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CATEGORIZATION OF SOME AREAS OF HIMACHAL PRADESH ON THE BASIS OF CLUSTER ANALYSIS OF PHYSICO-CHEMICAL CHARACTERISTICS AND WATER QUALITY INDEX OF GROUNDWATER

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Abstract :- The present study was conducted to carry out cluster analysis of physico-chemical characteristics and water quality index of groundwater samples collected from Solan and Una districts of Himachal Pradesh. Physico-chemical characteristics of water samples include pH, Specific Conductivity (SC) at 25ºC, carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), Alkalinity, Chloride (Cl^-), Sulphate (SO_4^{2-}), Nitrate (NO_3^-), Fluorine (F), Calcium (Ca), Sodium (Na), Magnesium (Mg), Potassium (K), Total hardness (TH) and Total dissolved solids (TDS). Water Quality Index suggests that 18 sampling areas were having excellent water quality whereas it was good and poor in 23 and 4 sampling areas, respectively. Cluster analysis resulted in division of sampling areas into less polluted (LP) regions, moderately polluted regions (MP) and highly polluted regions (HP). In conclusion, evaluation of Water Quality Index and multivariate analysis helps in assessing the groundwater quality.

Keywords- Cluster analysis, Groundwater, Physico-chemical characteristics, Water Quality Index

I. Introduction

Groundwater is used as an important supplier of irrigation and drinking water, and it has a strong impact on rivers and aquatic ecosystems for animals and plants (Twarakavi and Kaluarachchi, 2006). Majority of Indian states are withdrawing groundwater due to the requirements for both agricultural and industrial purposes at a rate more than what can be recharged (Jat et al., 2008). Groundwater suffer a lot of problems due to human activities like uncontrolled withdrawal of bore well water at a high rate compared to recharge rate (Kazi et al., 2009). The main factors obtained influencing groundwater quality of the clusters is mainly related to natural (dissolution of soil and rocks), point source (municipal wastewater and industries) and non-point source pollution (agriculture) in the region. Multivariate statistical techniques such as Cluster Analysis (CA), Discriminant Analysis (DA) and Principal Component Analysis (PCA) can be used to determine sources of pollution (Singh *et al.* 2005). In present study, some areas of Himachal Pradesh have been categorized on the basis of physico-chemical characteristics and water quality index of groundwater.

II. Materials and Methods

(a) **Data samples and collection** The water quality parameters data for the groundwater is obtained from Central Ground Water Board (CGWB), Dharamshala, Himachal Pradesh, the regulatory body accountable for collecting and storing the data. The data includes mean annual values for 15 water quality parameters including pH, Specific Conductivity (SC) at 25ºC, carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), Alkalinity, Chloride (Cl^-), Sulphate (SO_4^{2-}), Nitrate (NO_3^-), Fluorine (F), Calcium (Ca), Sodium (Na), Magnesium (Mg), Potassium (K), Total hardness (TH) and Total dissolved solids (TDS). Only 15 parameters were selected due to their continuity and availability in measurement at all selected water quality monitoring stations.

The study is carried out by taking the samples from the region of Himachal Pradesh. In the study Una and Solan region of Himachal Pradesh are chosen (Table 1).

Table 1: Monitoring stations

S. No.	District	Well From	S. No.	District	Well from
1	Solan	Bhageri	23	Una	Lalehri
2	Solan	Bhatoli	24	Una	Una
3	Solan	Baruna	25	Una	Jawer
4	Solan	Palahi	26	Una	Rajli Panjal
5	Solan	Panjiara	27	Una	Bhangana
6	Solan	Jagatpur	28	Una	Bawal
7	Solan	Mahadeva	29	Una	Dharampur
8	Solan	Dabota	30	Una	Badsali
9	Solan	Khera_chak	31	Una	Panjawar
10	Solan	Barotiwala	32	Una	Singhnei
11	Una	Daulatpur	33	Una	Mawa Kalan
12	Una	Amb	34	Una	Babehr
13	Una	Gagret	35	Una	Raipur marwadi
14	Una	Panoh	36	Una	Nangran
15	Una	Khawaja	37	Una	Khanpur
16	Una	Kuthera jaswan	38	Una	Santokhgarh
17	Una	Ganehri	39	Una	Jankaur
18	Una	Mubarikpur	40	Una	Loharli
19	Una	Guglehar	41	Una	Talhiwal
20	Una	Kaluwal	42	Una	Thathal
21	Una	Jalehra	43	Una	Karluhi
22	Una	Ishpur	44	Una	Dharampur

(b) Water quality index (WQI)

We need to find out the water quality index as it will give an idea about the water quality whether it is excellent, good or poor (Table 2).

