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# Correlation Coefficient for Physico-chemical Parameters to Assess the Quality of Tannery Effluents at Kanpur

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**Abstract:** In the present study, a monthly sample of tannery effluent was collected and analyzed from May 2021 to April 2022. The samples were collected from a tannery in the Jajmau area of Kanpur city. Based on the correlation matrix, Pearson's correlation coefficient (r) value was calculated to identify the highly correlated and interrelated water quality standards issued by the Bureau of Indian Standards (IS-10500:2012). Almost all of the samples from the tannery were found to be above acceptable limits and unusable. The analysis revealed that the effluent discharged by the above-stated tannery contained additional chemical loads such as iron, calcium, magnesium, carbonate, bicarbonate, chloride, and BOD. Different physicochemical characteristics of tannery effluents differ according to the month, and the results reveal certain relationships between these physicochemical characteristics.

**Keywords:** tannery; Pearson correlation; Regression equation; BOD; potassium permanganate.

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## 1. Introduction

Blood in the human body is analogous to water on Earth. It is easy to imagine Earth without water as a sterile, desolate, gray hunk of rock orbiting the sun [1]. Humans pollute the Earth's blood, which is water, through urbanization and industrialization. Industrial processes primarily cause water pollution, and the nature of industries may vary widely. The wastewater from manufacturing units, employees' sanitary wastes, water discharged from washing factory floors, and relatively uncontaminated heating and cooling water comprise the wastewater from industries [2].

One of the most polluting and water-intensive industries is the tanning industry. During the tanning process, raw materials and auxiliary agents (proteins, acids, bases, chromium salts, sulfides, chlorides, tannins, solvents, dyes, auxiliaries, and other compounds) are the main

sources of contamination of tannery wastewater (TWW) [3-5]. TWW generally has high concentrations of COD (chemical oxygen demand), BOD (biological oxygen demand), TDS/TSS (total dissolved solids/total suspended solids), chromium, and phenolics, resulting in a strong odor and dark brown color [6,7]. A variety of nutrients, including nitrogen and phosphorus, are also present in TWW [8-10]. The TWW still contains TSSs (35-250 mg/L), BODs (250-2960 mg/L), and chromium (4.5-15 mg/L) [11-14]. The tanning industry's pollution problem has been receiving increasing attention due to studies on pollutants, genotoxicity, and environmental behavior in TWW [15-17].

There are several processes used to convert animal hide and skin into leather. Raw materials for the leather industry come from slaughterhouse waste. The meat industry produces it as a by-product. Animal skins are converted into useful products as waste products. As a result, the leather industry eliminates the problem of disposing of unbeatable hides and skins. Pollution load in tanneries can be somewhat reduced by implementing cleaner technology [18].

There is often a problem with raw tannery effluent being discharged into municipal sewage systems. Stringent regulatory standards must be met before effluent can be disposed of. Due to urbanization and industrialization, environmental pollution has become a major problem worldwide. Water pollution is primarily caused by the release of effluents into receiving waters [19]. The pollutants contaminate aquatic ecosystems like rivers, ponds, and lakes, posing a health risk to humans and ecosystems.

Globally, Kanpur is the top and most famous tannery city. In addition to their pollution, Kanpur is one of the most polluted cities in the world. Tanneries are the primary source of pollution in Kanpur. In the tanning process, only about 20% of the chemicals are absorbed by the leather. The rest are released as waste, absorbed by cultivated crops through bioaccumulation [20,21]. Tanned and untanned solids, waste effluents, and waste gases comprise thetannery's waste products [22]. One of the 's biggest issues, environmental pollution, is getting more serious every day due to urbanization and industrialization. Large-scale chemical use in various human activities has rapidly increased over the last few decades, especially in nations like India [23]. Groundwater is crucial for delivering potable water, agricultural irrigation, and industrial production. The threat of pollution to groundwater resources from urbanization, industrial development, and agricultural practices is growing [24].

A major issue in the modern world is global water contamination brought on by the growth of industry [25]. The primary cause of water pollution is the discharge of effluents into receiving bodies of water. These contaminants end up in aquatic ecosystems, including rivers, ponds, and lakes, endangering human and ecosystem health [26]. Almost all industries release waste-containing water at some point throughout the production process. Industrial waste varies depending on the situation. Because of this, the presence of contaminants in water causes a variety of physicochemical parameters to deviate from the normally prescribed levels [27]. Increases in turbidity, color, nutrient load, and the addition of hazardous and persistent chemicals are all detrimental effects on water quality [28,29]. The physical, chemical, and biological diversity of tannery effluent is so extensive that individual studies are needed for each effluent habitat.

