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Drinking water quality management through correlation studies among various physico-chemical parameters: A case study

Navneet Kumar [1], D.K. Sinha[2]
[1]Assistant Professor, Department of Applied Science and Humanities, College of Engineering, Teerthanker Mahaveer University, Moradabad-244001, U.P., India
[2]Reader and Head, Department of Chemistry, K.G.K.(P.G.) College, Moradabad.

ABSTRACT

Statistical regression analysis of twelve data points of underground drinking water of IM2 hand pumps at Moradabad, India was carried out to study the correlation between various physico-chemical parameters. Twelve water quality parameters of water of all sites were estimated following standard methods and procedures of sampling and estimation. Comparison of estimated values with W.H.O. standards revealed that water of study area is polluted and water quality management is urgently needed. Regression analysis of these data points suggests that conductivity of drinking water is an important parameter and it is significantly correlated with ten parameters out of twelve water quality parameters studied. It may be suggested that drinking water quality can be checked effectively by controlling the conductivity of water. Present study may be treated as one step ahead towards the drinking water quality management.

Keywords: Water quality parameters, regression equations, correlation, water quality management

1. Introduction

Ground water is the principal source of drinking water in our country and indispensable source of our life. The problem of ground water quality is acute. The resulting degradation of water quality in water body creates a condition so that water can not be used for intended beneficial uses including bathing, recreation and as a source of raw water supply (Biswas2000, Wesley2000, Khan et al 2004.). According to Central Pollution Control Board, 90% of the water supplied in India to the town and cities is polluted, out of which only 1.6% gets treated. Therefore, water quality management is fundamental for the human welfare (Gupta1991, Madhuri et al.2004).

The statistical regression analysis has been found to be a highly useful tool for correlating different parameters. Correlation analysis measures the closeness of the relationship between chosen independent and dependent variables. If the correlation coefficient is nearer to +1 or –1, it shows the probability of linear relationship between the variables x and y . This way analysis attempts to establish the nature of the relationship between the variables and thereby provides a mechanism for prediction or forecasting (Mulla et al. 2007, Drapper1966, Snedecor1967,Kumar et al.2005).

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Moradabad is a B class city of western Uttar Pradesh having urban population more than 38 lacs. Moradabad is situated at the bank of Ram Ganga river and its altitude from the sea level is about 670 feet. It is extended from Himalaya in north to Chambal river in south. It is at 28°20', 29°15' and 78°4', 79°E. District Bijnor and Nainital are in the north, Rampur in the east, Ganga river in the west and district Budaun is in the north of district Moradabad. Moradabad has seen rapid industrialization and population growth during the last few decades. The major industries are brassware, steelware, paper mills, sugar mills, crushers, dye factories and a number of associated ancillaries. Most of these industries and different kinds of human activities are playing their roles in multiplying the level of water pollution.

2. Material and Methods

Thirteen different water quality physico-chemical parameters including conductivity at twelve different underground drinking water sites of different India Mark II (IM2) hand pumps were estimated following standard methods and procedures of sampling and estimation (APHA1995, Merck1974). All chemicals of Anal R grade were used for quantitative analysis. For the determination of pH, turbidity, conductivity and fluoride, Century CP901 pH meter, Century nephelometer, RI 215 R conductivity meter and Hach spectrophotometer 2010 were used respectively. A brief description of sampling sites for quantitative estimation of water quality parameters is presented in Table 1.
To find the relationship between two parameters x and y, the Karl Pearson's correlation coefficient, r is used and it is determined as follows –

$$r = \frac{n \sum x y - \sum x \sum y}{\sqrt{[n \sum x^2 - (\sum x)^2][n \sum y^2 - (\sum y)^2]}} \qquad \text{----------------(1)}$$

here, n = number of data points ; x = values of x–variable ;
y = values of y–variable

To evaluate the straight–line by linear regression , following equation of straight line can be used

$$y = a x + b \qquad \text{----------------(2)}$$

here, y = dependent variable ; x = independent variable ;
a = slope of line; b = intercept on y–axis

$$a = \frac{n \sum x y - \sum x \sum y}{n \sum x^2 - (\sum x)^2} \qquad \text{----------------(3)}$$

$$\text{and} \quad b = \bar{y} - a\bar{x} \qquad \text{----------------(4)}$$

here, x = mean of all values of x ; y = mean of all values of y

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To study the correlation between various water quality parameters, the regression analysis was carried out using computer software SPSS, version–7.5.

