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Classification on the Basis of Physicochemical Properties of Ground Water of Majha Region of Punjab, India

Y. Kumar[1], N. Munjal[1], U. Kamboj[1*]

[1] Department of Physics, School of Chemical Engineering and Physical Sciences, Lovely professional university, Phagwara, Punjab

* Correspondence: amukam@gmail.com

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Abstract: Groundwater plays an important role in our daily life and it is very precious natural resource. Water is getting contaminated due to various anthropogenic and geogenic activities. For checking the issue of contamination in Majha region of Punjab, India, (four districts fall in this region which are Amritsar, Taran taran, Gurdaspur, Pathankot), 56 ground water samples were collected from hand pumps and submersible pumps, and these were examined for their pH value, total dissolved solids (TDS), Chlorine content (Cl), turbidity, total hardness (TH) and electrical conductivity (EC). The mean values obtained for pH, TDS, Cl, Turbidity, TH, EC, respectively are 7.3713, 534.4143 mg/L, 59.9125 mg/L, 0.50 NTU, 229.3214 mg/L, 824.0714 µS/cm. The standard deviation for the pH values is least among all the quality parameters with a value of 0.5875 and the electrical conductivity shows maximum variation with a standard deviation of 329.6654 µS/cm. The other parameters TDS, TH, Cl, Turbidity have standard deviation values as 214.3521 mg/L, 90.3038 mg/L, 26.2141 mg/L, 1.0617 NTU respectively. For obtaining in-depth information from physicochemical data, Correlation and regression analysis was also done. Furthermore, Principal component analysis (PCA) was used to classify on the basis of districts, depth range and groundwater source.

Keywords: Groundwater**,** Principal Component Analysis (PCA), Total Dissolved Salts, Electrical Conductivity, pH, Turbidity, Total Hardness.

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1. Introduction

Groundwater is very precious and important entity provided by nature to the living world. Humans use this water for their daily coursework i.e. for drinking, for preparing meals, for washing clothes etc., water is also used in industry, in agriculture and in various other activities. The total available groundwater, which can be used by humans, has very low percentage as compared to the total water available on earth. Availability of water is 97.2% saline water (oceans), 2.0% fresh water (ice caps and glaciers), only 0.62% water is groundwater and comparatively very little percentage is available in the fresh water lakes (0.009%), inland seas/salt lakes (0.008%), atmosphere (0.001%), rivers (0.0001%) etc.[1].It is clear that less than 1% of total global water is fresh water and out of this 99% is groundwater. In the report published by UNESCO [2], it is mentioned that 70% water requirement forirrigated agriculture, 50% water need of global urban populationis fulfilled by groundwater.

Bureau of Indian Standards (BIS) [3], and World Health Organization (WHO) [4] have given acceptable limits of contaminations in drinking water. Agricultural and industrial activitieshave increased the contamination of groundwater to a great extent.Contamination of the groundwater may causedifferent types of diseases like cancer, dental fluorosis, skin diseases, Arsenicosisetc.[5-6]. Coal thermal power plants also cause heavy metal pollution [7-8]. In a previous study it is mentioned that concentration of Arsenic is very high in groundwaters of various countries, like Afghanistan, Bangladesh, Pakistan, India, Sri Lanka etc., Arsenic is responsible for various types of diseases [9].Selenium can have carcinogenic effects if consumed in excess [10].Fluoride contamination is also a concern [11-12]. Physicochemical properties of water from Amritsar, Punjab,India were correlated with the presence of Uranium in the water and a positive correlation was observed [13].In Tarantaran district a study was done on groundwater, which revealed that 96% samples had Arsenic contamination, it is also mentioned in the study that the presence of As is more dangerous for children as compared to adults [14].In another study of groundwaterphysicochemical properties like pH, Cl etc. were studied in the Malwa region of Punjab, India which revealed that 92% sites were found to have high level of nitrate from the acceptable limit of BIS [15]. In the present work physicochemical properties of groundwater samples, taken from the four districts of Majha region of Punjab, India, are studied. To analyze the physicochemical data, descriptive statistics, correlation analysis, regression analysis and Principal Component

Analysis (PCA)is done.

2. Material and Methods

2.1 Sample Collection

Samples were collected (56 in number) from the districts of Majha region (Figure-1) of Punjab, India viz. Amritsar (31°35′N 74°59′E, average elevation of 234 meter), Pathankot(31°55′N 75°15′E, average elevation of 332 meter),Gurdaspur(31°55′N 75°15′E, average elevation of 264meter) and Tarantaran(31°28′N 74°56′E, average elevation of 226meter).