In addition to providing job opportunities, the leather industry has contributed significantly to economic growth. The industry ranks 5th in export earnings based on foreign exchange earnings. By contributing 2 billion US dollars in exports and 2% of world trade, the leather industry occupies a prominent position in the Indian economy. Nearly 2.5 million people are employed in the leather industry, and most tanneries are small and medium-sized

businesses [30]. Several chemicals are involved in leather production, including sodium chloride, lime, chromium sulfate, ammonium sulfate, sodium sulfate, and dyes [31].

The current study compares the chemical characteristics of polluted water released by tanneries.

## 2. Materials and Methods

The chemicals used were all AR grade. pH, electrical conductivity, and turbidity were measured with the MAC Digital Portable Kit (MSW-551). A flame photometer (Model Systronic 128) was used to determine metal ions $Na^+$, $K^+$, and $Ca^{2+}$. The silver nitrate method was used to estimate the chloride present in water samples. Sulphate was determined by the turbidimetric method. Total hardness was calculated using complexometric titration with EDTA.

### *2.1. Samples and sampling sites.*

We collected samples from a tannery in Kanpur's Jajmau area. On-site assessments and interviews with relevant personnel, including workers, managers, and other stakeholders, were conducted as part of the study: (i) visits to tanneries and surrounding areas and (ii) on-site assessments and interviews. One-month intervals of effluent samples were collected from the tannery from the spots fixed. Each sample was taken in a glass bottle (1.0 liter) and corked immediately after collection. During analysis, all samples were stored at $4^oC$ in refrigerators until they were analyzed. All chemical assays were completed on the same day or the following evening. To obtain a comprehensive sample of the water, all four or five samples from various areas were merged. The experiments listed below use this sample. The sampling method was the same as that outlined in the Indian Standard Methods of Sampling and Testing for water used in industries, I.S.I. New Delhi, India.

Color, temperature, pH, carbonate, bicarbonate, chloride, total alkalinity, nitrite, total hardness, alkaline hardness, total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), oxygen consumed by potassium permanganate, BOD, calcium, chromium, potassium, magnesium, phosphorus, sulfur, nitrogen, iron, and manganese were the physical and chemical characteristics analyzed for the Each of the components above had their pH and temperature measured according to procedures outlined in IBH Handbook No. 8 [32], USDA Handbook No. 60 [33], and Laboratory Methods for Blue Green Algae, respectively [34]. ISI New Delhi's 2490 standard [35] is used for water sampling and testing, as it was originally developed by Choubey [36,37]. The links between the various wastewater testing characteristics were determined. The Winkler technique measured the amount of dissolved oxygen (DO) in effluent samples. Alkalinity was determined using sodium thiosulfate as an indicator [38]. Using established techniques, the BOD, TDS, and TS of effluent samples were measured [39]. The calculation of COD was done following Ademoroti [40].

All data were statistically examined, and the 5% and 10% probability levels were used to evaluate significance. One and two asterisks have been used for ''r' values, respectively significant and very significant.

*2.2. Statistical analysis.*

Water quality estimation is performed using a linear regression model, which requires two parameters to describe the situation. In correlation analysis, independent and dependent variables are compared for their closeness to each other [41,42]. It indicates the probability of a linear relationship between variables x and y if the correlation coefficient approaches +1 or 1.

Based on correlation, the parameters are classified as strong, moderate, and weak. A parameter is considered strong when it lies between +0.8 to 1.0, and a parameter is moderate when it lies between +0.5 to 0.8, and a parameter is weak when it lies between +0.0 to 0.5, and a parameter is weak when it lies between −0.0 to −0.5 [43]. Correlation analysis provides a mechanism for forecasting and predicting based on the nature of the relationship between the variables [44]. Pearson correlation coefficient, commonly referred to as the Pearson r test, was used in the present study to measure the strength of relationships between variables. To determine how strong the relationship between the two variables is, we can use this coefficient correlation value:

$$r = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2 \sum(y - \bar{y})^2}}$$

where, *x* (*x* = values of *x*-variable, $\bar{x}$ = average value of *x*) and y (y = values of *y*-variable, $\bar{y}$ = average values of *y*) represent two different water quality parameters. A high correlation coefficient ''R' between two variables X and Y indicates a high degree of correlation between them. Here is an equation for a straight line that can be used to determine straight linear regression:

$$y = a + bx$$

In this equation, y is the dependent variable, and x is the independent variable, a represents slope, and b represents intercept on the y-axis. Here is the equation used to calculate the empirical parameters' a' and 'b':

$$b = \frac{\sum(xy - \bar{x}\sum y)}{\sum x^2 - \overline{x\sum y}}$$

$$a = \bar{y} - b\bar{x}$$

Statistics uses correlations to describe statistical relationships between variables. In practical situations, correlation studies are useful for discovering predictable relationships. Statistical significance is measured by measuring the relationship between two or more water quality parameters [45]. The regression analysis has been performed using the past-4 software versions to study the correlation between different water quality parameters.

