between stations (Sig = 0.336). The highest mean concentration was recorded at Station 2 (3.9950 mg/L) and the lowest at Station 1 (2.4883 mg/L). Similarly, no statistically significant differences were observed between months (Sig = 0.645), indicating a limited spatial and temporal impact on iron concentrations. Heavy metals did not show strong correlations with most physical and chemical variables, suggesting that their sources are often local and associated with dust, metal corrosion, vehicle waste, and local discharges. These results are consistent with (4; 22).

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**Table No. 9 Shows iron (Fe) values (mg/L) for the stations during the study period.**

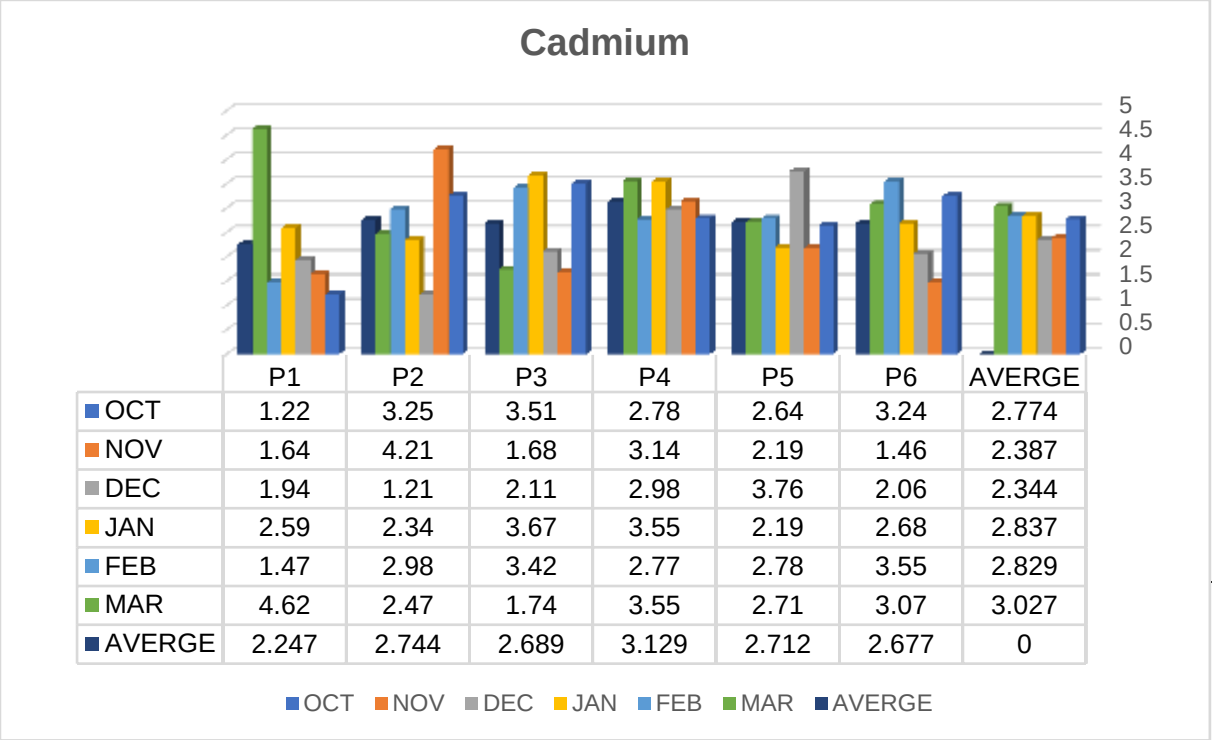



| | P1 | P2 | P3 | P4 | P5 | P6 | AVERGE |
|---|---|---|---|---|---|---|---|
| OCT | 2.2 | 8.6 | 3.08 | 4.11 | 2.94 | 2.69 | 3.936 |
| NOV | 1.9 | 3.74 | 3.66 | 3.05 | 3.16 | 1.87 | 2.896 |
| DEC | 3.54 | 2.64 | 2.95 | 2.88 | 1.98 | 3.49 | 2.913 |
| JAN | 1.89 | 3.33 | 2.41 | 2.06 | 4.03 | 2.77 | 2.748 |
| FEB | 3.22 | 1.54 | 2.51 | 4.48 | 3.26 | 3.08 | 3.015 |
| MAR | 2.18 | 4.12 | 5.26 | 3.57 | 2.78 | 1.76 | 3.278 |
| AVERGE | 2.489 | 3.995 | 3.312 | 3.359 | 3.025 | 2.61 | 0 |

**Cadmium (Cd)**

Cadmium concentrations shown in Table 10 ranged between 1.21 and 4.62 mg/L, with the highest value recorded at Station 1 during March and the lowest value at Station 2 during December. Its presence is attributed to suspended dust, corrosion of metal parts, oil and fuel residues, and tire and brake debris. Statistically, no significant differences were observed between stations (Sig = 0.685) or between months (Sig = 0.709), indicating that cadmium sources are either similar or irregular. Cadmium also showed weak correlations with most physical and chemical variables, suggesting that its presence is primarily associated with local sources, such as vehicle waste, dust, sediment, and suspended solids, rather than general changes in water quality. These results are consistent with those of (24; 23).

Table No. 10 Shows cadmium (Cd) values (mg/L) for the stations during the study period.




| | P1 | P2 | P3 | P4 | P5 | P6 | AVERGE |
|---|---|---|---|---|---|---|---|
| OCT | 1.22 | 3.25 | 3.51 | 2.78 | 2.64 | 3.24 | 2.774 |
| NOV | 1.64 | 4.21 | 1.68 | 3.14 | 2.19 | 1.46 | 2.387 |
| DEC | 1.94 | 1.21 | 2.11 | 2.98 | 3.76 | 2.06 | 2.344 |
| JAN | 2.59 | 2.34 | 3.67 | 3.55 | 2.19 | 2.68 | 2.837 |
| FEB | 1.47 | 2.98 | 3.42 | 2.77 | 2.78 | 3.55 | 2.829 |
| MAR | 4.62 | 2.47 | 1.74 | 3.55 | 2.71 | 3.07 | 3.027 |
| AVERGE | 2.247 | 2.744 | 2.689 | 3.129 | 2.712 | 2.677 | 0 |

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