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COMPARATIVE ANALYSIS OF SOME HEAVY METALS AND PHYSICOCHEMICAL PARAMETERS OF EFFLUENTS FROM YOLA AND NUMAN ABATTOIRS, ADAMAWA STATE NIGERIA

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Abstract

This work compared some heavy metals and physicochemical properties of Effluents from Numan Abattoir, Numan Local Government Area and Yola Abattoir, Yola North Local Government Area. A combination of field sampling, laboratory analysis, and Past 4.03

Keywords: Policymakers, Environment, Waste, Management, Practices, Health.

INTRODUCTION

The environmental impact of abattoirs is a growing concern, particularly in developing countries where regulations and waste management practices may be insufficient. Abattoirs, or slaughterhouses, generate significant amounts of waste, including blood, fat, feces, urine, and cleaning agents, which can contaminate nearby soil and water sources if not properly managed. The contamination from abattoirs often includes heavy metals, which are toxic at high concentrations and can pose serious health risks to humans and wildlife. This study focuses on the comparative analysis of heavy metal and physicochemical parameters in soil and water samples from Yola and Numan abattoirs in Adamawa State, Nigeria. Environmental pollution, particularly contamination by heavy metals, has emerged as a critical issue due to its significant adverse impacts on ecosystems and human health. Heavy

software was used to generate the correlation analysis. There is strong positive correlation between Total Dissolved Solid (TDS) and conductivity is (0.9992); that is nearly perfect and expected, since TDS and conductivity are directly related. The TDS and temperature (0.9878), and Conductivity and temperature (0.9848) which suggests temperature increase may raise TDS and conductivity. The Chemical Oxygen Demand (COD) in relation to Dissolved Oxygen (DO)is (0.8956), it is somewhat unusual; generally, COD increases as DO decreases in polluted water. In the other hand, there are strong negative correlations between pH and temperature which is (-0.7330); it indicates that as temperature rises, pH tends to drop. pH, conductivity and TDS (~ -0.75) which suggest that higher ionic content leads to lower pH (Hydrogen ion concentration). Pb and Mn shows moderate correlations with other parameter, e.g Pb and Fe (0.5041), Mn and DO (0.8821), this is quite strong, indicating Mn levels rise with dissolved oxygen (possibly due to geochemical oxidation). The spatial analysis highlighted areas of concern, particularly around effluent discharge points. This study underscores the need for regular environmental monitoring and the implementation of improved waste management practices to mitigate the potential health risks associated with heavy metal contamination. The findings provide valuable insights for policymakers and environmental managers, emphasizing the importance of geospatial analysis in environmental health studies.

Metals, which are naturally occurring elements with high atomic weights and densities, are ubiquitous in the environment. However, anthropogenic activities such as industrial processes, agricultural practices, and waste disposal have exacerbated their concentrations to harmful levels (Alloway, 2013).

The physicochemical parameters of soil and water, such as pH, nitrates, phosphates, and organic matter content, are also critical indicators of environmental quality. These parameters influence the mobility and bioavailability of heavy metals, affecting their potential impact on the environment and human health (Anzene *et al.,* 2024). For instance, pH levels can alter the solubility of heavy metals, with acidic conditions generally increasing their availability and mobility. High levels of nitrates and phosphates can lead to eutrophication, further compounding environmental degradation.

The discharge of untreated effluents from abattoirs into surrounding environments poses severe threats to soil and water quality. These effluents often contain high levels of organic matter, nutrients, and heavy metals, leading to the degradation of natural resources (Dewi *et al.,* 2020). Heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), and mercury (Hg) are of particular concern due to their toxicity, persistence, and bioaccumulation potential (Tchounwou *et al.,* 2012).

From the previous research, the waterwaste discharge from abattoir infiltrated into upstream and downstream has a negative impact on the public health from the outcomes of some researchers (Ayeni, Olusola- Makinde and Arotupin (2014); Adeyemi-Ale, (2024);

Anele *et al,* 2023; Akawau *et al.,* 2020 ; Dauda, Duro and Ujah (2016); Jegede *et al.,* 2022; Ezeet *et al.,* 2013).