## 3. Results and Discussion

Table 1 shows the acceptable and minimum permissible limits of individual parameters for drinking water recommended by the Bureau of Indian Standards (BIS 2012) and the World Health Organization (WHO 2002). The physical and chemical properties of tannery effluent varied significantly from month to month (Table 2). Table 3 shows that traits were correlated in the following ways.

*3.1. Positive correlation-ships were determined between.*

Temperature with nitrite; pH with each TS, total chromium, DO, and oxygen consumed by $KMnO_4$; $CO_3^{--}$ with each $HCO_3^{--}$, $Cl^-$, total hardness, alkaline hardness, TS and TSS; $HCO_3^{--}$ with each $Cl^-$, total hardness, alkaline hardness and TS, TDS, and TSS; $Cl^-$ with each $NO_2^-$, total hardness, alkaline hardness, total chromium, TS and TSS; total alkalinity with each nitrite, total chromium and TDS; total hardness with each alkaline hardness, TS, TDS, and TSS; nitrite with each total chromium, TDS and BOD; alkaline hardness with TSS, TS, TDS; TS with each TDS, TSS, DO and BOD; J.C. Akan et al. were studied a positive correlation between these parameters: TDS with TSS; DO with oxygen consumed by $KMnO_4$; Ca with each K, P, N, Fe, Mg, and S; Mg with S, N, Fe, and Mn [46].

*3.2. Negative correlation ships were determined between.*

Similar results have also been observed by Piyush et al. during their study of the impact of distillery effluent on seed germination behavior: pH with each. $CO_3^{--}$, $HCO_3^{--}$, $Cl^-$, total hardness, alkaline hardness, TDS, and total suspended particles; $CO_3^{--}$ with DO, Ca, K, Mg, N, Fe, and oxygen consumed by $KMnO_4$; chloride with K, Mg, P, DO, oxygen consumed by $KMnO_4$, and BOD; Nitrite with each oxygen consumed by $KMnO_4$, K, Mg, P, S, Fe, and Mn; TS with oxygen consumed by $KMnO_4$, Ca, K, Mg, N, Fe and Mn [47].

Temp. = Temperature (°C), pH = potentio Hydrogeni, carbonate = $CO_3^{--}$, bicarbonate = $HCO_3^{--}$, chloride = $Cl^-$, TA = Total Alkalinity as $CaCO_3$, TH = Total Hardness as $CaCO_3$, AH = Alkaline Hardness as $CaCO_3$, TS = Total Solids (meq.$L^{-1}$), TDS = Total Dissolved Solids (meq.$L^{-1}$), TSS = Total Suspended Solids (meq./$L^{-1}$), DO = Dissolved Oxygen (meq.$L^{-1}$), BOD = Biological Oxygen Demand (meq.$L^{-1}$), COD = Chemical Oxygen Demand (meq.$L^{-1}$), OC = Oxygen Consumed by $KMnO_4$ in 3 hrs.

**Table 1.** Standards of drinking water quality as per BIS and WHO.

| S. no. | Parameters | BIS standards (BIS 10500:2012) | | World Health Organization (WHO) (2002) [48] |
|---|---|---|---|---|
| | | Permissible limit | Acceptable limit | |
| 1 | pH | No relaxation | 6.5–8.5 | 6.5–9.2 |
| 2 | Chloride | 1000 | 250 | 200 |
| 3 | Total alkalinity | 600 | 200 | 500 |
| 4 | Total hardness | 600 | 200 | 300 |
| 5 | Total dissolved solids | 2000 | 500 | 250 |
| 6 | Calcium | 200 | 75 | 150 |
| 7 | Magnesium | 100 | 30 | 200 |

Note: All values are in mg.$L^{-1}$, except pH

**Table 2**. The physico-chemical characteristics of the tannery effluent.

| Color | Sample No. | Temp. | pH | Carbonate | Bicarbonate | Chloride | TA | Total Cr | TH | AH | TS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Light Brown | May 21 | 24.7 | 4.5 | 5.0 | 1.3 | 266 | 1266 | 14.23 | 3450 | 650 | 1002 |
| Gray | June 21 | 24.6 | 5.3 | 5.4 | 1.2 | 322 | 1360 | 14.76 | 3430 | 770 | 750 |
| Brown | July 21 | 30.5 | 4.4 | 3.1 | 2.0 | 243 | 1344 | 13.65 | 3200 | 560 | 1222 |
| Brown | Aug. 21 | 28.5 | 4.8 | 5.1 | 5.7 | 272 | 1472 | 14.45 | 2400 | 770 | 1965 |
| Brown | Sept. 21 | 28.6 | 5.7 | 5.2 | 4.8 | 282 | 1242 | 12.45 | 2600 | 760 | 1960 |
| Brown | Oct. 21 | 30.4 | 4.8 | 4.3 | 1.4 | 237 | 1390 | 14.25 | 2550 | 620 | 1875 |
| Brown | Nov. 21 | 26.5 | 3.7 | 4.3 | 2.8 | 274 | 1355 | 14.66 | 2840 | 670 | 2055 |
| Brown | Dec. 21 | 24.4 | 4.2 | 5.7 | 3.6 | 258 | 1205 | 13.52 | 3200 | 640 | 1950 |
| Gray | Jan. 22 | 21.2 | 4.5 | 5.2 | 3.1 | 288 | 1354 | 13.43 | 2970 | 580 | 1760 |

