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Water Quality of Pong Reservoir-A Ramsar site

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ABSTRACT

The present investigation was carried out for the assessment of the water quality of the Pong reservoir constructed on river Beas in Talwara, India. Water samples were collected for two years to study temporal variations in water quality parameters during different seasons. Most water quality parameters were within permissible limits according to BIS/WHO/CCME standards. A slight increase in the concentration of heavy metals like Cu, Mn, Pb, and Cd was observed. The correlation coefficient (r) of these parameters ranged from ±0.76 to 1.0. Obtained values were subjected to regression analysis suggesting a significant linear relationship between the observed physico-chemical parameters.

***Key words*:** Beas; heavy metals; Pong Reservoir; temporal variations; India

1) INTRODUCTION

Rivers are complex systems of flowing water draining specific land surfaces that are defined as river basins or watersheds [8]. These systems are modified naturally or artificially, and a reservoir is one of the most important such modifications made to a river structure. Reservoirs not only regulate flow regime of a river but also play important role in fish production. Therefore, water quality of a reservoir is of equally importance as that of river. Both, natural factors and anthropogenic activities contribute to deterioration of water quality. Pong reservoir is constructed over river Beas. It is one of the largest man-made reservoirs in India. Primarily the reservoir was constructed for hydroelectric power generation, flood control and irrigation purpose. To increase economic value of the reservoir major and minor carps were introduced that has led to rise in the production of fishes to many folds. The reservoir has transformed to home for large number of birds and thus, known as bird sanctuary also. Tourism and fish diversity has been providing livelihood to locals and thus, anthropogenic activities by locals and tourists have been significantly increased from last few decads which in turn affecting water quality of the reservoir. Therefore, present study is aimed at assessment of water quality parameters and its seasonal variations in Pong reservoir. Results indicate ecological health status of the reservoir and shall form the baseline for its future management strategies.

2) MATERIALS AND METHODS

Pong reservoir (31°58′17′′N 75°56′48′′E) also known as Maharana Pratap Sagar Dam was constructed in 1975 on river Beas (*one of the five major rivers of the Indus basin*) as it enters in plains at Talwara. It was declared a Ramsar site in November 2002. The characteristic features of the Dam are given as shown in table 1.

Table 1: Characteristics features of Pong Reservoir (Dam)

Height	133 m
Length	1,951 m
Elevation	435.86 m
Volume	35,500,000 m^3
Total capacity	8,570,000,000 m^3
Catchment area	12,560 km^2
Surface area	260 km^2



Figure 1: Pong reservoir (Google earth map 2021)

Sampling was done in selected seasons i.e., spring,

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summer, rains and winter for two years. Grab water samples were collected in polyethylene bottles and were immediately preserved following standard protocols as given in APHA/AWWA/WEF [1]. For Total Nitrogen (∑N), Total Phosphate (∑P) and Potassium (K), water samples were collected in amber bottles whereas for heavy metals, samples were digested with nitric acid during storage. Bottles containing samples were stored in insulated coolers containing cool packs at 4°C and were brought to laboratory and placed in refrigerator until further processing and analysis was done. 25 water quality parameters were analyzed by following different methods. Dissolved Oxygen (DO), Electrical Conductivity (EC), pH and water temperature were analyzed on site using HACH DR1900 portable water analyzer kit. Biochemical Oxygen Demand (BOD) was calculated using oxytop bottles. Alkalinity (AK), Acidity (AD), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Free Carbon Dioxide (CO_2) and Chlorides (Cl) were measured by titration method as given by Trivedy and Goel [24]. Turbidity was measured with the help of Turbiquant 1100 IR. Total Solids (TS), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) were analyzed using standard methods as recommended in manual of APHA/AWWA/WEF [1]. Chemical Oxygen

Table 2: Water quality characteristics of Pong Reservoir.