Literature Review

According to Ayeni, Olusola-Makinde and Arotupin (2024) in recent research tittle comparative study on Heavy Metal and Bacterial Contamination of Abattoir Effluent, upstream and Downstream in Akure South Local Government Area of Ondo State. Heavy metal were investigated from some samples of the wastewater discharge of the abattoir using atomic absorption spectrometry and bacteria load using standard pour plate technique. Some heavy metals were detected from the sample analysis e.g Copper (Cu), Chrominm (Cr), Cadmium (Cd), Lead (Pb) and (Zn). The analysis revealed that Cu in downstream of both abattoirs, 0.61 ± 0.01^a and 0.74 ± 0.06^a which was higher than upstream 0.11 ± 0.06^a and 0.23 ± 0.06^a . In the same vain for Cr, Cd and Zn in both abattoirs except Pb was absent in Toplad upstream and downstream with 0.13 ± 0.06^a and 0.02 ± 0.06^a respectively. Total bacterial mean count of upstream and downstream of both abattoirs was $8.1 x 10^4 \pm 0.10$ cfu/ml and $2.28 \times 10^5 \pm 0.10$ cfu ml respectively.

Adeyemi-Ale (2014) worked on impact of Abattoir Effluent on the Physico-Chemical Parameter of Gbagi Stream (Odo-Eran), Ibadan, Nigeria using standard method to physic-chemical quantities of water along upstream and downstream section of the river. From the analysis Physicochemical Parameter were obtained which include: PH 6.2- 8.2; dissolve oxygen, below detection limit 4.67 mg/c; biochemical oxygen demand 23.25-141.21 mg/c ; Chemical oxygen demand 132.81-540 mg/l ; Chloride 24.53- 94.16 mg/l; Phosphate, below detection limit- 383.67 mg/l; Sulphate 100.00-2731.25 mg/l; lead below detection limit- 0.6355 mg/l; Copper, below detection limit -0.4386 mg/l, Iron, below detection limit-18.21 mg/l; Zinc, below detection limit -18.1510 mg /l ; nickel, below detection limit- 0.2389 mg/l and Cadmium below detection – 0.0910 mg/l. From the result obtained, the mean values of the physicochemical parameters were significantly higher ($p < 0.05$) than the recommended limit by the National Environmental Standard and Regulatory Enforcement Agency (NESREA) in Nigeria for effluent discharge into surface water bodies.

Anele *et al,.* (2023) carried out research on environmental impact assessment of abattoirs in Rivers State, Nigeria. According to the result obtained physicochemical parameters of air, soil and water were found to be varies across the locations, though significant ($p < 0.05$). All heavy metals were within the tolerable limit except Zn which exceed 0.2mg/l.

The comparative analysis approach of this study provided insights into the extent of pollution from abattoirs in different locations and the effectiveness of existing waste management practices. By examining both Yola and Numan abattoirs, this identify specific areas where intervention is needed and propose recommendations for improving waste management to protect environmental and public health.

Study Area

Yola is the capital city of Adamawa State in northeastern Nigeria, located on the banks of the River Benue. It serves as an administrative and commercial center, playing a significant role in the region's economy. The geographical coordinates of Yola are approximately 9.2035° N latitude and 12.4957° E longitude. The city is characterized by a tropical climate with distinct wet and dry seasons, influencing the hydrological and environmental dynamics of the region. The Yola abattoir, situated near the River Benue, is a key facility for meat processing, providing essential services to the local population. However, its proximity to the river poses a risk of contaminant dispersal, making it a critical site for environmental monitoring. Numan is another important town in Adamawa State, located approximately 67 kilometers southeast of Yola. The geographical coordinates of Numan are roughly 9.4577° N latitude and 12.0322° E longitude. Numan is situated in a predominantly agricultural area, contributing significantly to the state's agricultural output. The Numan abattoir, serving the town and surrounding communities, plays a crucial role in the local economy. Its location amidst farmlands necessitates a thorough examination of the potential environmental impacts, particularly concerning soil and water quality, due to the discharge of abattoir effluents.

Yola and Numan, two prominent towns in Adamawa State, house significant abattoirs that cater to the meat consumption needs of the region. The Yola abattoir is situated near the River Benue, while the Numan abattoir is located closer to agricultural lands. The geographic positioning of these abattoirs influences the dispersion and concentration of pollutants, making a geospatial analysis crucial for understanding the environmental impact. Previous studies have indicated varying levels of heavy metal contamination in different geographic settings, highlighting the need for a location-specific approach to environmental monitoring (Ogundele et al., 2015).

