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Selective Studies of Industrial Effluents for the Betterment of Mankind

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ABSTRACT

The effluents of manufacturing industries are characterized by high Biological Oxygen Demand, Chemical Oxygen Demand, Iron, Lead, Chromium, Zinc and Cadmium metals, oil-grease and many other nutrients like phosphates, nitrates and sulphates. The effluent samples were collected monthly from selected sites (Banmore, Malanpur, Ghirongi and Gwalior) for a period of three years. The study found that some parameters exceed the permissible limit prescribed by BIS. The drained chemicals are either directly or percolated through the soil bed, entered in water sources and made unsuitable for drinking purposes which cause serious health problems in human beings. This work reveals the need for enforcing adequate effluent treatment before their discharge to reduce health hazards.

1. INTRODUCTION

Earth is a live planet because of certain unique ingredients from which water has been considered as the most important and vital resource for the upbringing of the biological sphere as well as human civilization. Along with the progress of our civilization, this resource has begun being polluted and its quality started depleting to numerous reasons like the onset of industries, runoff from urban areas, domestic wastes, urban and rural garbage. During the past few decades, Indian industries have registered a quantum jump, which has contributed to high economic growth but simultaneously it has also given rise to a threat on the environment[1]. Effluent from manufacturing plants contain a wide variety of organic pollutants, depends on such type of industrial sources. Most factories dispose of their effluents untreated. It is observed that one-third of the overall water pollution comes in the form of discharge of effluent, solid waste and other hazardous waste. Such industrial effluents have a detrimental impact on the quality of water, habitat quality and intricate effects on flowing waters.

2. MATERIAL AND METHODS

The selected research area Gwalior is a historical and major city of Madhya Pradesh in India. Gwalior has a subtropical climate typically temperate and severely cold for short period. The average rain is about 850 mm per year. The extreme variation in climatic conditions significantly affects resident efficiency and attitude. Gwalior city is surrounded by various industrial zones. Although a part of the Bhind and Morena district, Malanpur-Ghirongi and Banmore are essentially Gwalior suburbs. The industrial areas have attracted more than one thousand manufacturing units viz. Mondelez India Food (P) Ltd., Godrej Consumer Products Ltd, Sun Pharma, SRF Ltd., Lapinus Rockwool Ltd., Marval Vinyl Ltd., Sparkle metal finishing Pvt. Ltd., Sterling Agro Industries Ltd, VRS Foods Ltd., Teva API India Ltd, Uflex Industries Ltd, Rail Spring Karkhana, Unipatch Rubber Ltd., J.B. Mangaram Foods Ltd., JK Industries Ltd., Gwalior Dugdh Sangh Ltd., I R S Metals Pvt. Ltd., Jepika Chemical Pvt. Ltd., Vijay Paints, Midas Chemical Pvt. Ltd. etc[2-4]. The activities of these industries regularly add stress to the environment by generating traditional pollutants such as organic & inorganic substances, particulates as well as newly recognized pollutants[5].

For the betterment of mankind in and around the industrial area of Gwalior city, industrial effluent samples were collected monthly over a period of three years from five different prime and marked locations in nearby industrial areas of Gwalior. The samples collected in cleaned polyethene bottles were labelled as S_1, S_2, S_3, S_4 and S_5, then preserved and further analyzed as per standard testing procedures [6-7]. All the chemical reagents used in the study were of analytical grade and instruments were calibrated. The pH of samples was recorded by SYSTONIC S-901 pH meter while Electrical conductivity of the diluted samples was measured by using SYSTONIC S-941 EC-TDS meter and gravimetrically also. Total dissolve solids, Sulphates and Oil & Grease were determined gravimetrically. Total alkalinity, Total Hardness, Total chlorides, BOD and COD were estimated by titrimetric method. Nitrates and Phosphates were measured by colorimetric method by using SYS-105 Spectrophotometer. Heavy metals like Fe, Ni, Pb, Cr, Cu, Mn, Zn and Cd were analyzed quantitatively by using Perkin-Elmer 3030A Atomic Absorption Spectrophotometer and some metals (Fe, Mn, Cr, and Cu) were also analyzed by SYS-105 spectrophotometer at a particular wavelength[6-8].