| Color | Sample No. | Temp. | pH | Carbonate | Bicarbonate | Chloride | TA | Total Cr | TH | AH | TS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gray | Feb. 22 | 26.0 | 4.6 | 3.4 | 3.8 | 261 | 1230 | 16.10 | 2690 | 585 | 1565 |
| Gray | Mar. 22 | 23.6 | 4.9 | 2.3 | 1.8 | 290 | 1006 | 15.60 | 2520 | 660 | 850 |
| Brown | Apr. 22 | 22.5 | 3.7 | 2.3 | 4.6 | 255 | 1123 | 13.67 | 2530 | 565 | 995 |

**Table 2.** continued….

| TDS | TSS | DO | BOD | COD | OC | Ca | K | Mg | P | S | N | Fe | Mn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10550 | 765 | 0.5 | 975 | 4445 | 1.6 | 535 | 764 | 375 | 365 | 256 | 2054 | 6.76 | 1.65 |
| 10770 | 835 | 1.6 | 880 | 4460 | 3.2 | 680 | 689 | 385 | 225 | 182 | 1176 | 7.05 | 1.75 |
| 10440 | 865 | 1.5 | 865 | 4805 | 1.6 | 570 | 940 | 375 | 247 | 226 | 1075 | 6.75 | 1.45 |
| 10675 | 760 | 0.4 | 840 | 4625 | 3.3 | 575 | 665 | 342 | 236 | 285 | 1080 | 7.75 | 2.90 |
| 10364 | 880 | 0.7 | 915 | 4552 | 3.2 | 655 | 870 | 365 | 224 | 165 | 1155 | 5.30 | 2.80 |
| 10475 | 865 | 0.6 | 855 | 4880 | 2.7 | 568 | 972 | 360 | 75 | 536 | 1153 | 6.50 | 3.80 |
| 10660 | 865 | 1.8 | 940 | 4750 | 3.3 | 675 | 489 | 335 | 180 | 265 | 1175 | 5.85 | 2.17 |
| 10445 | 825 | 1.8 | 925 | 4625 | 2.5 | 556 | 872 | 380 | 167 | 190 | 1090 | 7.30 | 3.55 |
| 10756 | 905 | 0.5 | 1005 | 4605 | 2.2 | 575 | 849 | 375 | 182 | 186 | 1050 | 5.75 | 2.50 |
| 10485 | 815 | 0.6 | 930 | 4524 | 2.1 | 650 | 970 | 350 | 135 | 170 | 1160 | 6.45 | 1.65 |
| 10565 | 762 | 1.4 | 976 | 4445 | 2.4 | 535 | 555 | 360 | 145 | 159 | 1042 | 6.45 | 2.73 |
| 10885 | 845 | 1.8 | 984 | 4420 | 3.7 | 570 | 945 | 375 | 155 | 250 | 1445 | 6.56 | 1.42 |

**Table 3.** Correlation statistic- Linear *'r'* (Pearson) and statistic table format correlation coefficients.

| Variables | Temp. | pH | Carbonate | Bicarbonate | Chloride | TA | Total Cr | TH | AH | TS | TDS | TSS | DO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp. | | +0.29* | + 0.04 | +0.007* | -0.468 | +0.487 | -0.106 | -0.188 | +0.200 | +0.369 | -0.615 | +0.075 | -0.213 |
| pH | | | +0.34 | -0.058** | -0.462* | +0.094 | -0.084 | -0.042* | +0.630* | -0.060 | -0.382 | -0.063 | -0.461* |
| Carbonate | | | | +0.060* | +0.315* | +0.579 | -0.390* | +0.420* | +0.546 | +0.462 | -0.134 | +0.135 | -0.302 |
| Bicarbonate | | | | | -0.108 | +0.035 | -0.280 | -0.579* | +0.175 | +0.503* | +0.088 | +0.003 | -0.153 |
| Chloride | | | | | | -0.041** | +0.144* | +0.228 | +0.616* | -0.316* | +0.391* | -0.084 | +0.077 |
| TA | | | | | | | -0.169 | +0.154 | +0.277 | +0.462* | +0.053 | +0.258* | -0.375 |
| Total Cr | | | | | | | | -0.116 | -0.050 | -0.317 | +0.118 | -0.551* | -0.008 |
| TH | | | | | | | | | -0.039 | -0.351 | -0.031 | +0.056 | +0.229 |
| AH | | | | | | | | | | +0.120 | -0.025 | -0.289 | -0.126 |
| TS | | | | | | | | | | | -0.348 | +0.357* | -0.284 |
| TDS | | | | | | | | | | | | +0.004 | +0.233* |
| TSS | | | | | | | | | | | | | +0.129 |
| DO | | | | | | | | | | | | | |
| BOD | | | | | | | | | | | | | |
| COD | | | | | | | | | | | | | |
| OC | | | | | | | | | | | | | |
| Ca | | | | | | | | | | | | | |
| K | | | | | | | | | | | | | |
| Mg | | | | | | | | | | | | | |
| P | | | | | | | | | | | | | |
| S | | | | | | | | | | | | | |
| N | | | | | | | | | | | | | |
| Fe | | | | | | | | | | | | | |
| Mn | | | | | | | | | | | | | |