Methodology

This research employed a combination of field sampling, laboratory analysis, and GIS techniques. Water samples were collected from various points around the Yola and Numan abattoirs. The samples were analyzed for heavy metals using Atomic Absorption Spectrophotometry (AAS) and for physicochemical parameters using standard methods. Past 4.03 software was used to generate the correlation analysis of the contaminants and identify the relationships within the study areas.

Result and analysis

Table 1. Mean Concentration of Some Heavy Metals and Physicochemical Properties of Effluent from Yola Abattoir.

Parameter\Sample Code	YAB_{WW1}	YAB_{WW2}	YAB_{WW3}
pH	7.51 ± 0.0100	8.06 ± 0.0100	8.23 ± 0.0071
Temperature (^{o}C)	37.0 ± 0.0707	35.2 ± 0.0707	38.0 ± 0.1000
Conductivity (µS/cm)	68.1 ± 0.1000	70.3 ± 0,0707	74.4 ± 0.0707
TDS (mg/L)	43.1 ± 0.0707	42.5 ± 0.1000	45.0 ± 0.1000
DO (mg/L)	1.6 ± 0.0707	1.2 ± 0.0707	1.2± 0.000
BOD (mg/L)	4 ± 0.7071	6 ± 0.7071	8 ± 1.0000
COD (mg/L)	18 ± 1.000	18 ± 0.7071	19 ± 1.0000
Cd (mg/L)	0.005 ± 0.0001	0.005 ± 0.0006	0.006 ± 0.0003
Cr (mg/L)	0.000 ± 0.0005	0.000 ± 0.0008	0.000 ± 0.0002
Fe (mg/L)	38.0990 ± 0.0028	21.933 ± 0.0008	16.400 ± 0.0004
Pb (mg/L)	0.000 ± 0.0003	0.000 ± 0.0006	0.000 ± 0.0004
Mn (mg/L)	1.607 ± 0.0025	1.912 ± 0.0011	1.385 ± 0.0012

Key:

YAB_{ww1} is waste water sample from Yola Abattoir location 1

YAB_{ww1} is waste water sample from Yola Abattoir location 2

YAB_{ww1} is waste water sample from Yola Abattoir location 3

Mean Concentration of Some of the Heavy Metals and Physicochemical Properties of Wastewater from Yola Abattoir.

The sampling point three (YABww3) had the highest temperature 38.0 ± 0.1000 ^{0}C while sampling point two had the least temperature 35.2 ± 0.0707 ^{0}C but sampling point one had a temperature of 37.0 ± 0.0707 ^{0}C.

Mean concentration of some heavy metals and physicochemical properties of effluent from Yola Abattoir were as shown in table 1 above. The pH and temperature values were from 7.51 ± 0.0100, 8.06 ± 0.0100 and 8.23 ± 0.0071 to 38.0 ± 0.1000 ^{0}C while the values for conductivity and Total Dissolved Solid (TDS) were from 68.1 ± 0.1000 to 74.4 ± 0.0707 (µS/cm) and 42.5 ± 0.1000 to 45.0 ± 0.1000 (mg/L) respectively. The Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) values were from 1.2± 0.000, 1.6 ± 0.0707 and 4 ± 0.7071, 4 ± 0.7071 (mg/L) to 8 ± 1.0000, 18 ± 1.000 to 19 ± 1.0000 (mg/L) accordingly. The mean plus standard deviation values for the elements determined are shown in table 1 above, therefore the values for Cd, Fe, and Mn were from 0.005 ± 0.0001 to 0.006 ± 0.0003 (mg/L); 16.400 ± 0.0004 to 38.0990 ± 0.0028 mg/L and 1.385 ± 0.0012 to 1.912 ± 0.0011 mg/L, while Cr and Pb stand at 0.000 mg/L.

Table 2. Mean Concentration of Some Heavy Metals and Physicochemical Properties of Effluent from Numan Abattoir.