3. RESULTS AND DISCUSSION

The results obtained of some physicochemical parameters of collected samples have shown variations (Mean ± S.D.) as represented in Table-1 and quality of these effluent samples has been assessed by comparing with the permissible limit for discharge into inland surface water, according to effluent discharge guideline, given by BIS[9]. It is obvious that pH, EC, TDS, TA, TH, TC, Sulphates, Ni, Cu, Mn and Cd of all samples were within the permissible limits, whereas the concentration of Nitrates and O&G were beyond the BIS permissible limit in S_1 and S_4. BOD and COD of all samples were above the prescribed limit. The concentration of Fe and Zn in S_3 were beyond the BIS reference limits. However, Fe content was much higher in S_2 than allowable limit of BIS.

The results of **Pearson correlation** statistical analysis (at < 0.05) illustrated (Table-2 to 6) a strong positive correlation between TDS with EC for all samples. The TA of effluent S_1 was strongly positively correlated with TH and BOD. Statistically, a strong positive correlation of TC noticed with EC and TDS in S_1 and S_5. BOD of effluent S_3 and S_4 were strongly positively correlated with Zn. **One-way ANOVA test** revealed statistically significant differences among the effluent samples of all sites and not obtained by chance. ANOVA analysis also confirmed that observed differences in concentrations of various physicochemical parameters of an effluent sample among the years are significant and not obtained by chance.

During the tenure of our research work, we observe that Industrial effluent taken as samples, S_1, S_3 and S_4 appear more hazardous in pollutant load, and the quantity of contaminants in all samples is increasing day by day which is a matter of concern as these industrial units are not strictly following the prescribed standards for water treatment. It is common that the industrial effluent released directly from manufacturing units in water bodies through runnels and also in the open or agricultural land without any prior treatment. These untreated effluents contaminate soil by accumulating various toxic substances in it and groundwater by percolating through soil bed. Once pollutants enter into soil, the concentration of toxic chemicals increases with time, which further transfer in plants and human beings via the food chain, especially heavy metals are the important contaminants that can be found in tissues, the surface of fresh fruits, vegetables and also water creature. Prolonged consumption of such contaminated food that has an unsafe concentration of heavy metals, may lead to the disruption of numerous biochemical and biological processes in the human body[10].

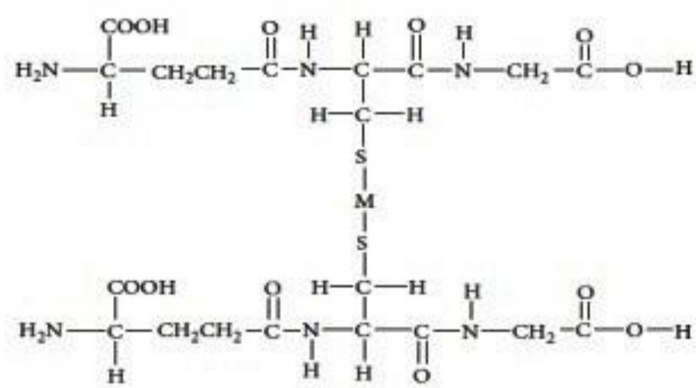

Figure No.1 Reaction of metal with glutathione (Metal-Glutathione Complex)[11].

The above figure shows the reaction of heavy metal (M) with glutathione (GSH), an important antioxidant in the body. Here, the metal replaces H atoms from SH groups on two adjacent glutathione molecules[11-12]. The engagement of the two glutathione molecules in the formation of a strong bond with the metal deactivates them for further reactions:

$$2\,GSH + M^{2+} \longrightarrow M\,(GSH)_2 + 2H^{+}$$

Therefore, samples need treatment to minimize the concentration of pollutants because these metals percolate through soil layers and contaminate groundwater.