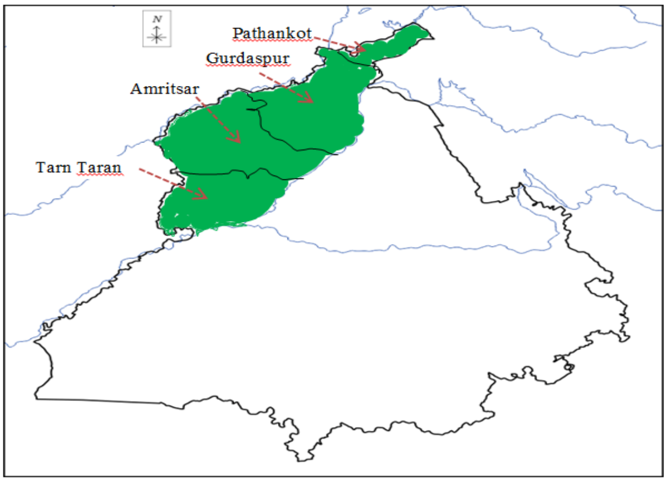

Figure 1 –Majha region, Punjab, India

The groundwater samples were collected from handpumps and submersibles. The depth ranges for handpumps lie between 20-220 feet and for submersibles (or motors) lie between 30-500 feet. The samples were collected in polythene vials having screw-on caps and these were kept at room temperature for further analysis.

Each groundwater sample was analysed for pH, chlorine, total dissolved solids, Total hardness, turbidity, electrical conductivity using standard procedures.

2.2 Statistical Analysis

Descriptive statistical analysis was done on the Physicochemical data using Microsoft excel software.Using MS Excel, correlation (given in Table 3) and linear regression analysis was also done, the regression analysis providelinear equations (1) to (6), showing relation between water quality parameters.

2.3 Principal Component Analysis

Principal component analysis was done using Clustvis-a web based tool [16-17]. It is done on the basis of properties, source of water, depth and district.

3. Results and Discussion

According to BIS and WHO the acceptable limit of pH value for drinking water should lie between 6.5 and 8.5(Table 1.

Table 1).The water which is either acidic or basic is not fit for drinking purpose and is also not good for agricultural purposes.Waterwith pH> 7, tastes bitter and can cause skin irritation.The effectiveness of water disinfection withChlorine is reduced if pH of the water is low. The acidic water also leads to corrosion of metal pipes through which it flows and the metallic containers in which it is kept. The water having low pH value, if used, it maycorrode metals used in buildings.

The water which has high TDS value tastes salty and is somewhat bitter in taste. TDS stands for total dissolved solids which may be organic or inorganic salts.These salts may be carbonates, bicarbonates, nitrates, chlorides, sulphates etc. of sodium, magnesium, potassium, calcium etc. It is mentioned in the report by WHO that inverse relation exist between TDS and incidence of cancer, some of the heart diseases, also the mortality rates are also inversely related to the TDS levels in drinking water [18]**.**The TDS if small or within limits as prescribed by WHO or by BIS, but contains toxic metals like Arsenic, Fluoride etc. even in small quantities can be harmful to humans. The water with high TDS values leave scales in washing machines, geysers etc.

If water contains chlorine, the water gives a typical smell. It can cause corrosion in the pipes also. In the report by WHO, it is mentioned that bladder cancer appears to be linked with the consumption of chlorine.[19]

The electrical conductivity indicates that ions arepresent in the water.

Turbidity indicates the cloudiness of water and is due the presence of suspension of particles of clay, silts, iron, manganese, plant debris and or pathogens.Higher value of turbidity reduces the acceptance of drinking water and higher value of turbidity may cause an outbreak of a disease, but this is not an established fact.[20]

Hardness is due to the presence of carbonates (temporary hardness) and non-carbonates (permanent hardness) of magnesium and or calcium. Such water on boiling can cause scaling in the container like boilers etc. Various types of diseases are associated with the inadequate and excess intake of calcium and magnesium like kidney stones, osteoporosis, insulin resistance and obesity, calcium may interact with iron, magnesium, phosphorous etc. and inhibits their absorption in the body [21].From the reports of WHO on different water quality parameters it is clear that there is need to monitored the quality of groundwater for the drinking purpose. The acceptable limits for these groundwater quality parameters or properties or characteristics are given in Table 1.