Parameter\Sample Code	NAB_{WW1}	NAB_{WW2}	NAB_{WW3}
pH	10.11± 0.0100	8.28± 0.0071	9.90± 0.0071
Temperature (^{o}C)	28.4± 0.0707	27.5± 0.0707	27.4± 0.1000
Conductivity (µS/cm)	7.8± 0.1000	7.9± 0,0707	8.1± 0.1000
TDS (mg/L)	6.3± 0.0707	5.0± 0.1000	5.8± 0.1000
DO (mg/L)	1.2± 0.1000	1.4± 0.0707	1.3± 0.0707
BOD (mg/L)	6± 1.0000	7± 0.7071	8± 0.7071
COD (mg/L)	25± 0.7071	22± 1.0000	124± 1.0000
Cd (mg/L)	0.009 ± 0.0005	0.008 ± 0.0002	0.007 ± 0.0003
Cr (mg/L)	0.000 ± 0.0013	0.000 ± 0.0004	0.000 ± 0.0004
Fe (mg/L)	47.095 ± 0.0019	7.446 ± 0.0009	6.934 ± 0.0003
Pb (mg/L)	0.000 ± 0.0005	0.000 ± 0.0005	0.000 ± 0.0005
Mn (mg/L)	1.282 ± 0.0013	0.934 ± 0.0010	1.214 ± 0.0019

Key:

NAB_{ww1} is waste water sample from Numan Abattoir location 1

NAB_{ww2} is waste water sample from Numan Abattoir location 2

NAB_{ww3} is waste water sample from Numan Abattoir location 3

Mean Concentration of Some of the Heavy Metals and Physicochemical Properties of Wastewater from Numan Abattoir.

Mean concentration of some heavy metals and physicochemical properties of waste water samples from Numan Abattoir were as shown in tables 2. The pH values were from 8.28 ±0.0071 to 10.11 ±0.0100 and the temperature from 27.4 ±0.1000 to 28.4 ±0.0707 **° C**. The values for conductivity and TDS were from 7.8 ±0.1000 to 8.1 ± 0.1000 mg/L and 5.0 ±0.1000 to 6.3 ±0.0707 mg/L. The DO, BOD and COD values were from 1.2 ±0.1000 to 1.4 ± 0.0707 mg/L; 6 ±1.0000 to 8 ± 0.7071 mg/L and 22 ±1.0000 to 124 ± 1.0000 mg/L respectively. The mean plus standard deviation values of the elements analyzed were as shown in table 2. The values of Cd, Cr, Fe and Mn were from 0.17 ±0.007 to 0.37 ±0.007 mg/Kg; 8.13 ±0.037 to 12.30 ±0.043 mg/Kg; 3,427.07 ±0.007 to 6,129.17 ±0.033 mg/Kg and 146.70 ±0.027 to 198.30 ±0.0.03 mg/Kg while the value for Pb is 0.47 ±0.007 mg/Kg. Sampling point one (NAB $_{WW1}$**)** had the highest pH, 10.11±0.0100 while sampling point two (NAB $_{WW2}$) had the least pH, 8.28±0.0071 but sampling point three (NAB $_{WW3}$) had a pH of 9.90±0.0071. These values were alkaline and is in consonant with similar work carried out by Akan, *et al*., (2010) and only that of sampling point two falls within the tolerant limit (6 to 9) set by WHO (2004), FEPA (1991) for the discharge of wastewater into the river while those of sampling points one and three exceeded. As reported by Ogbonna and Ideriah (2014), pH is important to microorganisms as it affects the functionality of virtually all enzymes, hormones and proteins that control metabolism, growth and development. Besides, it is also a major factor in all chemical reactions associated with formation, alteration, dissolution of minerals. Sampling point one (NAB $_{WW1}$**)** had the highest temperature, 28.4 ±0.0707 ° C while sampling point three had the least temperature, 27.4 ±0.1000 ° C but sampling point two had a temperature of 27.5 ±0.0707 ° C The permissible limit for the discharge of wastewater into the river is less than 40 ° C and the value for sample points one, two and three, 28.4 ±0.0707 ° C, 27.5 ±0.0707 ° C and 27.4 ±0.1000 ° C are within the tolerant level. The highest conductivity value was obtained at sampling point three, 8.1 ±0.1000 µS/cm while the least value was obtained at sampling point one, 7.8 ±0.1000 µS/cm. The FEPA tolerable limit for domestic water is 70 µS/cm (DWAF, 1996a). These values obtained were below it. TDS value were 6.3 ± 0.0707 mg/L, 5.0 ± 0.1000 mg/L and 5.8 ± 0.1000 mg/L at sample point one, two and three respectively which were below the tolerable limit set by WHO/USEPA.