4. CONCLUSIONS-

The activities of industries situated nearby Gwalior, add stress to the environment by generating traditional pollutants such as organic & inorganic substances, particulates as well as newly recognized pollutants. The industrial effluents have a very complex and toxic composition depending on the type of product produce. Despite this, similar industries produce highly variable wastewater composition when specific production methods are employed. Industrial effluent S_1 and S_4 appear more promising in pollutant load concerns, and the quantity of contaminants in all samples is increasing day by day which is a matter of concern. Especially nitrates, BOD, COD, O&G and Heavy metals (Fe, Pb, Zn, Cd) are drawing the attention of environmental activists. Various manufacturing industries such as Pharmaceuticals, Paint & Varnish, Diary and Food products, Soap & Detergents, Polymer industry located in research area release their inefficiently treated effluents openly which contaminate water bodies directly or after percolating through soil layers and increase serious health problems in mankind like gastrointestinal irritation, calcification of arteries, indigestion, abdominal pain, liver damage, skin ailments etc. Therefore, there is an urgent need to sustain efficiency of effluent treatment plants established in manufacturing units.

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Table No. 1: Physicochemical characterization (Mean ± S.D.) of effluent samples collected from Selected and different industrial sites of Gwalior during a study period (1-36 Months).

*EQPs	S_1	S_2	S_3	S_4	S_5	BIS
pH	7.151 ± 1.088	6.943±0.772	6.798±0.944	6.595±0.924	6.954±0.537	**5.5 – 9.0**
EC	1951.47±288.156	1479.28±264.733	1158.42±164.052	1845.72±193.791	1851±178.374	**3000 µS/cm**
TDS	1075.22±161.514	806.056±142.553	628.222±88.921	1016.33±109.007	1017.92±101.346	**2100 mg/L**
TA	110±29.476	68.861±16.215	188.917±20.056	100.972±31.169	203.611±30.871	**600 mg/L**
TH	211.25±67.148	176.472±42.921	108.861±30.916	199.972±57.773	208.361±14.444	**1000 mg/L**
TC	475.25±97.066	323.722±82.094	66.778±9.949	418.972±70.964	429.556±85.412	**1000 mg/L**
NO_3^-	31.434±5.29	4.796±2.125	8.769±2.238	29.839±3.69	11.905±1.917	**10 mg/L**
PO_4^{3-}	2.255±0.53	5.242±1.926	1.969±0.941	2.496±0.698	4.634±0.942	**5.0 mg/L**
SO_4^{2-}	242.194±71.174	228.167±69.43	231.389±74.44	255.167±55.276	156.117±17.066	**1000 mg/L**
BOD	49.639±30.17	177.389±42.088	141.917±53.458	49.389±31.618	160.222±13.2	**30 mg/L**
COD	258.278±56.275	497.333±88.709	462.5±209.102	260.25±65.524	422.278±25.066	**250 mg/L**
O&G	10.647±2.222	6.284±1.085	5.158±1.265	10.674±1.351	4.942±0.95	**10 mg/L**
Fe	2.764±2.777	3.973±2.446	5.261±1.294	2.208±2.991	0.41±0.0789	**3.0 mg/L**
Ni	0.0136±0.0118	0.0358±0.037	0.0164±0.0153	0.0242±0.0309	0.0347±0.0202	**3.0 mg/L**
Pb	0.171±0.121	0.0731±0.0566	0.0253±0.0163	0.163±0.0774	0.0338±0.0252	**0.1 mg/L**
Cr	0.0541±0.0476	0.0806±0.0661	3.006±0.822	0.0553±0.0458	0.0119±0.00907	**2.0 mg/L**
Cu	0.0923±0.0519	0.146±0.0783	1.299±0.19	0.0917±0.0529	0.0225±0.00951	**3.0 mg/L**
Mn	0.154±0.0778	0.0344±0.0466	0.0178±0.0151	0.12±0.0567	0.165±0.0338	**2.0 mg/L**
Zn	1.596±1.223	1.61±1.375	6.54±3.006	1.698±1.402	0.281±0.0726	**5.0 mg/L**
Cd	0.0656±0.044	0.0858±0.0805	0.958±0.274	0.0394±0.0406	0.0547±0.0802	***2.0 mg/L***

* All the values are in mg/L except pH and EC. EC is in µS/cm.

