Summary of the Minor Research Project

1. Name of Principal Investigator: Dr. K. V. Mehta
2. Department of P.I.: Chemistry
3. Name of College: R. R. Mehta College of Science & C. L. Parikh College of Commerce, PALANPUR-385001, Dist.-Banaskantha, State-Gujarat.
4. U.G.C. approval letter no. and date: 47-2100/11(WRO), Dated: 18.04.12
5. Title of the Research Project: " Physicochemical, Statistical and Drinking Water Quality Analysis of Groundwater of Five Talukas of Banaskantha District of Gujarat State "
6. Period of Project: 18/04/2012 to 18/04/2014.

Summary of the Project

Banaskantha district is located in the northern part of Gujarat state. It shares its border with Rajasthan state in north, Sabarkantha district in east, Kutch district in west and Patan and Mehsana districts in south.

Banaskantha district includes the area around the Bank of Banas river. Sipu and Luni are also rivers of the district. These rivers remain almost dry in all seasons except in good monsoon.

According to 2001 census, the district has population 2504244 out of which 11% are urban i.e. most of the population of the district is located in rural areas. In summer, maximum temperature is very high (45^{o}C), while in winter, temperature remains very low (5^{o}C) in the district. Here rainfall is very irregular and drought is not a new phenomenon.

Due to increase in the population in last decades, stress on groundwater resources has been increased. In most of the part of the district, groundwater is used for drinking purpose also. Five talukas (Danta, Palanpur, Vav, Kankrej, Dhanera) of Banaskantha district were selected for this research work.

Most of the population in the selected five talukas of the Banaskantha district is in rural area and relies on ground water as a source of drinking water. Hence, if groundwater does not satisfy the quality standards for drinking water, it creates health hazards. Hence, quality analysis of water has become important.

Extensive field-work was carried out in the area of five talukas: Vav, Kankrej, Dhanera, Danta and Palanpur of Banaskantha district for collecting groundwater samples. Such samples were collected from sources like bore wells and tube wells. Collected water samples were stored in the pre-cleaned plastic containers.

Physicochemical Assessment (Laboratory Work):

These samples were collected, preserved and analyzed for physicochemical characteristics such as temperature, colour, odour, turbidity, electrical conductivity, pH, total dissolved solids, total alkalinity(CO_3^{2-} and

HCO_3^{1-}) and concentrations of ions like chloride, fluoride, calcium, magnesium, nitrate, sodium, potassium and sulfate.

Colour, odour and temperature were recorded as preliminary observations of the water samples. Instrumental methods and Chemical methods were used in laboratory work. Turbidity meter, pH meter, Colourimeter, Conductometer, TDS meter, flame photometer were used for the instrumental analysis while titration methods were used for ions like Ca^{2+}**,** Mg^{2+}, CO_3^{2-}, HCO_3^{1-}.

Physical parameters like pH and electrical conductivity(E.C.) were determined by pH meter and E.C. meter respectively. Total dissolved solids(TDS) and turbidity were measured by TDS meter and turbidity meter respectively. Chemical parameters like sulfate(SO_4^{2-}) was determined by colorimetric method, whereas, calcium(Ca^{2+}) and magnesium(Mg^{2+}) were determined by standard EDTA titration method. Carbonate(CO_3^{2-}) and bicarbonate(HCO_3^{1-}) were estimated by titrating with H_2SO_4. Chloride(Cl^{1-}) was determined by argentometric titration method. Sodium(Na^{1+}) and potassium(K^{1+}) were measurement by flame photometric method. Fluoride(F^{1-}) was measured by ion selective electrode. Nitrate (NO_3^{1-}) was measured by colorimetric method.