Table 2: Range of water quality index (WQI) specified for drinking water

WQI	Water Quality
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very poor
>300	Unsuitable

(c) Cluster analysis

It starts with each observation in a separate cluster. In each step two similar cluster combine to form a new cluster this process is repeated till all observation combine into a single cluster.

(d) Software used

- XLSTAT plug-in software in MS Excel 2013
- IBM SPSS 22.0 statistical analysis including correlation matrix, cluster analysis (CA) and principal component analysis.

III. Results and Discussion

The pH values of collected water samples ranged from 7.3 to 10.36, in some places beyond the limit range of 6.5-8.5 allowed by the CPCB for drinking purpose showing strong basic characteristics, SC cycle showed significant variations ranging from 160-1140 S/m, CO_3^{2-} has values ranging from 0-66 mg/L, HCO_3^- ranges from 36.6- 561.2 mg/L, Alkalinity from 50 to 460

mg/L. The major anions Cl^- (7-188 mg/L), SO_4^{2-} (0-208 mg/L), NO_3^- (0-58 mg/L), F (0.01-1.30 mg/L), were high in some regions. The major cations Ca (10-80 mg/L), Na (8.40-220 mg/L), Mg (0-88 mg/L), K (0.79-42.33 mg/L) were found to be present from lower to very high concentrations throughout the regions. Total hardness was in the range of 65-385 mg/L whereas the total dissolved solids ranges from 102- 730 mg/L.

After knowing the physic-chemical values of 15 water quality parameters, Water Quality Index (WQI) was calculated and areas have been categorized as Excellent, Good and Poor (Table 3). Ramakrishnaiah et al., (2009) also carried out the work for assessing the water quality index for the groundwater of Tumkur taluk. Mohebbi et al., (2013) used an innovative drinking water quality index (DWQI) for assessing the water quality in all of the groundwater resources in Iran and suggested that it describes the quality of water bodies correctly. Contrarily, Shroff et al., (2013) concluded that WQI is not a true indicator of water quality.

Table 3: Water Quality Index

S.No.	Sample area	WQI	Water Quality		S.No.	Sample area	WQI	Water Quality
1	**Bhageri**	42.22	Excellent		**23**	**Lalehri**	49.59	Excellent
2	**Bhatoli**	55.77	Good		**24**	**Una**	97.80	Good
3	**Baruna**	60.67	Good		**25**	**Jawer**	45.19	Excellent
4	**Palahi**	58.72	Good		**26**	**Rajli Panjal**	59.34	Good
5	**Panjiara**	32.30	Excellent		**27**	**Bhangana**	49.54	Excellent
6	**Jagatpur**	44.28	Excellent		**28**	**Bawal**	58.35	Good
7	**Mahadeva**	73.59	Good		**29**	**Dharampur**	53.47	Good
8	**Dabota**	63.13	Good		**30**	**Badsali**	53.43	Good
9	**Kherachak**	57.14	Good		**31**	**Panjawar**	90.45	Good
10	**Barotiwala**	35.42	Excellent		**32**	**Singhnei**	51.54	Good
11	**Daulatpur**	77.57	Good		**33**	**Mawa_Kalan**	33.95	Excellent
12	**Amb**	56.86	Good		**34**	**Babehr**	44.86	Excellent
13	**Gagret**	56.34	Good		**35**	**Raipur_Marwadi**	46.08	Excellent
14	**Panoh**	52.24	Good		**36**	**Nangran**	127.83	Poor
15	**Khawaja**	83.34	Good		**37**	**Khanpur**	55.24	Good
16	**Kuthera_Jaswan**	47.04	Excellent		**38**	**Santokhgarh**	44.88	Excellent
17	**Ganehri**	31.74	Excellent		**39**	**Jankaur**	52.70	Good
18	**Mubarikpur**	44.84	Excellent		**40**	**Loharli**	41.97	Excellent
19	**Guglehar**	114.11	Poor		**41**	**Talhiwal**	50.81	Good
20	**Kaluwal**	52.17	Good		**42**	**Thathal**	77.23	Good
21	**Jalehra**	44.02	Excellent		**43**	**Karluhi**	28.15	Excellent
22	**Ishpur**	102.72	Poor		**44**	**Dharampur**	36.90	Excellent

After evaluating WQI, the water quality could be divided into three polluted areas on the basis of cluster analysis. Cluster 1 represented less polluted (LP) regions, cluster 2 represented moderately polluted regions (MP) and cluster 3 represented highly polluted regions (HP). There were 10 observing stations in LP, 25 observing stations in MP and 9 observing stations in HP (Table 4).