Table 1Standards for Drinking Water

PROPERTY	BIS ACCEPTABLE LIMIT[22]	WHO ACCEPTABLE LIMIT[23]
pHvalue	6.5-8.5	6.5-8.5
Turbidity,(in NTU)	1	1
total dissolved solids, (TDS) mg/L	500	500
Chloride (as Cl), mg/L	250	250
Total Hardness (TH) (as $CaCO_3$), mg/L	200	200
Electrical conductivity (µS/cm)	-	1500

.3.1 Statistical parameters for the physicochemical properties

The statistical parameters obtained for physicochemical properties of groundwater samples are given in Table 2, which are obtained with the help of MS excel software. It is clear that standard deviation for pH values is the least and the maximum standard deviation is for electrical conductivity. The same is clear from the range values also.

Table 2- Statistical Parameters for the collected ground water samples

STATISTICAL PARAMETERS	TURBIDITY (NTU)	TOTAL DISSOLVED SALTS(TDS) (mg/L)	ELECTRICAL CONDUCTIVITY (µS/cm)	pH VALUE	TOTAL HARDNESS ($CaCO_3$)(mg/L)	CHLORIDE as Cl (mg/L)
Mean	0.5000	534.4143	824.0714	7.3713	229.3214	59.9125
Median	0.0000	467.5000	718.0000	7.3600	231.0000	58.0000
Standard Deviation	1.0617	214.3521	329.6654	0.5875	90.3038	26.2141

Range	5.0000	950.0000	1460.0000	3.0700	388.0000	125.0000
Minimum	0.0000	198.0000	305.0000	6.4800	70.0000	23.0000
Maximum	5.0000	1148.0000	1765.0000	9.5500	458.0000	148.0000

3.2 Correlational Analysis of Physicochemical Properties

Correlation coefficients between all the six physicochemical properties of the groundwater samples were obtained using MSExceldataanalysisaddin software, and the values are given in Table 3, it is clear from the table that there is correlation between TDS and EC and correlation coefficient is 0.9997, other coefficients between TDS and TH, TDS and Cl, EC and TH, EC and Cl, TH and Cl respectively are 0.5973, 0.7168, 0.5933, 0.7147, 0.7989.

Table 3- Correlation Coefficients between the various physical chemical parameters of ground water samples

Water quality parameters	Turbidity (NTU)	Total Dissolved Salts (TDS) (mg/L)	Electrical Conductivity (μS/cm)	pH Value	Total Hardness ($CaCO_3$) (mg/L)	Chloride as Cl (mg/L)
Turbidity (NTU)	1.0000					
Total Dissolved Salts (TDS) (mg/L)	0.0012	1.0000				
Electrical Conductivity (μS/cm)	-0.0011	**0.9997**	1.0000			
pH Value	0.2317	-0.0420	-0.0440	1.0000		
Total Hardness ($CaCO_3$)(mg/L)	0.2475	**0.5973**	**0.5933**	0.0202	1.0000	
Chloride as Cl (mg/L)	0.1668	**0.7168**	**0.7147**	0.0478	**0.7989**	1.0000

3.3 Regression analysis

For the pair of physicochemical properties which showed correlation coefficients greater than 0.5 a regression analysis was also done to find the line of best fit. Equations (1) to (6) are the Regression line equations obtained using MS Excel software.

$$EC = 1.5374\,(TDS) + 2.4461, \quad R^2 = 0.9993 \qquad (1)$$

$$TH = 0.2526\,(TDS) + 94.327, \quad R^2 = 0.3595 \qquad (2)$$

$$Cl = 0.0914\,(TDS) + 11.068, \quad R^2 = 0.5586 \qquad (3)$$

$$TH = 0.1630\,(EC) + 94.959, \quad R^2 = 0.3543 \qquad (4)$$

$$Cl = 0.0593\,(EC) + 11.079, \quad R^2 = 0.5554 \qquad (5)$$

$$Cl = 0.2180\,(TH) + 9.9894, \quad R^2 = 0.5643 \qquad (6)$$

Linear relations are between EC-TDS, TH-TDS, Cl-TDS, Cl-TDS, TH-EC, Cl-EC and Cl-TH respectively.