Table No. 2: Correlation matrix of industrial effluent sample (S_1) showing Pearson's correlation coefficient between physicochemical parameters.

EQPs	pH	EC	TDS	TA	TH	TC	NO_3^-	PO_4^{3-}	SO_4^{2-}	BOD	COD	O&G	Fe	Ni	Pb	Cr	Cu	Mn	Zn	Cd
pH	1.000																			
EC	0.499*	1.000																		
TDS	0.487*	0.988*	1.000																	
TA	0.985*	0.506*	0.488*	1.000																
TH	0.372*	0.524*	0.572*	0.341*	1.000															
TC	0.550*	0.722*	0.686*	0.548*	0.158	1.000														
NO_3^-	-0.262	0.191	0.201	-0.209	0.306	-0.202	1.000													
PO_4^{3-}	0.161	0.640*	0.645*	0.158	0.253	0.454*	0.221	1.000												
SO_4^{2-}	-0.214	0.337*	0.338*	-0.222	0.240	-0.119	0.446*	0.403*	1.000											
BOD	-0.031	0.318	0.369*	-0.034	0.699*	-0.045	0.324*	0.043	0.034	1.000										
COD	-0.174	0.360*	0.411*	-0.177	0.637*	0.053	0.382*	0.163	0.220	0.819*	1.000									
O&G	-0.121	0.210	0.206	-0.173	-0.002	0.158	0.007	0.278	0.260	-0.061	0.234	1.000								
Fe	-0.503*	-0.158	-0.142	-0.524*	0.205	-0.442*	0.327*	0.030	0.385*	0.333*	0.300	-0.003	1.000							
Ni	0.073	-0.120	-0.100	0.065	0.079	0.119	-0.09	-0.038	-0.179	-0.080	0.057	0.086	-0.137	1.000						
Pb	-0.095	0.081	0.061	-0.084	-0.129	0.046	0.089	-0.149	-0.244	0.087	0.015	-0.079	-0.125	-0.035	1.000					
Cr	0.016	0.018	0.016	0.073	-0.010	0.067	0.120	0.009	-0.125	-0.032	0.044	-0.003	0.043	-0.065	0.093	1.000				
Cu	-0.167	-0.074	-0.060	-0.141	-0.149	-0.110	0.332*	-0.052	0.029	0.014	-0.061	-0.461*	0.078	-0.040	0.160	0.172	1.000			
Mn	-0.215	-0.106	-0.166	-0.194	-0.025	-0.180	0.267	-0.240	0.079	0.117	0.012	-0.150	0.253	0.064	0.193	-0.144	-0.005	1.000		
Zn	-0.348*	-0.173	-0.193	-0.275	-0.259	-0.229	0.273	-0.307	-0.167	0.232	0.145	-0.103	0.072	-0.237	0.253	0.415*	0.341*	0.275	1.000	
Cd	-0.022	-0.082	-0.099	-0.081	-0.088	-0.077	-0.135	-0.067	0.159	-0.071	-0.056	0.015	0.260	0.143	-0.209	-0.359*	0.031	-0.001	-0.411*	1.000

* Correlation is significant at the 0.05 level (2-tailed)

Table No. 3: Correlation matrix of industrial effluent sample (S_2) showing Pearson's correlation coefficient between physicochemical parameters.