Temperature was measured in ^oC unit, turbidity was measured in NTU (Nephelometric Turbidity Unit) and pH was measured on pH scale (0 to 14). E.C. was recorded in μs cm^{-1} unit while values of parameters like TDS, concentrations of ions like Na^{1+}, K^{1+}, Ca^{2+}, Mg^{2+}, Cl^{1-}, F^{1-}, CO_3^{2-}, HCO_3^{1-}, SO_4^{2-} were expressed in mg/l unit.

Statistical Analysis:

Statistical analysis can be applied to represent the data of the water research work and useful in understanding the internal relations of various

parameters used for the physicochemical analysis. As initial part of statistical analysis, mean and standard deviation(S.D.) for the values of different parameters were calculated.

Correlation is a broad class of statistical relationship between two or more variables. Hence, it can be considered as a normalized measurement of covariance. The correlation study is useful to find a predictable relationship which can be exploited in practice. It is used for the measurement of the strength and statistical significance of the relation between two or more water quality parameters. Hence, it is helpful for the promotion of research activities. It can put forward possible causal or mechanistic relationships of research work. The correlation coefficients(r) were calculated. Pearson correlation matrix was obtained. Here, r is a dimensionless index which is in the range of -1.0 to +1.0 inclusive 0. It exhibits the extent of a relation between variables. The values of r from 0 to 1 and its indications are shown in the following Table. According to these indications, relation between variables was determined (Table-1).

Table - 1: Indications of values of coefficient (r)

Value of r	0.0 - 0.2	0.2 - 0.4	0.4 - 0.6	0.6 - 0.8	0.8 - 1.0
Indication of the relation	Very poor correlation	Slightly significant correlation	Moderate correlation	High correlation	Very high correlation

Drinking Water Quality Comparison:

The standard or guideline for drinking water prescribes the essential or desirable characteristics to be tested for ascertaining the appropriateness of water for drinking purpose. These standards drew up directives for the purity of water intended for human consumption. Quality of water samples has been compared with the Indian Standard (IS: 10500) and ICMR (Indian Council of Medical Research) specifications for drinking water, guidelines suggested by the World Health Organisation (WHO) and EU (European Union). This comparison becomes helpful in determining suitability of water for drinking purpose.

Conclusion:

The present work has led to conclude that the quality of water samples studied were acceptable from the some of the physicochemical parameters but as pH, TDS, F^{1}, Cl^{1-}, NO_3^{1-} and Na^{1+} values of many samples were violating the desirable limit suggested by ICMR, the water should be treated properly before its usage as drinking water to avoid probable unpleasant effects. Remedial measures should be taken. If the groundwater used for drinking and other domestic activities is contaminated, it creates intimidation to the health of the people. If the ground water is not suitable as to be used in irrigation, it affects farming. Hence, periodical evaluation of water quality requires serious attention. Water quality assessment is pre-requisite to the water quality management. To protect and manage quality and quantity of groundwater is essential for the healthy progress of any nation.

Temperatures of these samples were in the range of 24.0^{o}C to 27^{o}C.

It was noted by direct observation that all the water samples were found colourless and clear. Odour is recognized as a quality factor affecting acceptability of drinking water and food prepared from it. Organic and

inorganic substances add taste and odour. Direct inspection of the samples for odour was done and found that samples were odourless.

Turbidity is an important physical property of water. Turbidity indicates dimness of water. High value of turbidity indicates presence of many suspended particles in water. Consumer acceptance of such water decreases. Clear water contains low turbidity level while grubby water contains high turbidity level. For all water samples, turbidity was in the range of 1 to 2.60 NTU(Nephelometric Turbidity Unit). It indicates that suspended and colloidal matters are present in very negligible amount in the samples of water.

The pH value of water is an expression of how acidic or basic the water is on the scale of 0 to 14. pH lower than 4 will produce sour taste and higher value above 8.5 will produce bitter taste. Higher pH accelerates the scale formation in water heating apparatus. pH below 6.5 starts corrosion in pipes, thereby releasing materials such as Zn, Cd, Cu, etc. pH values of water samples were found in the range of 4.1 to 8.9.