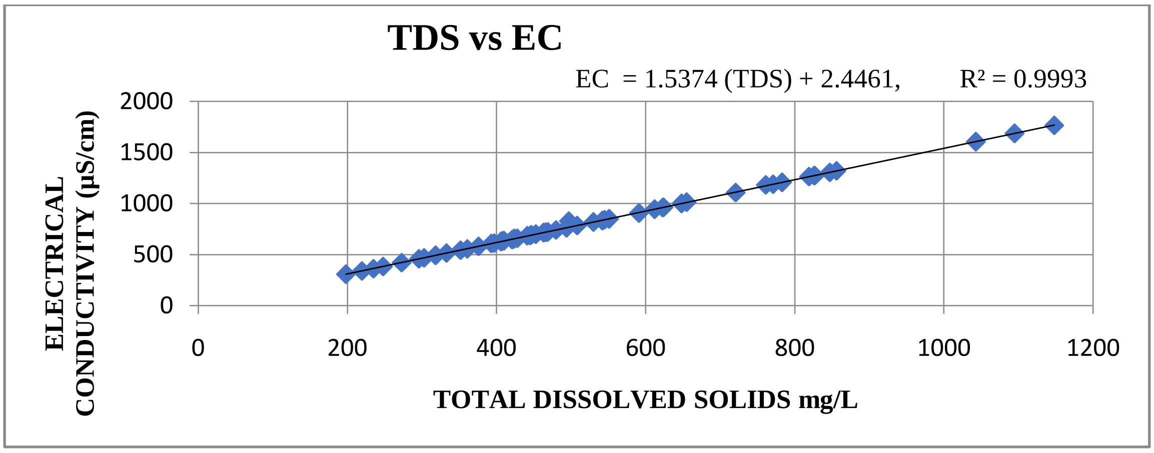

Figure 2Linear Regression Total Dissolved Solids Vs Electrical Conductivity

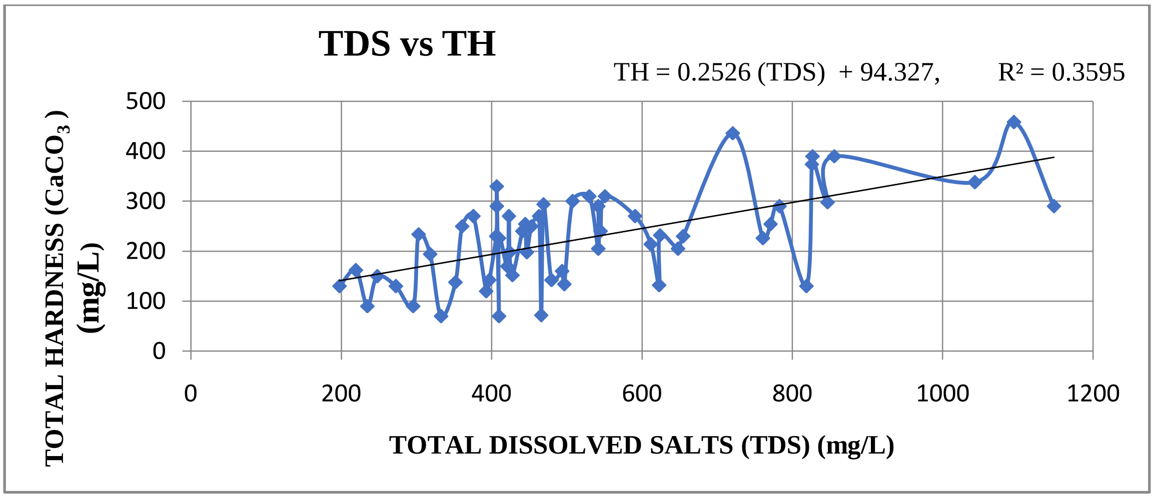

Figure 3Linear Regression Total Dissolved Solids Vs Total Hardness

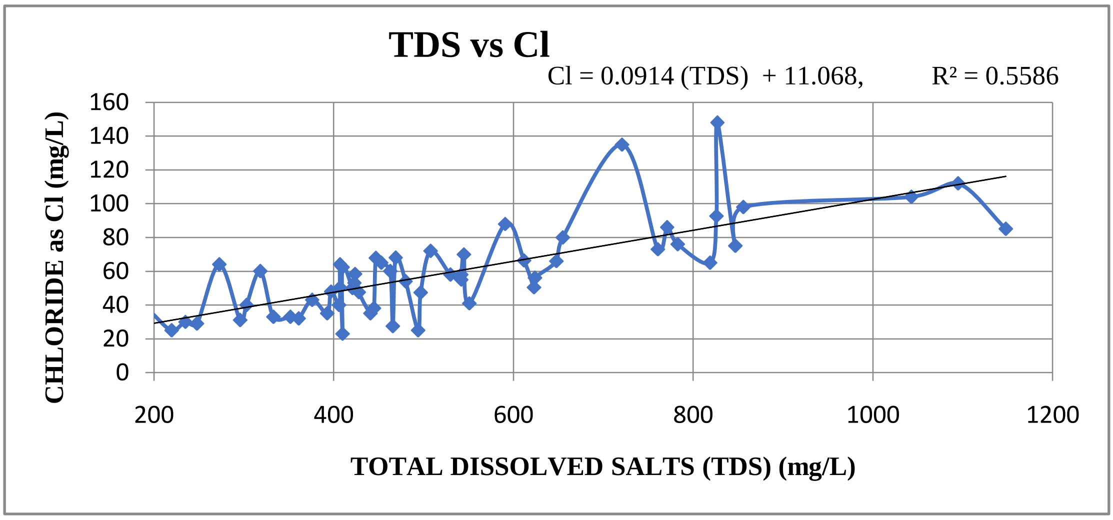

Figure 4Linear Regression Total Dissolved Solids Vs Chlorine Content

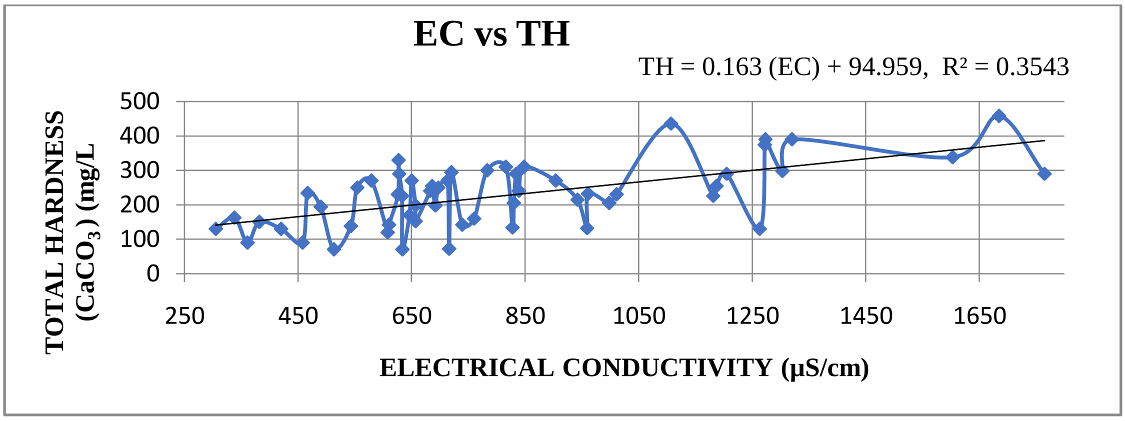

Figure 5Linear Regression Electrical Conductivity Vs Total Hardness

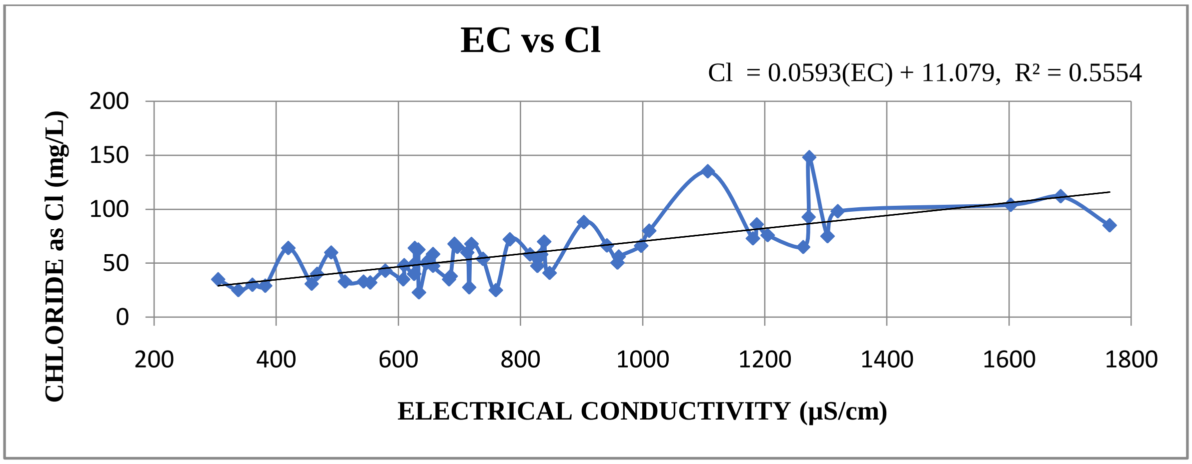

Figure 6 Linear Regression Electrical Conductivity Vs Chlorine Content

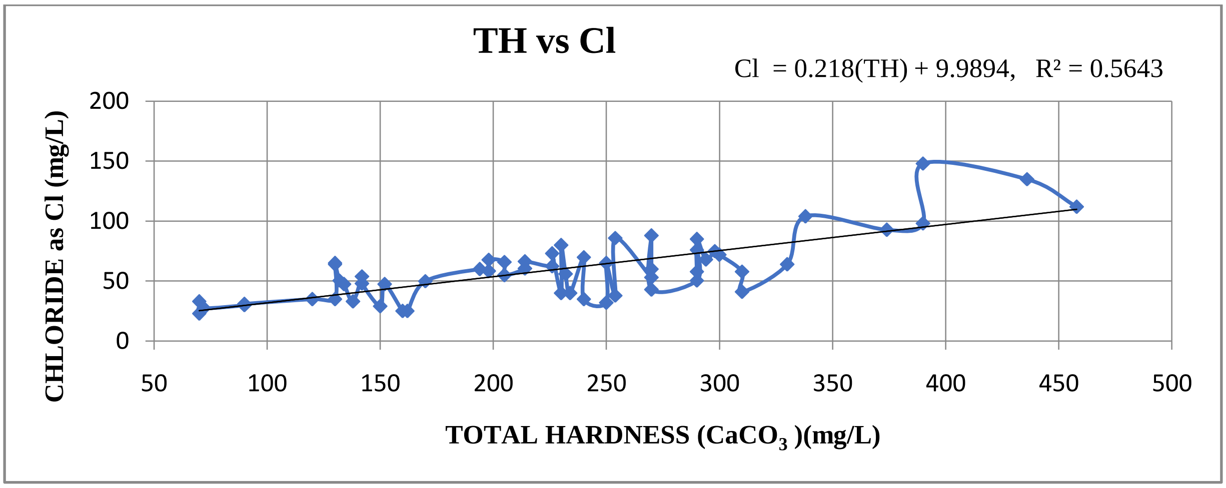

Figure 7Linear Regression Total Hardness Vs Chlorine Content

3.4 Principal component analysis

Principal component analysis (PCA) was doneusing Clustvis-a web tool.PCA analysis was performed on basis of physicochemical parameters (fig 8), it was observed that almost complete data was covered using two principal components. In the PCA loading plot, it was observed that as total hardness (TH) was lying near the center of the PCA, thus no specific relation for TH could be observed with other parameters. Further Turbidity, pH and chlorine content of the samples have similar values for PC1 and PC2 showing that these parameter values are interrelated for the collected set of samples. This shows that the three parameters are positively correlated to each other and if one is known, other two can be easily calculated using the bivariate regression equations between them. The left side of PCA shows that EC and TDS are positively related with each other with a lower correlation as compare to coefficient of correlation between turbidity, pH and chlorine content. Thus the PCA shows us that by calculating two parameters rest three parameters can be calculated. Total hardness showed no correlation with any of the other parameters.