EQPs	pH	EC	TDS	TA	TH	TC	NO_3^-	PO_4^{3-}	SO_4^{2-}	BOD	COD	O&G	Fe	Ni	Pb	Cr	Cu	Mn	Zn	Cd
pH	1.000																			
EC	0.176	1.000																		
TDS	0.122	0.962*	1.000																	
TA	0.914*	0.285	0.248	1.000																
TH	0.495*	0.412*	0.395*	0.592*	1.000															
TC	-0.495*	0.301	0.376*	-0.308	-0.106	1.000														
NO_3^-	-0.615*	0.211	0.276	-0.449*	-0.096	0.857*	1.000													
PO_4^{3-}	-0.603*	0.209	0.264	-0.427*	-0.128	0.857*	0.907*	1.000												
SO_4^{2-}	-0.304	0.255	0.306	-0.119	0.152	0.868*	0.833*	0.859*	1.000											
BOD	-0.537*	0.237	0.313	-0.380*	-0.130	0.885*	0.861*	0.874*	0.806*	1.000										
COD	-0.488*	0.272	0.355*	-0.288	-0.011	0.819*	0.819*	0.833*	0.810*	0.941*	1.000									
O&G	-0.317	0.359*	0.425*	-0.151	-0.039	0.768*	0.722*	0.676*	0.753*	0.810*	0.802*	1.000								
Fe	-0.336*	0.179	0.224	-0.115	0.079	0.407*	0.523*	0.474*	0.439*	0.390*	0.393*	0.430*	1.000							
Ni	-0.140	0.271	0.344*	-0.005	-0.033	0.516*	0.538*	0.439*	0.482*	0.402*	0.322	0.520*	0.346*	1.000						
Pb	-0.483*	0.133	0.190	-0.340*	-0.091	0.648*	0.783*	0.800*	0.681*	0.634*	0.607*	0.530*	0.523*	0.569*	1.000					
Cr	-0.306	0.0768	0.191	-0.210	0.030	0.444*	0.596*	0.514*	0.423*	0.449*	0.381*	0.379*	0.434*	0.631*	0.636*	1.000				
Cu	-0.393*	0.061	0.124	-0.262	-0.214	0.598*	0.721*	0.614*	0.615*	0.565*	0.552*	0.661*	0.473*	0.512*	0.541*	0.506*	1.000			
Mn	0.264	0.308	0.333*	0.413*	0.647*	0.181	0.103	0.089	0.350*	0.125	0.237	0.311	0.195	0.116	0.014	0.002	-0.003	1.000		
Zn	-0.210	0.231	0.255	0.080	0.294	0.302	0.316	0.291	0.332*	0.289	0.354*	0.358*	0.836*	0.118	0.272	0.160	0.229	0.358*	1.000	
Cd	-0.055	-0.013	0.032	-0.009	0.122	0.358*	0.403*	0.355*	0.413*	0.189	0.171	0.156	0.268	0.241	0.466*	0.426*	0.296	0.406*	0.035	1.000

* Correlation is significant at the 0.05 level (2-tailed)

Table No. 4: Correlation matrix of industrial effluent sample (S_3) showing Pearson's correlation coefficient between physicochemical parameters.