Sr. No.	Variable	Mean±S.E.	Min. Conc.	Season	Max. Conc.	Season	PL (BIS*)	MPL
1	DO	8.93±0.59	7.55	summer	10.05	winter	-	-
2	EC	221.0±32.7	178.1	rains	318.1	winter	-	-
3	pH	7.24±0.14	7.54	spring	6.9	winter	6.5	8.5
4	TD	2.33± 1.26	0.59	summer	6.05	rainy	-	-
5	WT	21.35±2.77	14.10	summer	25.75	winter	-	-
6	AK	91.6±15.0	47.5	rains	115	spring	200	600
7	CO_2	9.11±2.21	5.50	summer	14.67	spring	-	-
8	TH	75.46±2.77	68.87	rains	82	summer	300	600
9	Ca	24.53±2.96	17.10	rains	31.5	summer	75	200
10	Mg	5.10±0.55	3.98	winter	6.61	rains	30	-
11	TDS	88.0±15.7	56.65	rains	128.08	winter	500	2000
12	COD	65.13±9.26	46.67	summer	83.83	winter	-	-
13	BOD	4.96±3.12	0.00	winter	13.83	summer	-	-
14	ΣN	5.04±0.56	3.50	spring	6.0	rainy	-	-
15	ΣP	0.13±0.031	0.05	spring	0.19	winter	-	-
16	K	8.3±4.42	3.58	rains	21.52	winter	-	-
17	SO_4	23.65±2.34	20.0	winter	30.0	summer	200	400
18	Cd	3.78±3.58	0.05	spring	1.45	summer	0.01	-
19	Pb	0.28±0.07	0.15	spring	0.47	winter	0.05	-
20	Ni	0.20±0.02	0.15	summer	0.21	rainy	0.02	-
21	Mn	0.29±0.02	0.25	spring	0.36	summer	0.1	0.3
22	Cu	0.09±0.01	0.06	winter	0.11	spring	0.05	-
23	Cr	0.05±0.02	0.02	rains	0.11	winter	0.05	-
24	Fe(III)	0.13±0.07	0.04	winter	0.36	summer	0.3	-
25	NO_3^-	1.48±0.50	0.46	winter	2.83	summer	-	-

S.E. (Standard error); BIS (Bureau of Indian Standards); PL- Permissible Limit; MPL- Maximum Permissible Limit. All parameters were measured in mg/L except WT-°C (Water temperature) pH- pH and EC- µS/cm. Min. conc. (minimum concentration); Max. conc. (maximum concentration). DO (Dissolved oxygen); TD (Turbidity); AK (Alkalinity); CO_2 (Carbon dioxide); TH (Total hardness); Ca (Calcium), Mg (Magnesium), TDS (Total Dissolved Solid); COD (Chemical Oxygen Demand); BOD (Biological Oxygen Demand); ∑N (Total Nitrogen); ∑P (Total Phosphate); K (Potassium); SO_4 (Sulphate); Cd (Cadmium); Pb (Lead); Ni (Nickel), Mn (Manganese); Cu (Copper); Cr (Chromate); Fe(III) (Iron); NO3(Nitrate)

Demand (COD) and heavy metals such as Total Nitrogen (ΣN), Total Phosphate (ΣP), Potassium (K), Sulphate (SO_4), Cadmium (Cd), Lead (Pb), Nickle (Ni), Manganese (Mn), Copper (Cu), Chromate (Cr), Iron (Fe(III)) and NO_3^- were analyzed using Merck cell test kits on UV/VIS spectrophotometer (Spectroquant® Pharo 300).

All the physicochemical parameters were subjected to regression model to ascertain correlation among various parameters. For this Karl Pearson coefficient was applied to various water quality parameters. Further F-test was applied on results of regression analysis for verification of the significance for 0.1%, 0.05% and 0.01% level of significance.

3) RESULTS AND DISCUSSION

Range of physico–chemical parameters (i.e. minimum and maximum values) with mean±S.E is given in Table 2.

Temporal variations in various parameters were evaluated through correlation matrix. Nature of relationship between various water quality parameters was determined by plotting concentrations of dependent variable against independent variables (as shown in Figures 2-4). All parameters were formulated for regression equations by using Pearson's correlation coefficient (r). This measures the degree of association between dependent and independent variables. Maximum correlation was shown by EC (with pH, WT, TDS, K, Pb and Cr) and pH (with TDS, ΣN, ΣP, K, Pb, Cu and Cr) and thus establishes the fact that these are important in water quality assessment.