Table 1 : Details of sampling sites

S.No.	Number and Name of site	Location of site	Depth of boaring	Type of source	Apparent water quality	Use of water
1	I, IM2 Hand pump at Preet Vihar	6 km south-west to Moradabad collectorate	Approx. 34 meter	Only source of water	Odourless, turns yellowish on standing	Drinking, domestic purposes
2	II, IM2 Hand pump at Balmiki Basti	2 km east to site no. I	Approx. 33 meter	Only source of water	Colourless, odourless	Drinking, bathing etc.
3	III, IM2 Hand pump at Balmilki Shiv Mandir, Khushalpur	5 km south-west to Moradabad collectorate	Approx. 35 meter	Only source of water	Colourless, odourless	Drinking, laundering
4	IV, IM2 Hand pump at Ambedkar park, Alkhnanda colony	0.5 km north to site no. III	Approx. 33 meter	Only source of water	Colour of water turns yellowish-brown on standing	Drinking, bathing
5	V, IM2 Hand pump at Bank Colony	1.5 km north to site no. III	Approx. 36 meter	Only source of water	Colourless, odourless	Drinking, domestic purposes
6	VI, IM2 Hand pump at Prathmik Vidyalay, Khushalpur	0.5 km south to site no. V	Approx. 35 meter	Only source of water	Colourless, odourless	Drinking, domestic purposes
7	VII, IM2 Hand pump at Community center, Budh vihar	1.5 km north to Mandi samiti	Approx. 34 meter	Only source of water	Colourless, Fishy smell	Drinking, domestic purposes
8	VIII, IM2 Hand pump at Bamiki Basti, Majhola	1.0 km north to site no VII	Approx. 33 meter	Only source of water	Colourless, odourless	Drinking, bathing etc.
9	IX, IM2 Hand pump at Shiv Mandir , Buddh Vihar	2.5 km east to site no. III	Approx. 33 meter	Only source of water	Colour of water turns pale yellow on standing	Drinking, domestic purposes
10	X, IM2 Hand pump at Police station, Mandi Samiti	7.0 km south to Moradabad collectorate	Approx. 34 meter	Only source of water	Colour of water turns yellowish-brown on standing	Drinking, bathing
11	XI, IM2 Hand pump at Prathmik Kanya Vidyalay, Majhola	1.0 km north-east to site no. X	Approx. 34 meter	Only source of water	Colourless, odourless	Drinking only
12	XII, IM2 Hand pump at Putlighar square, Majhola	1.0 km east to site no. X	Approx. 33 meter	Only source of water	Colour of water turns yellow on standing	Drinking, washing

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3. Results and Discussion

Site-wise estimated values of thirteen water quality physico-chemical parameters with their prescribed W.H.O. standards are presented in Table 2 (W.H.O.1984). The comparison of estimated values of different parameters with W.H.O. standards indicated that drinking water is polluted with reference to all the parameters studied and water quality management is urgently needed in the study area. Following regression equations were obtained through statistical regression analysis of data presented in Table 2, taking conductivity as dependent variable for all the twelve data points of drinking water at Moradabad , India.

Conductivity = -0.191×Temperature+5.471 ------------------(5)
n = ,12 r = 0.825, F = 21.231, S = 0.09

here , n = number of data points ; r = correlation coefficient ;
F = variance ratio ; S = standard error of estimate

Conductivity = +1.143×pH-8.169 -----------------(6)
n = 12, r = 0.900, F = 42.716, S = 0.07

Conductivity =+0.006 ×Alkalinity –0.410 -----------------(7)
n = 12, r = 0.910, F = 48.001, S = 0.07

Conductivity = +0.003×Total Hardness-0.007 -----------------(8)
n = 12, r = 0.912, F = 49.165, S = 0.07

Conductivity = +9.656×Total Solids+0.082 ----------------(9)
n = 12, r = 0.969, F = 153.450, S = 0.04

Conductivity = +9.659×Total Dissolved Solids+0.236 ---------------(10)
n = 12, r = 0.907, F = 42.973, S = 0.07

Conductivity = +0.034×Biological Oxygen Demand+0.342 ----------------(11)
n = 12, r = 0.292, F = 0.933, S = 0.160

Conductivity = +0.009×Chemical Oxygen Demand+0.447 ---------------(12)
n = 12, r = 0.916, F = 51.916, S = 0.07