In cluster 1 pH ranges from 7.71 to 10.05, SC is 160-340 S/m, CO_3^{2-} from 0 to 30 mg/L, HCO_3^- from 79.3 to 152.5, Alkalinity from 65-125 mg/L, Cl^- from 7- 138 mg/L, SO_4 from 8-114 mg/L , NO_3^- from 1 to 51mg/L , F^- from 0.01 to 0.71 mg/L, Ca^{2+} from 12-80 mg/L , Mg^{2+} from 0- 44 , Na^+ from 8.4 to 71.7 mg/L, K^+ from 0.92 to 2.39 mg/L,TH from 110-225 mg/L and TDS from 102 to 230 mg/L.

In cluster 2, pH is from 7.44 to 10.36, SC is from 360 to 670 S/m, CO_3^{2-} is from 0 to 66 mg/L, HCO_3^- is from 36.6 to 372.1 mg/L, alkalinity is from 50 to 305 mg/L, Cl^- is from 11 to 107 mg/L, SO_4^{2-} 0 to 132 mg/L, NO_3^- is from 0 to 46 mg/L, F is from 0.03 to 1.3 mg/L, Ca^{2+} from 10-62 mg/L, $Mg^{2+}$from 7 to 47 mg/L, Na^+ is from 10.8 to 88.2 mg/L, K^+ from 0.79 to 42.33, TH is from 65 to 240 mg/L and TDS is from 218 to 429 mg/L.

In cluster 3, pH ranges from 7.9 to 9.01, SC is 810 to 1140 S/m, CO_3^{2-} have 0 value, HCO_3^- from 97.6 to 561.2 mg/L, alkalinity ranges from 80 to 460 mg/L, Cl^- ranges from 14 to 188mg/L, SO_4^{2-} from 0 to 208 mg/L, NO_3^- from 3 to 61 mg/L, F is from 0.01 to 0.67 mg/L, Ca^{2+} from 12-80 mg/L, Mg^{2+} from 22 to 88 mg/L, Na^+ is from 42 to 220 mg/L, K^+ from 1.15 to 29.49 , TH is from 160 to 400 mg/L and TDS is from 432 to 730 mg/L.

Usman et al., (2014) suggested that quality assessment has received little attention for groundwater and suggested that hydrochemistry data was analyzed using multivariate statistical techniques such as Cluster Analysis (CA) with the objectives of determining the spatial variability of groundwater. Singh et al., (2005) found good results by dividing Gomti river into three different groups using cluster analysis. Gulgundi et al., (2018) used hierarchical cluster analysis to group the 67 sampling stations into two groups, cluster 1 having high pollution and cluster 2 having lesser pollution. Chen et al., (2007) found that cluster analysis results in most groundwater samples collected from the same well in the study area during summer and winter fall into the same clusters. However, in order to identify the sources of pollution which affect the groundwater Principal Component Analysis (PCA) can be used in place of cluster analysis.

Table 4: Classification of monitoring stations in clusters

S. No.	Less polluted (LP)	Moderately polluted (MP)	Highly polluted (HP)
1	Mawa kalan	Burana	Daulatpur
2	Dharampur	Palahi	Khawaja
3	Panjiara	Bhatoli	Mahadeva
4	Karluhi	Khera Chak	Panjawar
5	Ganehri	Dabota	Nangran
6	Kuthera Jaswan	Dharampur	Ishpur
7	Loharli	Amb	Una
8	Barotiwala	Bawal	Guglehar
9	Mubarikpur	Kaluwal	Thathal
10	Badsali	Singhnei	
11		Khanpur	
12		Panoh	
13		Rajli panjal	
14		Bhageri	
15		Jagatpur	
16		Lalehri	
17		Jalehra	
18		Babehr	
19		Jawer	
20		Rajpur marvadi	
21		Bhangana	
22		Gagret	
23		Santokhgarh	
24		Jankaur	
25		Talhiwal	

IV. Conclusion

In conclusion, evaluation of Water Quality Index and multivariate analysis helps in assessing the groundwater quality. Also, assessment of groundwater quality is important as most of the human and animal population is dependent on it. Not a lot water bodies in sampling areas have been found unsuitable for drinking purpose. Also, Cluster analysis can be a helpful tool in dividing the multivariate dataset into natural clusters and categorization of polluted areas.

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