The value of TDS describes the general quality of water. Total dissolved solids in water originates from various factors like minerals, sewage, natural sources, the nature of piping which is used to convey the water, agricultural runoff, etc. Many dissolved substances are undesirable in water. TDS values for the samples of Dhanera taluka region varied from 696 to 1500 mg/l. For TDS, ICMR suggests 500 mg/l as the desirable limit while 1500-3000 mg/l as the maximum permissible limit. Here, the groundwater samples of Alwada, Dedha, Rajoda, Kunwarala, Bhatram, Vasan, Bapla, Pengiya and Valer showed TDS values which were exceeding the desirable limit. High TDS value reduces the quality and affects the taste of water. If drinking water contains high TDS, palatability decreases and may cause gastro intentional irritation. The presence of high levels of TDS may also be

objectionable to consumers, owing to too much scaling in water pipes, boilers and domestic appliances.

TDS values for the samples of Kankrej taluka varied from 770 to 1029 mg/l having mean value 892.60 and standard deviation(S.D.) 93.56. For TDS, IS suggests 500 mg/l as the desirable limit while 2000 mg/l as the maximum permissible limit in the absence of alternate source. Here, the water samples of Panswal, Tervada, Kunwarva, Adhgam, Tana, Khasa, Raner, Mota Jampura, Khariya, and Jakhel showed TDS values which were exceeding the desirable limit. High TDS values: 960 and 1100 mg/l were also observed respectively in the samples of Dalwada and Dhelana of Palanpur Taluka. The water sample from Nagel of Danta taluka also showed higher value of TDS(1210 mg/l). TDS values for the samples of Vav taluka region varied from 875 to 1600 mg/l. Here, samples of Eta, Fangadi, Golgam, Kareli, Vandhiyavas, Limbuni, Dharadhara, Boru Dudosan and Joradiyali of vav taluka showed TDS values which were exceeding the desirable limit. High TDS value reduces the quality and affects the taste of water.

In water resources, concentration of fluoride is increasing due to geochemical dissolution of fluoride containing minerals, fast urbanization and modern industrialization. Fluoride concentrations in water differ with the type of rock from which water flows. Higher concentration of fluoride also causes respiratory failure, variation in blood pressure and general paralysis. The permissible limit for F^{1-} is 1.0-1.5 mg/l indicated by IS and WHO. Presence of large amount of fluoride (> 1.5 mg/l) is associated with dental and skeletal fluorosis, while inadequate amount of fluoride (<1.0 mg/l) is associated with dental carries. In all these five talukas, F^{1-} was found in the range of 0.60 to 1.52 ppm. The F^{1-} concentration in samples of Vav taluka was from 0.80 to 1.50 mg/l having mean value 1.15. Three samples of

Fangadi, Vandhiyavas, Dudosan of Vav region were not up to the desirable limit (1.0 mg/l) indicated by ICMR.

Alkalinity levels vary across India. If alkalinity value in drinking water is higher, the taste of the water becomes unlikeable. Total alkalinity(CO_3^{2-} and HCO_3^{1-}) of samples was from 214 to 578 mg/l.

Cl^{1-} is one of the major inorganic anion of water. The salty taste is produced by the chloride concentration is variable and dependent on the chemical composition of water composition. High chloride may harm metallic pipes and growing plants. For, Cl^{1-}, ICMR suggests the limit 200 mg/l while EU suggests the limit 250 mg/l. In the water samples, concentration of Cl^{1-} was from 77.39 to 300 mg/l. Samples of Rajoda, Kunwarala, Valer, Sadarpur and Kesarpura crossed the limit indicated by EU.

Sulfate is found in most mineral waters. It can cause a pungent odour and taste in water and may have a laxative effect. For SO_4^{2-}, ICMR indicates 200 mg/l as desirable limit. Concentration of SO_4^{2-} was in the range of 5.20 to 62.41 mg/l. So, all the samples were within the limit for SO_4^{2-} indicated by ICMR and EU.