Conductivity = +0.003×Calcium+0.324 ----------------(13)
n = 12, r = 0.885, F = 36.056, S = 0.08

Conductivity = +0.009×Chloride+0.312 ----------------(14)
n = 12, r = 0.918, F = 53.453, S = 0.07

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$$\text{Conductivity} = +0.291 \times \text{Iron} + 0.244 \qquad \text{----------------(15)}$$

n=12, r = 0.802, F = 17.973, S = 0.10

$$\text{Conductivity} = +0.015 \times \text{Silica} + 0.298 \qquad \text{----------------(16)}$$

n = 12, r = 0.423, F = 2.180 , S = 0.15

Critical and logical analysis of above regression equations reveal following facts regarding correlation studies among various physico-chemical parameters when conductivity is taken as a dependent variable.

Conductivity shows significant correlation with eight water quality parameters namely pH value , alkalinity , total hardness , total solids , total dissolved solids , chemical oxygen demand , calcium, and chloride concentration of water with value of regression coefficient , r more than 0.90 i.e. there is more than 90% association in data. This correlation coefficient measures the degree of association or correlation that exists between two variables, one taken as dependent variable. The greater the value of regression coefficient, the better is the fit and more useful the regression variables. The values of variance ratio, F are high and standard error of estimate, S is low and these are also necessary requirements for significant correlation. Considerably significant correlation of conductivity with temperature and amount of iron in water with values of correlation coefficient, r more than 0.80 i.e. more than 80% association or correlation in data is also noticed during the regression analysis. The correlation of conductivity with biological oxygen demand and amount of silica in water is found to be insignificant with low values of variance ratio and high values of standard error of estimate.

4. Conclusion

On the basis of above discussion at may be concluded that conductivity is an important physico-chemical water quality parameter. Conductivity shows significant correlation with ten parameters out of twelve parameters studied for all the twelve data points. The parameters are : temperature , pH value , alkalinity , total hardness , calcium , total solids, total dissolved solids , chemical oxygen demand , chloride and iron concentration of water.

Since other parameters and their functions can be explained by using these conditions, utilization of such methodology will thus greatly facilitate the task of rapid monitoring of the status of pollution of water economically and this is the most important part of any pollution study to suggest some effective and economic way for water quality management. On the basis of present study it may be suggested confidently that the underground drinking water quality of study area can be checked effectively by controlling conductivity of water and this may also be applied to water quality management of other study areas. Present study may be treated as one step ahead towards the drinking water quality management.

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Table 2 : Site-wise estimated values of water quality physico-chemical parameters with their W.H.O. Standards

S. No.	Parameters	Site No. I	Site No. II	Site No. III	Site No. IV	Site No. V	Site No. VI	Site No. VII	Site No. VIII	Site No. IX	Site No. X	Site No. XI	Site No. XII	W.H.O. Std.
1	**Conductivity (μ Siemens/cm)**	0.82	0.57	0.64	0.80	0.62	0.47	0.60	0.83	0.92	0.99	0.60	0.59	0.300
2	**Temperature (^{o}C)**	24.5	26	25.5	25	25.5	26	25	24.5	24	24	24.5	25	-
3	**pH value**	7.85	7.55	7.70	7.80	7.75	7.65	7.75	7.90	7.90	7.95	7.70	7.60	7.0-8.5
4	**Alkalinity (ppm)**	215	185	170	205	165	155	165	220	210	215	170	165	100
5	**Total Hardness (ppm)**	255	220	290	310	230	205	225	315	325	385	235	230	100
6	**Total Solids (ppm)**	785	420	565	775	560	470	550	790	820	900	515	550	500
7	**Total Dissolved Solids (ppm)**	565	300	315	555	325	365	415	615	685	735	410	495	500
8	**Biological Oxygen Demand (ppm)**	9.5	11	12	9	10.5	11.5	10.5	11.5	11.5	13	8	10	6
9	**Chemical Oxygen Demand (ppm)**	45	10	15	40	15	15	12	48	54	52	20	30	10
10	**Calcium (ppm)**	105	100	120	180	130	90	110	200	230	250	120	115	100
11	**Chloride (ppm)**	60	25	30	55	30	35	30	55	70	75	45	35	200
12	**Iron (ppm)**	1.2	1.2	1.3	1.8	1.3	1.45	1.53	1.95	2.3	2.4	1.2	1.2	0.5
13	**Silica (ppm)**	22	20	20	25	30	26	28	25	30	35	25	28	-

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