The DO; BOD and COD Values from sampling points one, two and three were 1.2 ±0.1000 mg/L, 1.4 ±0.0707 mg/L, 1.3 ±0.0707 mg/L; 6 ±1.0000 mg/L, 7 ±0.7071 mg/L, 8 ±0.7071 mg/L and 25 ±0.7071 mg/L, 22 ±1.0000 mg/L and 124 ±1.0000 mg/L respectively. Sampling point three had the highest BOD, 8±0.7071 mg/L and COD, 124 ±1.0000 mg/L and the least DO, 1.2±0.1000 mg/L at sampling point one as well as the least BOD value, 6±1.0000 mg/L and the least COD value, 22±1.0000 mg/L was at sampling point two. DO is a measure of the degree of pollution by organic matter, the destruction of organic substances as well as the self-purification capacity of the water body (Akan, *et al.,* 2010*).*DO is a vital factor used for water quality control. The effect of waste discharge on surface water is majorly determined by the oxygen balance of the system and its presence is important in maintaining biological life within a system (DFID, 1999). The range of concentration of

DO in unpolluted water is usually from 8 to 10 mg/L and below 5 mg/L will adversely affect aquatic life (DFID, 1999; Rao, 2005), below 2 mg/L may lead to death (Chapman, 1997). 6 mg/L is the standard for drinking water but for sustenance of fish and aquatic life is between 4 to 5 mg/L (Rao, 2005). The values obtained for DO, BOD and COD fall within the permissible limit set by WHO (2004), 4 mg/L; 20 mg/Land 1,000 mg/L USEPA (1999), 5 mg/L; 20 mg/L and 1,000 mg/L; and FEPA (1991), greater than 4 mg/L; 30 mg/L and 80 mg/L.

The concentration of Cd; Fe and Mn at the sampling points one, two and three for effluent were 0.009 ±0.0005mg/L, 0.008 ±0.0002 mg/L and 0.007 ±0.0003 mg/L; 47,095 ±0.0019 mg/L, 7.446 ±0.0009 mg/L and 6.934 ±0.0003 mg/L and 1.282 ±0.0013 mg/L, 0.934 ±0.0010 mg/L and 01.214 ±0.0019 mg/L respectively. Sampling point one had the highest concentration for Cd, 0.009 ±0.0005 mg/L; Fe, 47.095 ±0.0019 mg/L and Mn, 1.282 ±0.0013 mg/L. sampling point two had the least concentration for Mn, 0.934±0.0010mg/L; three for Fe, 6.934 ±0.0003 mg/L and Cd, 0.007 ±0.0003. As for both Cr and Pb the concentration was 0.000 mg/L. These results obtained showed that they were within the permissible limit for discharge of wastewater into river by FEPA (1991), less than 1 mg/L for Cd, Cr and Pb; 5 mg/L for Mn and 20 mg/L for Fe, with the exemption of the concentration of Fe, 47.095 ±0.0019 mg/L at sampling point one which exceeded it by at least two times. But the permissible limit for the discharge of wastewater into river set by WHO/USEPA is 0.03 mg/L Cd; 0.1mg/L Cr and 0.1 mg/L Pb.

Table 3. Correlation analysis of heavy metals and physiochemical properties of Yola and Numan Abattoir.