Water quality and its various parameters have huge importance for the biological communities and are

Table 3: Linear regression model among significantly correlated parameters of Pong reservoir

Y	X	r	F value	Y	X	r	F value
DO	AK	0.801	0.002 N.S.	**Mg**	TDS	-0.865	0.001 N.S.
	Mg	-0.870	0.005 N.S.	**TDS**	K	0.864	12.578 L.S.
	COD	0.920	0.004 N.S.		Pb	0.830	52130.5 H.S.
EC	pH	-0.851	56252 H.S.	**COD**	SO_4	-0.895	15.637 L.S.
	WT	-0.808	139.5 H.S.	**BOD**	N	-0.891	31.632 H.S.
	TDS	0.917	4.348 N.S.	**∑N**	Ni	-0.841	960.891 H.S.
	K	0.995	54.69 H.S.		Mn	0.759	575.35 H.S.
	Pb	0.940	226664.4 H.S.	**∑P**	Pb	0.860	0.209 N.S.
pH	TDS	-0.870	0.000 N.S.		Cu	-0.988	8.143 L.S.
	∑N	-0.841	0.062 N.S.	**K**	Pb	0.941	4144.62 H.S.
	∑P	-0.779	19.25 H.S.		Cu	-0.771	161243.8 H.S.
	K	-0.815	0.001 N.S.	**SO_4**	Cd	0.938	0.429 N.S.
	Pb	-0.939	4.029 N.S.		Ni	-0.849	17152.69 H.S.
	Cu	0.777	156.76 H.S.		Mn	0.943	10270.39 H.S.
TD	AK	-0.930	0.007 N.S.		Fe(III)	0.958	937.81 H.S.
	CO_2	0.812	0.326 N.S.	**Cd**	Ni	-0.925	40009.4 H.S.
	TH	-0.861	0.207 N.S.		Mn	0.966	23956.21 H.S.
	Ca	-0.868	0.182 N.S.		Fe(III)	0.998	2187.495 H.S.
	Mg	0.893	5.24 N.S.	**Pb**	Cu	-0.897	38.904 H.S.
WT	P	-0.904	7759.89 H.S.	**Ni**	Mn	-0.977	0.599 N.S.
	K	-0.863	0.392 N.S.		Fe(III)	-0.910	0.055 N.S.
	Pb	-0.892	1624.28 H.S.	**Mn**	Fe(III)	0.965	0.091 N.S.
	Cu	0.959	63191.73 H.S.	**Cu**	Cr	-0.858	0.322 N.S.
AK	CO_2	-0.884	46.32 H.S.	**Cr**	EC	0.976	0.000 N.S.
	TH	0.782	29.4 H.S.		pH	-0.899	0.020 N.S.
	Ca	0.814	25.84 H.S.		WT	-0.894	0.000 N.S.
	Mg	-0.866	744.93 H.S.		TDS	0.855	0.000 N.S.
CO_2	TH	-0.917	0.635 N.S.		∑P	0.800	0.381 N.S.
	Ca	-0.942	0.558 N.S.		K	0.980	0.000 N.S.
	∑P	0.762	4943.82 N.S.		Pb	0.990	0.080 N.S.
TH	Ca	0.998	0.878 N.S.		Cu	-0.858	3.107 N.S.
	Cd	0.770	0.600 N.S.	**NO_3^-**	WT	0.763	0.032 N.S.
Ca	TD	-0.868	5.502 N.S.		COD	-0.833	0.003 N.S.
	AK	0.814	0.039 N.S.		SO_4	0.953	0.045 N.S.
	CO_2	-0.942	1.793 N.S.		Cd	0.917	0.019 N.S.
	TH	0.998	1.139 N.S.		Ni	-0.723	766.79 N.S.
					Mn	0.844	459.13 N.S.

Y (Independent variable); X (Dependent variable); r (Karl Pearson's correlation values significant at 0.05 level); H.S (highly significant); L.S. (Least Significant); N.S. (Not Significant).

interlinked with each other also. Dissolved oxygen is crucial parameter for growth, behavior and physiology of aquatic organisms [3]. Minimum concentration of DO required for functioning and survival of biological communities is 5 mg/L. Stone and Thomforde [23] recommended that range of Electrical conductivity (EC) for aquatic fauna especially for fish is 100-2000 $\mu S/cm^{-1}$. pH maintains balance in an ecosystem when it ranges between 5.5-8.5. Permissible range for alkalinity is 200-600. Bureau of Indian Standards [4] recommended limits for Total hardness, Calcium, Magnesium and Total dissolved solids ranges are 300-600 mg/L, 75-200 mg/L, 30 mg/L, 500-2000 mg/L respectively. Chemical Oxygen Demand (COD) is a reliable measure for judging the extent of pollution in water as it is the measure of oxygen equivalent to the organic matter content of water susceptible to oxidation (Garg 2010). Permissible limit for COD is 250 mg/L [8]. According to World Health Organization [27] maximum permissible limit for phosphate is 10 mg/L. For drinking water prescribed range for SO_4 is 200-400 mg/L. Permissible limits for heavy metals as prescribed by BIS [4] are: Cd (0.01 mg/L), Pb (0.05 mg/L), Ni (0.02 mg/L), Mn (0.1 mg/L), Cu (0.05 mg/L), Cr (0.05 mg/L) and Fe (III) (0.3 mg/L). Maximum limit of NO^{-}_{3} for aquatic fauna should not exceed 10 mg/L [7].