EQPs	pH	EC	TDS	TA	TH	TC	NO_3^-	PO_4^{3-}	SO_4^{2-}	BOD	COD	O&G	Fe	Ni	Pb	Cr	Cu	Mn	Zn	Cd
pH	1.000																			
EC	0.286	1.000																		
TDS	0.282	0.970*	1.000																	
TA	0.905*	0.287	0.258	1.000																
TH	0.352*	0.577*	0.636*	0.287	1.000															
TC	0.307	0.630*	0.578*	0.341*	0.346*	1.000														
NO_3^-	0.098	0.817*	0.842*	0.113	0.533*	0.481*	1.000													
PO_4^{3-}	-0.158	0.540*	0.573*	-0.099	0.243	0.372*	0.442*	1.000												
SO_4^{2-}	-0.225	0.563*	0.620*	-0.232	0.190	0.173	0.567*	0.756*	1.000											
BOD	0.053	0.822*	0.806*	0.130	0.358*	0.685*	0.744*	0.743*	0.612*	1.000										
COD	0.019	0.810*	0.811*	0.076	0.408*	0.614*	0.866*	0.639*	0.585*	0.885*	1.000									
O&G	0.122	0.601*	0.534*	0.186	0.159	0.740*	0.470*	0.540*	0.376*	0.768*	0.702*	1.000								
Fe	-0.019	0.571*	0.537*	-0.012	0.101	0.683*	0.498*	0.500*	0.475*	0.753*	0.711*	0.895*	1.000							
Ni	-0.330*	0.097	0.102	-0.265	-0.263	-0.107	0.211	0.300	0.477*	0.214	0.278	0.203	0.196	1.000						
Pb	-0.243	-0.038	-0.117	-0.222	-0.169	0.043	-0.057	0.142	-0.011	0.115	0.128	0.273	0.192	-0.013	1.000					
Cr	-0.275	0.292	0.297	-0.285	0.039	0.229	0.445*	0.550*	0.528*	0.585*	0.566*	0.559*	0.550*	0.376*	0.282	1.000				
Cu	-0.183	0.247	0.256	-0.177	-0.011	0.229	0.327*	0.402*	0.471*	0.442*	0.401*	0.566*	0.489*	0.378*	0.234	0.625*	1.000			
Mn	0.017	0.352*	0.359*	0.031	0.028	0.082	0.426*	0.296	0.474*	0.410*	0.370*	0.393*	0.384*	0.506*	0.061	0.506*	0.454*	1.000		
Zn	-0.250	0.551*	0.580*	-0.214	0.088	0.305	0.591*	0.776*	0.852*	0.723*	0.688*	0.547*	0.616*	0.457*	0.073	0.611*	0.637*	0.477*	1.000	
Cd	-0.291	0.424*	0.473*	-0.300	0.108	0.066	0.410*	0.750*	0.818*	0.562*	0.566*	0.374*	0.458*	0.350*	0.152	0.572*	0.435*	0.328*	0.770*	1.000

* Correlation is significant at the 0.05 level (2-tailed)

Table No. 5: Correlation matrix of industrial effluent sample (S_4) showing Pearson's correlation coefficient between physicochemical parameters.

EQPs	pH	EC	TDS	TA	TH	TC	NO_3^-	PO_4^{3-}	SO_4^{2-}	BOD	COD	O&G	Fe	Ni	Pb	Cr	Cu	Mn	Zn	Cd
pH	1.000																			
EC	0.266	1.000																		
TDS	0.206	0.922*	1.000																	
TA	0.800*	0.419*	0.369*	1.000																
TH	0.170	0.404*	0.391*	0.391*	1.000															
TC	0.275	0.409*	0.417*	0.095	-0.221	1.000														
NO_3^-	-0.235	0.474*	0.444*	-0.056	-0.013	-0.018	1.000													
PO_4^{3-}	-0.200	0.660*	0.698*	0.024	0.058	0.075	0.769*	1.000												
SO_4^{2-}	-0.273	0.486	0.503*	-0.122	-0.108	0.149	0.827*	0.785*	1.000											
BOD	-0.173	0.527*	0.547*	0.069	0.099	-0.137	0.747*	0.769*	0.729*	1.000										
COD	-0.162	0.483*	0.493*	0.087	0.121	-0.104	0.678*	0.795*	0.812*	0.856*	1.000									
O&G	-0.241	0.365*	0.394*	0.001	0.080	0.111	0.636*	0.556*	0.757*	0.619*	0.458*	1.000								
Fe	-0.456*	0.432*	0.442*	-0.205	0.061	0.057	0.642*	0.702*	0.709*	0.674*	0.914*	0.755*	1.000							
Ni	-0.129	0.357	0.269	0.166	0.055	-0.043	0.292	0.397*	0.261	0.434*	0.547*	0.255	0.537*	1.000						
Pb	-0.283	0.258	0.297	-0.162	0.024	0.040	0.630*	0.447*	0.750*	0.454*	0.286	0.726*	0.594*	0.035	1.000					
Cr	-0.235	0.275	0.266	-0.136	0.040	0.042	0.670*	0.493*	0.742*	0.587*	0.333	0.686*	0.605*	0.201	0.713*	1.000				
Cu	-0.319	0.147	0.160	-0.253	-0.058	0.062	0.467*	0.431*	0.651*	0.342*	0.153	0.612*	0.551*	-0.070	0.675*	0.642*	1.000			
Mn	-0.427*	0.301	0.310	-0.142	0.129	-0.270	0.700*	0.606*	0.699*	0.626*	0.721*	0.676*	0.655*	0.233	0.660*	0.715*	0.574*	1.000		
Zn	0.033	0.576*	0.614*	0.280	0.261	0.125	0.436*	0.664*	0.481*	0.540*	0.784*	0.375*	0.588*	0.709*	0.284	0.212	0.210	0.363*	1.000	
Cd	-0.188	0.345	0.349	0.049	0.240	-0.215	0.435*	0.514*	0.585*	0.631*	0.353	0.569*	0.506*	0.298	0.554*	0.276	0.278	0.456*	0.500*	1.000