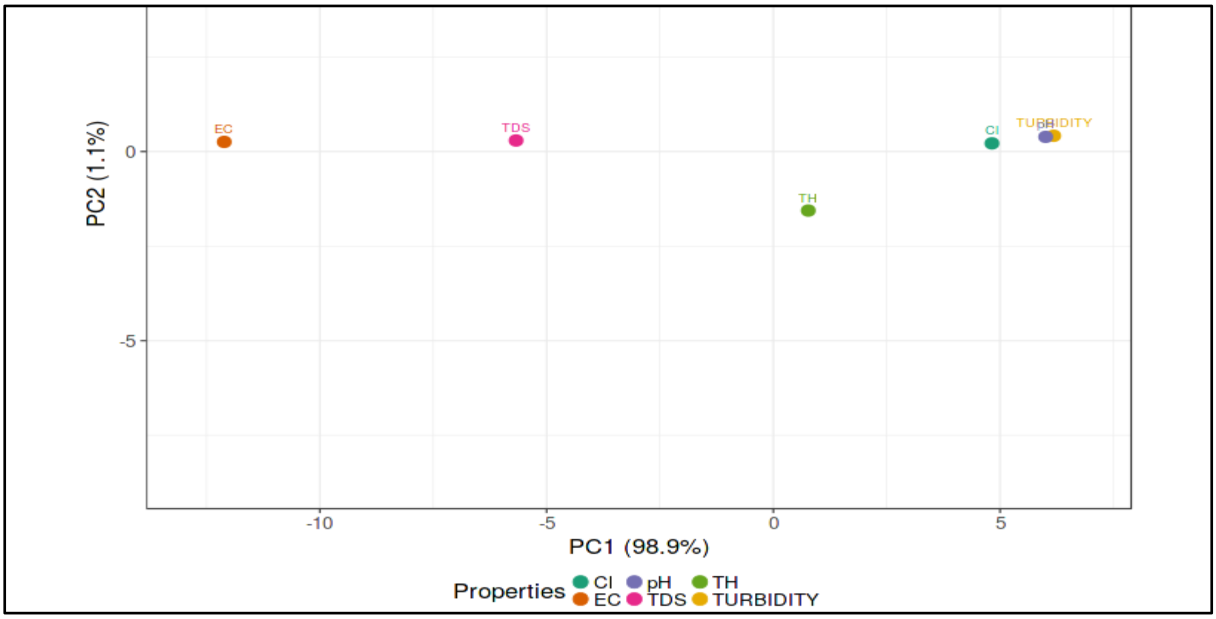

Figure 8 PCA for properties

Second PCA (fig 9) was developed on the basis of the sources of water– handpump and motor. First two PCs cover 73% of the complete data set. PCA shows that though the samples cannot be classified with good accuracy on basis of sources of water, but the samples collected by motor source were present in the upper portion of PCA and that collected with handpump were clustered on the south east part of PCA.

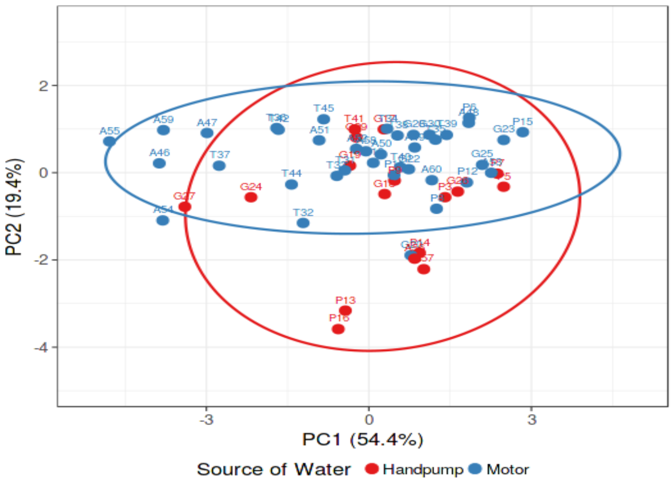

Figure 9 PCA on the basis of source of water

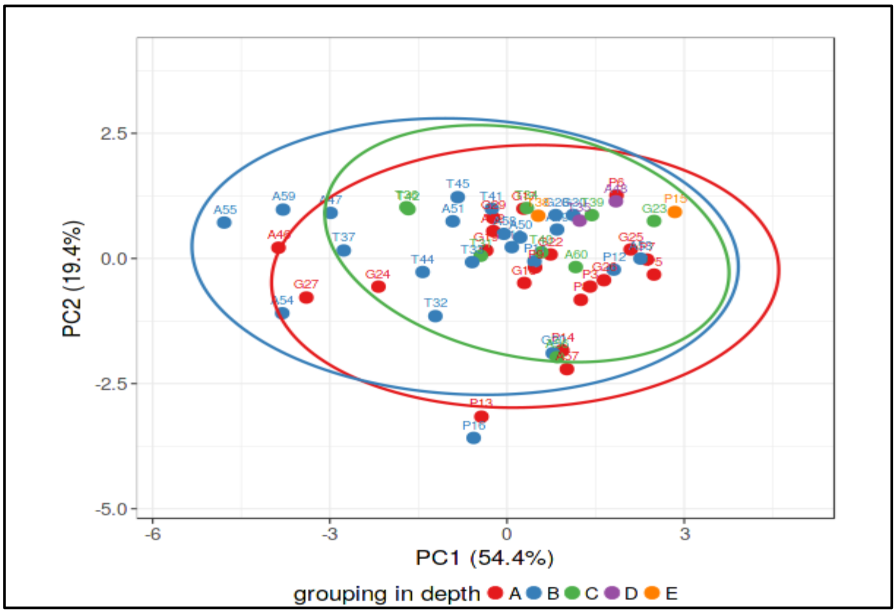

Figure 10 PCA on the basis of depth

PCA was employed on the all the samples on the basis of depth of the procured samples. The depth of the samples were given code A, B, C, D, E; where A is used for the range 0-100ft., B for 100-200ft, C for 200-300ft., D for 300-400ft and E for 400-500ft. respectively. It can be observed that 73% data was covered using the two PCs and no specific categorization and classification was possible on the basis of the depth of the collected ground water samples. On depth analysis it was observed that the samples collected with depth in range of 100-200 ft were lying on the left side of the PCA and could be considered in different groups from the other samples. Further samples of A and B group were on opposite sides of the PCA showingthat the property of the samples was not similar for the different depth samples, though they could not be differentiated with good accuracy.