Statistical analysis of selected water quality parameters is given as in table 2. Average value recorded for DO is 8.93±0.59 mg/L. Low concentrations may adversely affect the aquatic fauna and below 2 mg/L may lead to fish mortality [18]. Similar trend to our study and the inverse relationship between temperature and DO is also suggested by Shreshtha and Kazama [21] that warmer water becomes more easily saturated with oxygen and therefore holds less dissolved oxygen. The average value of EC for different seasons was calculated as 221.0±32.7$\mu S/cm^{-1}$. Freshwater limit for Electrical conductivity ranges from 10 to 1000 $\mu S/cm^{-1}$ that may be higher in polluted water or due to excessive land run off. In present study value of pH ranged from 6.90 -7.54 indicating almost alkaline nature of the reservoir and indicating fitness of water for aquatic life. In present study average value recorded for turbidity (TD) was 2.33±1.26 NTU. Increase in TD was noticed due to higher average discharge in rainy season in contrast to winter and summer [17]. Water temperature has noteworthy effect on aquatic system. Dissolved oxygen, rate of photosynthesis and rates of aquatic life are significantly affected by temperature variations [20]. Alkalinity in the water is imparted by carbonates, bicarbonates, phosphates, nitrates, borates, silicates etc. [24]. The range (91.6±15.0) lies within permissible limits of BIS [4] (i.e. 200 mg/L). Free CO_2 is one of the essential constituents of an aquatic ecosystem. It can exist as bicarbonate or carbonates in the dissolved form and is also contributed by respiratory activity of animals [3]. Lower CO_2 concentration during summer may be due to increased photosynthetic activity [14]. A decrease in free CO_2 concentration during summer was also noticed by Mustapha [16]. An increased value of Total hardness during summer was observed by Khan et al. [12] and is a parallel to our observation. Calcium (Ca) is an important micronutrient in an aquatic environment and variations in its concentration affect the aquatic ecosystem by adsorption of calcium ion on metallic oxides [25]. Minimum values of calcium ion concentration during rainy season might be due to greater dilution due to addition of rainwater. Higher concentration of Ca during winter possibly may be due to concentration of water due to evaporation. Present study showed a decreased trend in Ca conc. in summer season and similar findings were also made by Jipsa et al. [10]. Decrease in Mg concentration may be possibly due to its uptake by the plants in the formation of chlorophyll-Porphyrin metal complexes and in enzymatic transformation [26]. The typical seasonal pattern of TDS concentration shows low TDS value in winter due to fresh inflow, followed by an increase in TDS of upto 100 mg/L over the summer and fall due to evaporation. "TDS can increase to more than 100 mg/L during years with low inflow and/or high TDS inflow in average and dry years. In wet years with high inflow, TDS in the reservoir will increase from 475 to 550 mg/L (as in our study) as there is a large increase in storage consisting of higher quality runoff" [19]. Similar to our study, decreased trend in concentration during summer was observed by Li et al. [13]. In present study maximum value for BOD recorded was 13.83 mg/L and minimum value was 0 mg/L. Similar findings were made by Singh et al. [22]. Temporal trends in concentration of total Nitrogen (ΣN) did not show much variation. Maximum concentration of Sulphate (SO_4) was recorded during rainy season (30.17 mg/L). This could be possibly due to surface run-off and leaching from nearby farmlands. Concentration of SO_4 is higher during rainy seasons, the period that is usually the peak of agricultural activities around the reservoir [16]. Lead (Pb) is present naturally in the environment. High concentration of Pb in water bodies is due to industrial and agricultural discharge [15]. In present study, no significant difference was recorded in concentration of Pb. Average Pb concentration recorded was 0.28±0.07 mg/L. Ni is required for living organisms in traces. It interacts with organic matter in aqueous phase and settles down leading to increased concentration in sediments [2]. Manganese (Mn) is an essential micronutrient and does not occur naturally as a metal in aquatic ecosystem [11]. Average concentration recorded for Mn was 0.29±0.02 mg/L. The average concentration recorded for copper (Cu) was 0.09±0.01 mg/L. Also, no significant variation was observed during four seasons in Mn and Cu.