Increasing nitrate in water is a big peril to the public health. High nitrate level was not found in this area except in some cases of Vav taluka. In the groundwater samples of Vav taluka, the nitrate values varied from 6.14 to 22.15 mg/l having standard deviation 10.58. Majority of the samples of Vav taluka were beyond the limit for nitrate indicated by ICMR(20 mg/l). One sample of Palanpur Taluka also showed higher concentration of Nitrate(32 mg/ml).

Potassium is present in rock and soil. Sources of potassium include fertilizer and erosion of potassium-bearing minerals like feldspar. In water, potassium has no smell or colour, but may give water a salty taste. Potassium is vital for the body. Undesirable health effects from exposure to higher

potassium in drinking water are unlikely in healthy people. Potassium and sodium maintain the body's water balance. Potassium is also associated with nerve function and blood pressure. Concentration of K^{1+} was in the range of 0.39 to 26 mg/l.

High level of Na^{1+} is associated with excessive salinity and is found in many minerals in water. Concentration of Na^{1+} in groundwater samples of Vav taluka was in the range of 159.85 to 215.05 mg/l, having standard deviation 19.15. Samples of Dharadhara and Dudosan of Vav region have higher concentration of Na^{1+} compared to EU limit for Na^{1+}(200 mg/l). Higher level of salinity(sodium hazard) was also noticed samples of Kudwa(Kankrej) and Dhareda(Danta region).

Hardness of water is caused by the presence of the multivalent cations and is largely due to calcium and magnesium ions. In the samples of Vav taluka, Ca^{2+} concentration ranged from 6.14 to 22.15 mg/l, while Mg^{2+} content was found from 4.68 to 21.73 mg/l. Thus, the amount of Ca^{2+} present in the samples was within the desirable limit indicated for Ca^{2+} by ICMR. Higher Ca^{2+} and Mg^{2+} concentration was found in some cases of Danta taluka, but the concentration of Ca^{2+} was below 75 mg/l and Mg^{2+} was below 30 mg/l. Hence, the concentrations were within the range of prescribed limit of Ca^{2+} and Mg^{2+} indicated by ICMR.

Water quality is affected by sewage and industrial discharges, run-off from agricultural fields and urban run-off. Water quality is also influenced by floods and droughts and can also arise from lack of awareness among people. The need for public involvement in maintaining water quality is also an important aspect to maintain the quality of water resources. Raising understanding of appropriate practices will help the people recognize the gloomy realities of depleting water resources and at the same time help in engaging them in monitoring and maintenance of water quality.

Public should be made aware of water quality. Watchful management of precious natural liquid asset is a need of time. For the welfare of the human being, water quality should be assessed on the regular basis. Monitoring alone will not solve groundwater problems. Active participation of people to keep the situation of groundwater under control is also of a great worth. With the people awareness, our future will be sparkling, indeed!

E-ISSN: 2278–179X

JECET; March - May 2013; Vol. 2, No. 2, 339-349.

Journal of Environmental Science, Computer Science and Engineering & Technology

An International Peer Review E-3 Journal of Sciences and Technology

Available online at www.jecet.org

Environmental Science

Research Article

A Study of Physicochemical, Statistical and Drinking Water Quality Analysis of Groundwater of Kankrej Taluka of Banaskantha District of Gujarat State (India)

Kiran V. Mehta

Department of Chemistry, R. R. Mehta College of Science and C. L. Parikh College of Commerce, PALANPUR-385001, Dist. – Banaskantha, State - Gujarat(India)