	pH	Temp (oC	Conductiv	TDS (mg/L	DO (mg/L)	BOD (mg/	COD (mg/	Cd (mg/L)	Cr (mg/L)	Fe (mg/L)	Pb (mg/L)	Mn (mg/L)
pH		0.097415	0.080715	0.082938	0.3106	0.39336	0.19982	0.087132	1	0.87944	0.43712	0.40137
Temp (oC)	-0.733		0.000344	0.000223	0.8268	0.52556	0.28741	0.044582	1	0.67848	0.34001	0.11593
Conductivi	-0.75807	0.98481		9.01E-07	0.8904	0.5481	0.31689	0.020174	1	0.78996	0.50413	0.067823
TDS (mg/L	-0.75461	0.98778	0.99923		0.85705	0.50989	0.31685	0.020089	1	0.74619	0.47233	0.064596
DO (mg/L)	-0.50169	0.11599	0.073195	0.095592		0.1916	0.8956	0.59055	1	0.84879	0.13325	0.88213
BOD (mg/L	0.43114	-0.32806	-0.31132	-0.33982	-0.61737		0.31844	0.53231	1	0.099681	0.45351	0.32637
COD (mg/L	0.60859	-0.52265	-0.49611	-0.49614	-0.06971	0.49474		0.75797	1	0.35948	0.73996	0.57009
Cd (mg/L)	0.74819	-0.82226	-0.88167	-0.88193	-0.28031	0.32303	0.16279		1	0.87588	0.59554	0.068051
Cr (mg/L)	0	0	0	0	0	0	0	0		1	1	1
Fe (mg/L)	0.080549	0.21779	0.14096	0.17087	0.10115	-0.72975	-0.45932	0.082939	0		0.57625	0.48002
Pb (mg/L)	0.39595	-0.47593	-0.34417	-0.36845	-0.68495	0.38307	0.17515	0.2767	0	-0.29069		0.92179
Mn (mg/L)	-0.4246	0.70736	0.77907	0.78461	-0.07874	-0.48777	-0.29518	-0.77868	0	0.36253	0.052184	

From the correlation table above, it is observed that there is strong positive correlation between TDS and conductivity is (0.9992); that is nearly perfect and expected, since TDS and conductivity are directly related. The TDS and temperature (0.9878), and Conductivity and temperature (0.9848) which suggests temperature increase may raise TDS and conductivity. The CO in relation to DO is (0.8956), it is somewhat unusual; generally, COD increases as DO decreases in polluted water.

In the other hand, there are strong negative correlations between pH and temperature which is (-0.7330); it indicates that as temperature rises, pH tends to drop. pH, conductivity and TDS (~ -0.75) which suggest that higher ionic content leads to lower pH (acidification).

Pb and Mn shows moderate correlations with other parameter, e.g Pb and Fe (0.5041), Mn and DO (0.8821), this is quite strong, indicating Mn levels rise with dissolved oxygen (possibly due to geochemical oxidation).