4) CONCLUSION

Present investigation was aimed to assess seasonal variations among various physico-chemical parameters of Pong reservoir-A Ramsar site in India. Concentrations of Cu, Mn, Pb and Cd were increased. Higher concentration of these heavy metals was due to anthropogenic activities and due to natural erosion of mineral and soil deposits from the surrounding topography. Correlation and regression analysis revealed that there is a significant linear relationship between different pairs of water quality parameters that can be further used for assessment of water quality. On the basis of present study, it has been concluded that physico-chemical water quality parameters

are within prescribed permissible limits (WHO/BIS/CCME) and is fit for human consumption as well as for fisheries therein. This water further is important for it supports a very small population of Indus River dolphins in the lower stretch of Beas River.

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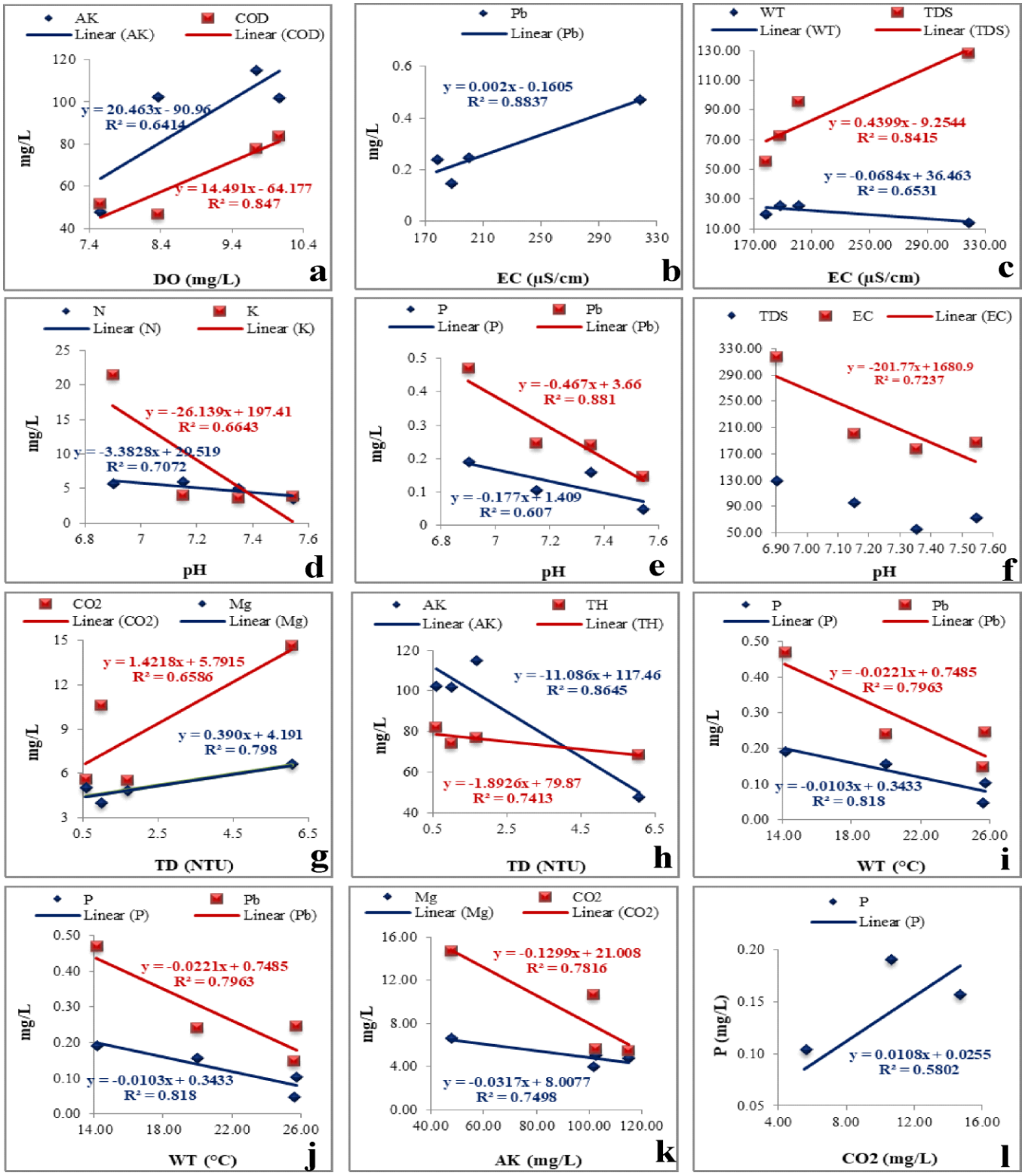