**Table 3.** continued….

| Variables | BOD | COD | OC | Ca | K | Mg | P | S | N | Fe | Mn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp. | -0.838* | +0.697* | -0.052 | +0.148 | +0.184 | -0.355 | -0.008 | +0.506 | -0.197 | +0.087 | +0.232 |
| pH | -0.359 | -0.151 | -0.012 | +0.225 | +0.023 | +0.148 | +0.122 | -0.128 | -0.191 | -0.112 | +0.259 |
| carbonate | -0.236 | +0.121 | +0.046 | +0.233 | -0.077 | +0.153 | +0.341 | +0.014 | +0.044 | +0.098 | +0.399 |
| bicarbonate | -0.041 | -0.132 | +0.497 | +0.118 | +0.137 | -0.347 | -0.088 | -0.221 | -0.242 | +0.016 | +0.104 |
| chloride | +0.194 | -0.552 | +0.270 | +0.440* | -0.580 | +0.154 | +0.219 | -0.561 | -0.120 | -0.108 | -0.146 |
| TA | -0.625** | +0.590 | +0.060 | +0.291* | +0.007 | -0.224 | +0.194 | +0.442 | -0.116 | +0.194 | +0.120 |
| Total Cr | -0.005 | -0.186 | -0.150 | +0.103 | -0.340 | -0.421 | -0.244 | -0.028 | -0.042 | +0.286 | -0.199 |

| Variables | BOD | COD | OC | Ca | K | Mg | P | S | N | Fe | Mn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TH | +0.078 | -0.090 | -0.488* | +0.039 | -0.005 | +0.625 | +0.585 | -0.256 | +0.389 | +0.177 | -0.345 |
| AH | -0.411 | -0.190 | +0.481** | +0.408 | -0.535 | -0.184 | +0.294 | -0.110 | -0.078 | +0.154 | +0.263 |
| TS | -0.262 | +0.607** | +0.197 | +0.197 | +0.073 | -0.528 | -0.276 | +0.279 | -0.383 | -0.210 | +0.611 |
| TDS | +0.332 | -0.386 | +0.482* | +0.059 | -0.275 | +0.085 | -0.015 | -0.055 | +0.112 | +0.140 | -0.378 |
| TSS | +0.045 | +0.455 | +0.131 | +0.392 | +0.390 | +0.188 | -0.317 | +0.099 | -0.348 | -0.640 | +0.035 |
| DO | +0.108 | -0.049 | +0.296 | +0.142 | -0.234 | +0.226 | -0.173 | -0.241 | -0.168 | +0.098 | -0.207 |
| BOD | | -0.562* | -0.139 | -0.215* | -0.104 | +0.201 | +0.050 | -0.441 | +0.347 | -0.464 | -0.278 |
| COD | | | -0.123 | +0.021 | +0.165 | -0.315 | -0.308 | +0.633 | -0.406 | -0.049 | +0.423 |
| OC | | | | +0.437* | -0.257 | -0.260 | -0.315 | +0.109 | -0.229 | -0.035 | +0.157 |
| Ca | | | | | -0.172 | -0.270* | -0.092 | -0.216 | -0.256 | -0.354 | -0.233 |
| K | | | | | | +0.422 | -0.212 | +0.208 | +0.038 | -0.042 | -0.016 |
| Mg | | | | | | | +0.248 | -0.232 | +0.231 | +0.111 | -0.168 |
| P | | | | | | | | -0.316 | +0.633 | +0.167 | -0.453 |
| S | | | | | | | | | +0.100 | +0.140 | +0.427 |
| N | | | | | | | | | | +0.065 | -0.411 |
| Fe | | | | | | | | | | | +0.0543 |
| Mn | | | | | | | | | | | |

However, some parameters with correlation coefficients with r < 0.05 are tabulated in Table 4. The linear regression analysis has been carried out for the tannery effluents parameters, which are found to have a better and higher level of significance in their correlation coefficient (r > 0.50) [49], which is depicted in Table 4.