* Correlation is significant at the 0.05 level (2-tailed)

Table No. 6: Correlation matrix of industrial effluent sample (S_4) showing Pearson's correlation coefficient between physicochemical parameters.

EQPs	pH	EC	TDS	TA	TH	TC	NO_3^-	PO_4^{3-}	SO_4^{2-}	BOD	COD	O&G	Fe	Ni	Pb	Cr	Cu	Mn	Zn	Cd
pH	1.000																			
EC	0.408*	1.000																		
TDS	0.422*	0.937*	1.000																	
TA	0.898*	0.414*	0.458*	1.000																
TH	-0.340*	0.384*	0.352*	-0.283	1.000															
TC	-0.300	0.394*	0.401*	-0.274	0.725*	1.000														
NO_3^-	0.051	0.562*	0.543*	0.058	0.672*	0.603*	1.000													
PO_4^{3-}	-0.349*	0.431*	0.401*	-0.305	0.625*	0.692*	0.645*	1.000												
SO_4^{2-}	-0.353*	0.372*	0.330*	-0.300	0.987*	0.720*	0.681*	0.655*	1.000											
BOD	-0.197	0.454*	0.411*	-0.242	0.592*	0.491*	0.631*	0.601*	0.588*	1.000										
COD	-0.030	0.513*	0.458*	-0.034	0.449*	0.465*	0.613*	0.728*	0.469*	0.665*	1.000									
O&G	-0.384*	0.375*	0.358*	-0.337*	0.660*	0.780*	0.612*	0.800*	0.686*	0.534*	0.627*	1.000								
Fe	0.120	0.470*	0.498*	0.162	0.204	0.050	0.417*	0.280	0.176	0.542*	0.604*	0.242	1.000							
Ni	0.406*	0.163	0.116	0.278	-0.204	-0.271	-0.159	-0.144	-0.183	-0.229	-0.139	-0.340*	0.200	1.000						
Pb	0.185	-0.128	-0.179	0.162	-0.365*	-0.195	-0.353*	-0.384*	-0.348*	-0.466*	-0.435*	-0.460*	-0.486*	0.316	1.000					
Cr	0.046	-0.347*	-0.398*	-0.008	-0.135	-0.299	-0.124	-0.204	-0.078	-0.343*	-0.369*	-0.314	-0.465	0.302	0.399*	1.000				
Cu	0.132	0.253	0.242	0.102	0.118	-0.065	0.154	0.070	0.104	-0.035	0.069	-0.072	0.297	0.068	0.102	0.123	1.000			
Mn	-0.430*	0.161	0.230	-0.398*	0.129	0.423*	-0.046	0.278	0.108	0.217	0.166	0.446*	0.096	-0.289	-0.281	-0.578*	-0.141	1.000		
Zn	-0.192	0.161	0.143	-0.283	0.116	0.212	0.225	0.226	0.113	0.311	0.456*	0.303	0.438*	-0.090	-0.159	-0.424*	0.010	0.303	1.000	
Cd	0.276	0.073	-0.028	0.282	-0.139	-0.267	-0.121	-0.143	-0.080	-0.227	-0.104	-0.299	-0.235	0.420*	0.301	0.535*	0.091	-0.301	-0.251	1.000

* Correlation is significant at the 0.05 level (2-tailed)