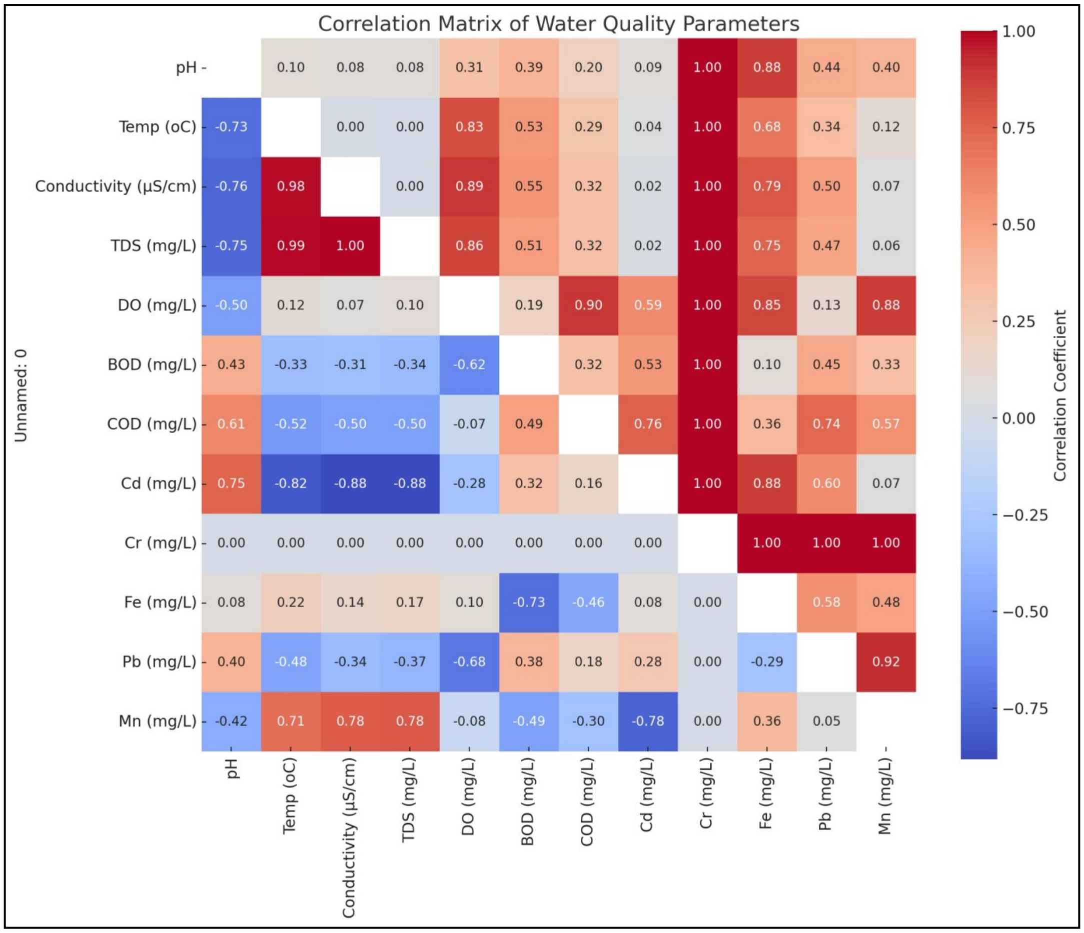

Figure 1: Correlation Insights & Projections (Correlation heat map)

The heat map reveals several key relationships among water quality variables:

Strong Correlations

Type	Variable Pair	Correlation	Implication
▲ **Positive**	**Conductivity – TDS**	**+0.999**	These are near-perfectly correlated, suggesting that TDS is largely composed of ionic substances influencing conductivity.
▲ **Positive**	**Conductivity – Temperature**	**+0.985**	As temperature increases, ion mobility increases, thus raising conductivity.

▲ **Positive**	**TDS – Temperature**	**+0.988**	Warmer temperatures might lead to increased solubility of solids.
▲ **Positive**	**DO – COD**	**+0.896**	Unusual, as DO and COD are typically negatively correlated. Could suggest high aeration or sampling anomaly.
▼ **Negative**	**pH – Temperature/Conductivity**	**~-0.73 to -0.76**	Higher temperatures and ion concentration are linked to lower pH—possibly due to acidic ion dissolution.

Metal-Specific Trends

Metal	Notable Correlations	Interpretation
Fe	High with **pH (0.879)** & **COD (0.746)**	Indicates that higher COD environments (more organic matter) may promote iron solubilization, possibly due to reducing conditions.
Mn	Strong with **DO (0.882)** & weak with COD	Suggests oxidative states may influence manganese solubility.
Cr	Uniform value (**1.0** across the board)	This is likely an artifact or data entry error — true correlations cannot all be perfect.

Projected Implications for Monitoring

1. **TDS and Conductivity as Proxy Measures:** Since TDS and conductivity correlate nearly perfectly, only one may be needed for routine monitoring, optimizing cost-efficiency.
2. **Temperature Management:** Thermal pollution may indirectly affect pH, conductivity, and heavy metal solubility—important for industrial discharge regulation.
3. **Feasibility of Predictive Modeling:** Given these strong linear relationships, predictive models (e.g., regression-based) could reliably estimate parameters like TDS from simpler metrics like conductivity and temperature.
4. **Cr Data Needs Verification:** The perfect correlation values for Chromium (Cr) indicate potential issues — this variable should be reviewed for consistency before inclusion in statistical modeling.

Conclusion

The correlation matrix revealed that temperature, TDS, and conductivity are tightly interlinked, suggesting that simple parameters can act as proxies for complex ones. Metal concentrations such as iron and manganese show meaningful correlations with oxygen and pH, guiding targeted monitoring in polluted waters. However, anomalies (e.g., Chromium) require data validation before they can inform reliable projections.

Recommendations

From the entire analysis carried out on the quality of water tested for in the laboratory, the following recommendations are:

i. The monitoring of temperature, TDS, and conductivity is pertinent, as the interrelationship between the three can cause a proxies for pollution and water quality change.
ii. Negative correlation of pH with TDS and temperature indicate a risk of acidic conditions in higher temperature or polluted water. Therefore, it is important to keep a watch.
iii. TDS and conductivity can be used as predictors for water quality modelling due to their strong correlation with other variables.
iv. The dissolve oxygen behavior need to be investigated, the positive correlation of COD and Mn suggests unusual geochemical or pollution sources. Typically, high COD reduces DO.

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