The various dependent characteristics of tannery effluent quality were calculated using the regression equation, and the values were substituted for the independent parameters in the equations [49]. These correlations revealed that the physicochemical parameters independent of anions and major cations in the Jajmau area and some cations, anions, and physical parameters were found interrelated [51]. $Ca^{2+}$, $Mg^{2+}$, $CO_3^{--}$, $HCO_3^{--}$, $Cl^-$ are positively correlated with the majority of water parameters. pH is negatively correlated with most of the water parameters. Highly negative correlation coefficients are found between temperature and BOD (r = −0.838) and TA and BOD (r = −0.625). The results indicate that regression relations have the same correlation coefficients [52,53].

**Table 4.** Correlation statistic- Linear correlation coefficient '*r*' and regression equation for some physic-chemical parameters which have significant value of correlation.

| S. No. | Parameter | r value | Correlation coefficient | | Regression equation |
|---|---|---|---|---|---|
| | | | a | b | |
| 1 | pH–TH | -0.0424 | 3.14326 | 0.0558 | TH = 0.0558 (Ph) + 3.14326 |
| 2 | TA–$Ca^{2+}$ | 0.2912 | 438.95153 | 0.12228 | $Ca^{2+}$ = 0.12228 (TA) + 438.95153 |
| 3 | TA–$Cl^-$ | -0.0414 | 280.24474 | -0.00749 | $Cl^-$ = 0.00749 (TA) + 280.24474 |
| 4 | $Ca^{2+}$–$Mg^{2+}$ | -0.270 | 411.89113 | -0.07918 | $Mg^{2+}$ = -0.07918 (Ca2+) + 411.89113 |
| 5 | $Ca^{2+}$–$Cl^-$ | 0.4403 | 157.94549 | 0.18934 | $Cl^-$ = 0.18934 (Ca2+) + 157.94549 |
| 6 | $Mg^{2+}$–$Cl^-$ | 0.1539 | 188.31131 | 0.22579 | $Cl^-$ = 0.22579 (Mg2+) + 188.31131 |

The correlation coefficients between various physicochemical parameters are plotted, which are given in fig.1. Stacked bar charts of various physicochemical parameters in percentage are given in fig. 2. Matrix of various physico-chemical parameters can be seen in fig. 3. Auto correlations of various physico-chemical parameters can be seen in fig. 4. Fig. In fig. 5 shows a significant negative correlation between BOD and TA.