Figure 2: Plots of water quality parameters as a linear regression model (a-l).

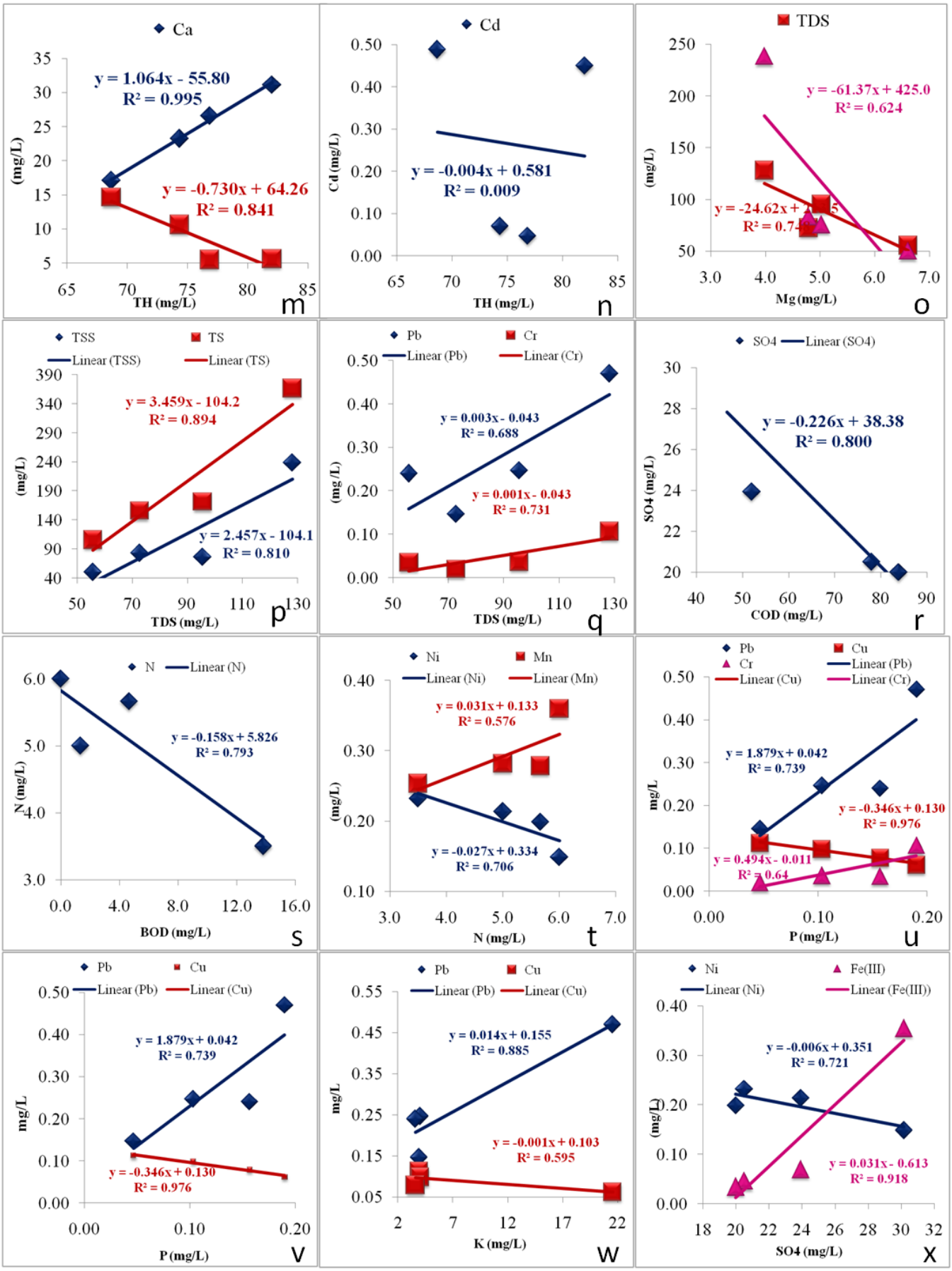


Figure 3: Plots of water quality parameters as a linear regression model (m-x).