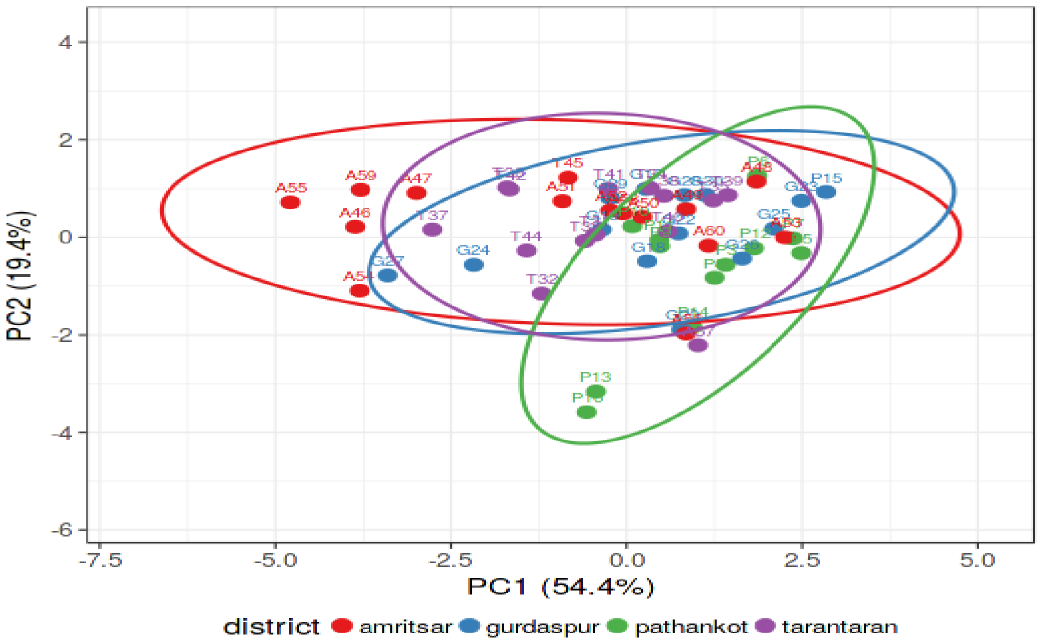

Figure 11 PCA on the basis of district

Last PCA was employed on the basis of district and it was also observed that no specific classification can be done on the basis of the district of the collected samples.

4. Conclusion

To follow the WHO and BIS guidelines it was observed that 16.67% samples in case of Turbidity, 45% in case of TDS, 6.67% in case of electrical conductivity, 10% in case of pH value, 65% in case of Total hardness and 0% in case of chloride are out of range. The percentage of out of range values of properties in the same order as above in case of Amritsar are 13.33, 66.67, 20.00, 66.67, 73.33, 0; in case of Pathankot 26.67, 6.67, 0, 26.67, 53.33, 0; in case of Gurdaspur 15.38, 30.77, 0, 0, 53.33, 0 and in case of Tarantaran 6.67, 66.67, 6.67, 13.33, 66.67, 0. When correlation among these properties is observed it was found that there was some correlation between TDS and EC with r=0.9997, TDS and TH with r= 0.5973, TDS and Cl with r=0.7168; between EC and TH with r= 0.5933, between EC and Cl with r = 0.7174, between TH and Cl with r = 0.7989. Only six pairs showed some correlation. For these six pairs regression equations have also been obtained. FurtherPrincipal component analysis was performed on the basis of depth, source of water and district, which showed that categorization of the samples, is not possible in any of the case.

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Conflicts of Interests

The authors declare that there is no conflict of interests.

The research profile of the authors can be verified from their ORCID ids, given below:

Y.Kumar https://orcid.org/0009-0002-7821-9064
N.Munjal http://orchid.org/0000-0002-9992-3512
U.Kamboj https://orcid.org/0000-0002-9884-9402

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