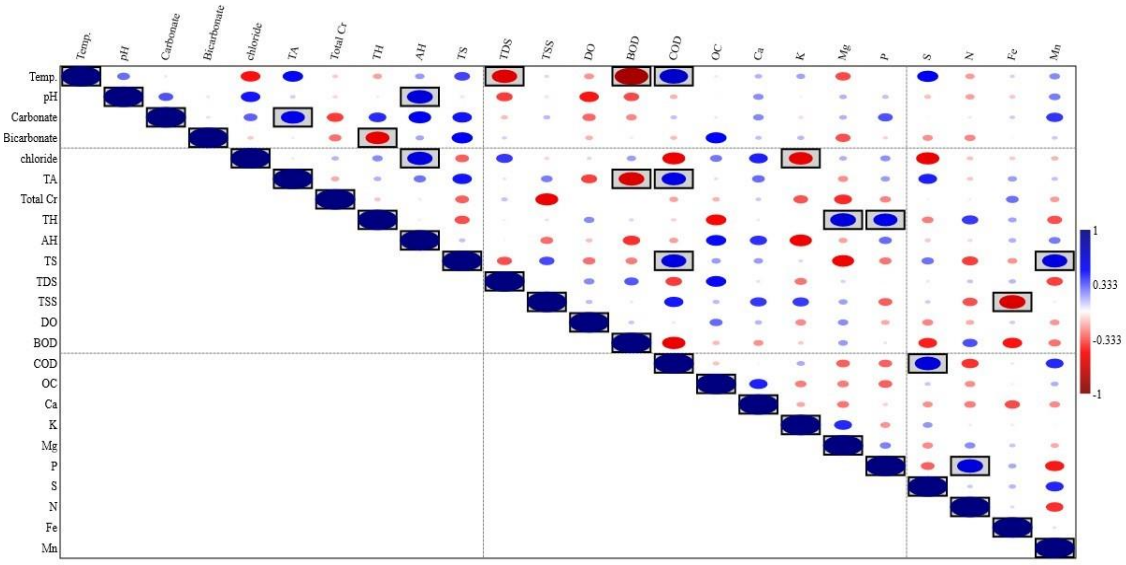


**Figure 1.** Plot of Correlation coefficients between various physico-chemical parameters.

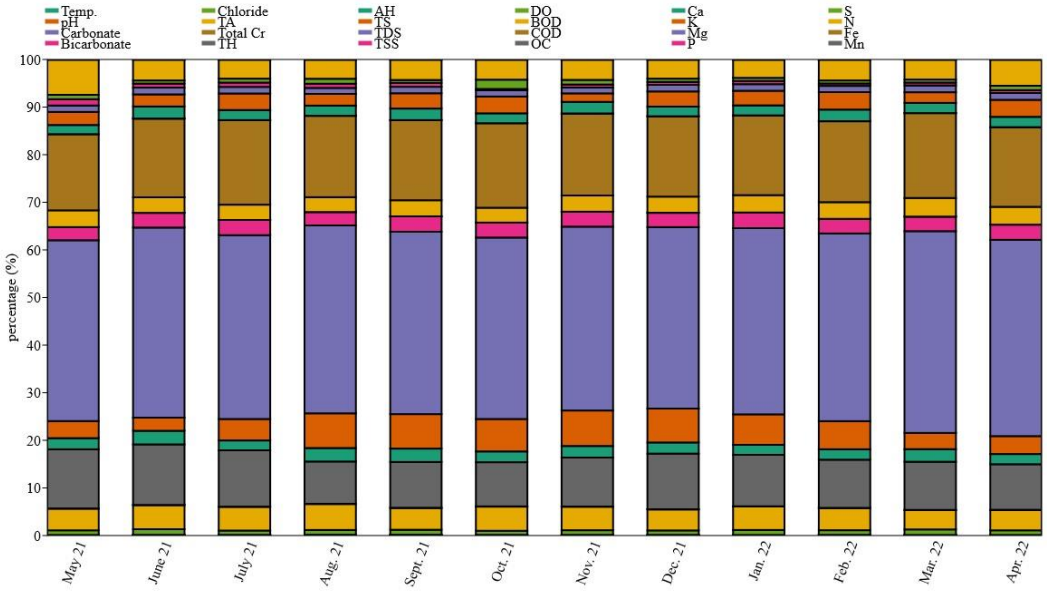


**Figure 2.** Stacked bar charts of various physicochemical parameters in percentage.

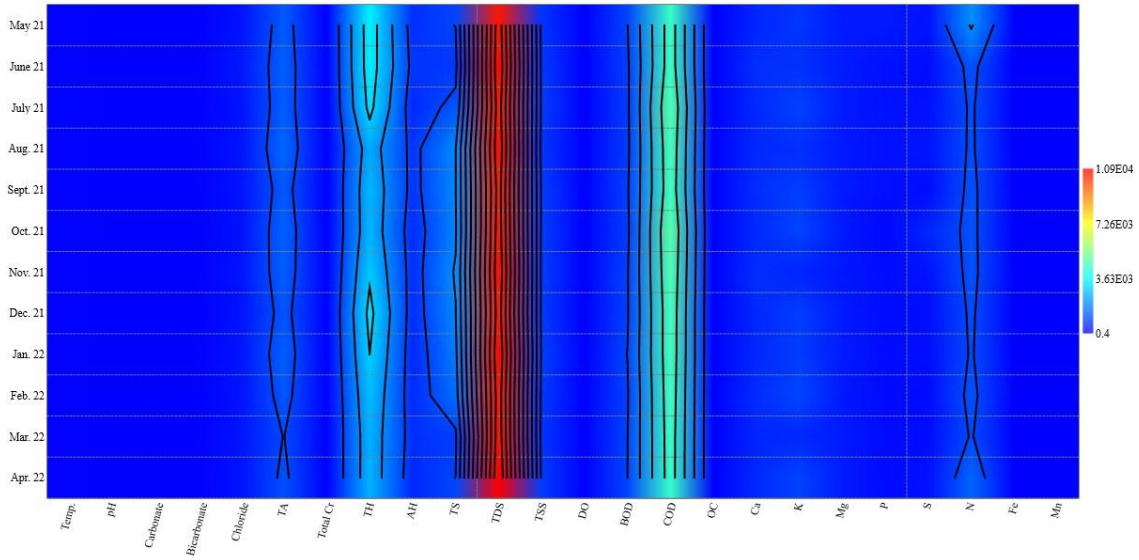


**Figure 3.** Matrix of various physicochemical parameters.

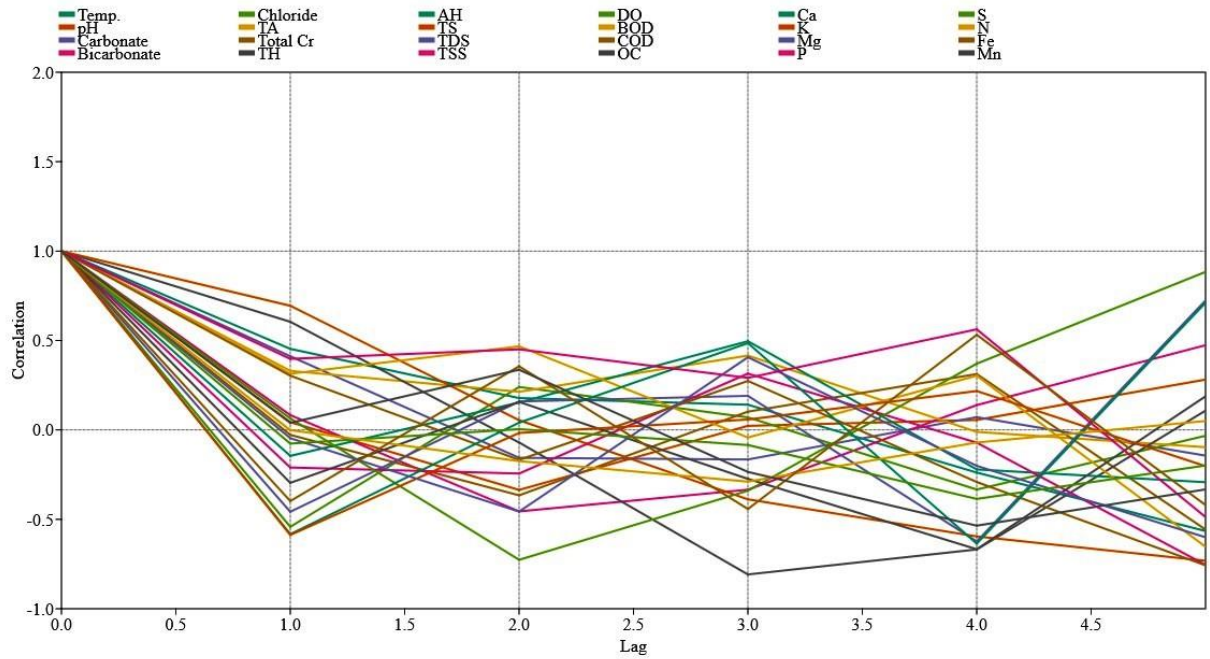


**Figure 4.** Autocorrelation various of physicochemical parameters.

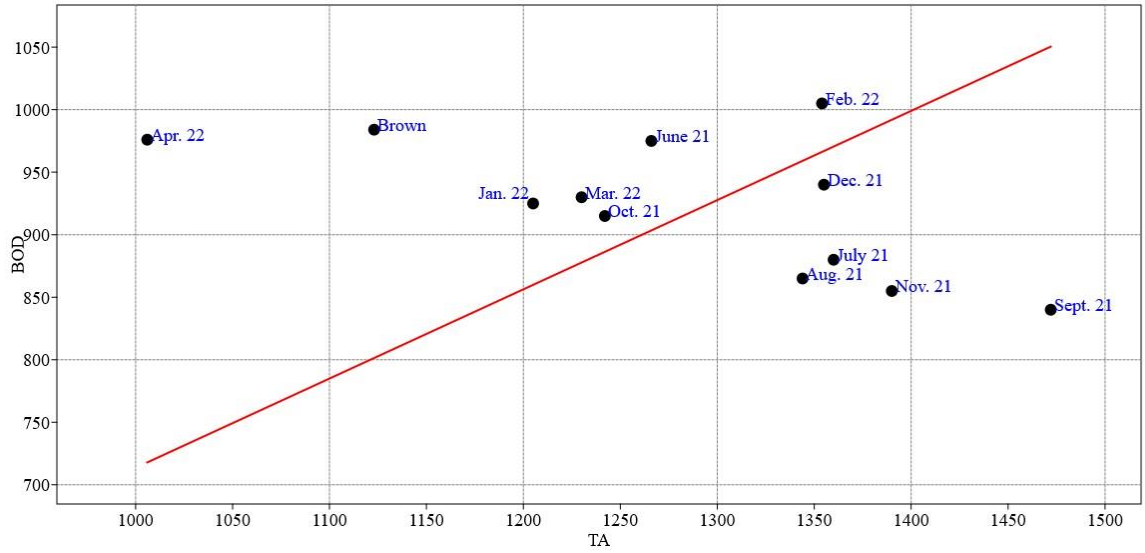


**Figure 5.** Strong negative correlation between BOD and TA (r = -0.625).

## 4. Conclusions

Analyses of tannery industry effluents were conducted, and it was concluded that the effluents were brown, turbid, and odorous. Effluent pH was in the acidic range. The effluent had high levels of total hardness, total suspended solids, and dissolved solids. COD, BOD, carbonate, bicarbonate, calcium, magnesium, chloride, potassium, nitrite, sulfur, and chromium are found to be much higher than the Bureau of Indian Standards (2012) permissible limits. As a result of tanneries pollution, groundwater quality rapidly deteriorates. Water's poor quality makes it difficult for us to use it in our daily lives and aquatic environments. A new technique for treating effluent can be developed with the help of this study.

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## Conflicts of Interest

The authors declare no conflict of interest.

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