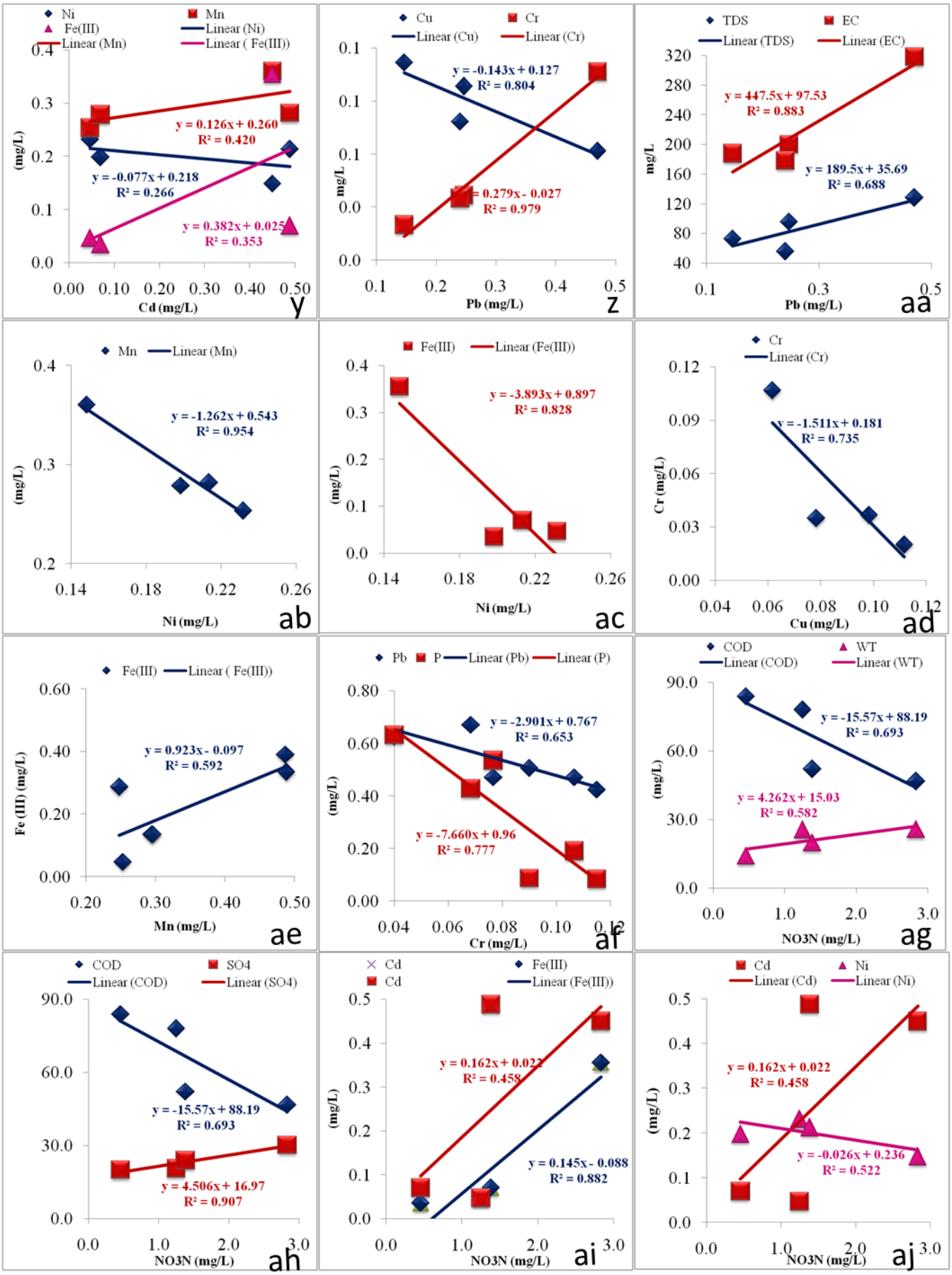


Figure 4: Plots of water quality parameters as a linear regression model (y-aj).