Received: 6 April 2013; **Revised:** 29 April 2013; **Accepted:** 2 May 2013

Abstract: As a supplementary resource to surface water, groundwater is a precious natural resource for drinking water. Like the other natural resources, it should be monitored sporadically and citizens should be made aware of the quality of drinking water. For the present study, different samples of groundwater were collected from the various locations of Kankrej taluka of Gujarat state of India and their physicochemical parameters like temperature, colour, odour, turbidity, electrical conductance (E.C.), pH, total dissolved solids (TDS), total alkalinity and concentrations of ions like fluoride, chloride, sulfate, nitrate, calcium, magnesium sodium and potassium were assessed. The results were compared with the drinking water guidelines of Indian Standard (IS) and World Health Organization(WHO). For the statistical studies, values of mean, standard deviations and correlation co-efficient (r) were calculated to determine the strength of relation between variables.

Key words: Groundwater, physicochemical parameters, statistical analysis, correlation co-efficient, drinking water quality, IS, WHO, welfare of human being.

INTRODUCTION

Water quality is characterized by many variables, which exhibit water composition in specific locations and time. Rainwater, if not contaminated by atmospheric pollutants, is highly pure while at

the other hand, the seawater contains large amount of salts. Water for a variety of uses can be obtained from the sources like precipitation in the form of rain, snow and hail while surface water in the form of glaciers, streams, rivers and seawater. Besides these sources of water, there is also a natural rich source of water in the form of groundwater, which is supplementary to the surface water.

Groundwater occurs as a part of the hydrological metamorphosis of permeable structured zones of the rocks, gravel and sand. Groundwater can be obtained from aquifers and hypopheric zones. Fractured crystalline bedrocks are excellent sources of potable water in many parts of the world. In today's world, the demand of water is swiftly increasing due to substantial increase in population, industrialization and urbanization. This demand fulfilled by surface water and groundwater. To provide safe drinking water is a very big accountability for the governments. Today, a big part of the population does not have pure water to drink. Easily and regularly available clean drinking water is still a harsh task to achieve not only in deserts but also in most of the mega cities and small towns. Man has yet to perfect his management of the liquid asset.

In rural arid and semi arid regions, where well managed water transportation system and related infrastructures are not available, groundwater serves as chief source of drinking water. Groundwater is an excellent reservoir of water but as rivers, lakes and streams influenced by natural and human factors, groundwater is also facing the same situation around the world. Human activities, hydrological aspects and characteristics of recharged water affect the quality of groundwater. As groundwater used in high extent, its quality becomes worse. Water quality has gained very high attention not only at local level, but also at global level also[1-11]. Similar to other countries, issue of groundwater has become an issue of importance for the progress of India. Unrestricted exploration of groundwater and excessive use of fertilizers and pesticides make possible the infiltration of detrimental constituents to the groundwater. Domestic and industrial waste also defiles groundwater. As a result, groundwater becomes unhygienic.

Groundwater is a valuable liquid asset for any country of the world. In India, as groundwater is ultimate and key water resource, people use groundwater for drinking purpose. In addition to this, groundwater is also used in agricultural and industrial fields. If the groundwater used for drinking and other domestic activities is contaminated, it creates intimidation to the health of the people. Hence, periodical evaluation of water quality requires serious attention. Water quality assessment is pre-requisite to the water quality management. To protect and manage quality and quantity of groundwater is essential for the healthy development of any country.

EXPERIMENTAL

The present study is related to the groundwater quality of some places of the Kankrej Taluka which is situated in Banaskantha district of Gujarat state of India. Banaskantha district includes the area around the Bank of Banas river. The district lies on the north-west side of Gujarat State. There are twelve talukas in the district and Kankrej taluka is one of them. Weather of this taluka is dry and hot. In winter, temperature goes down to 5^0 to 10^0 C, while in summer, temperature raises up to 45^0C. In this taluka, agriculture and dairy production are the key monetary activities. Wheat, Bajara and Juwar are general crops of the taluka. From this taluka, groundwater samples of bore/tube wells were collected in November-December, 2012. The samples were collected from the different places like: (a) Panswal, (b) Tervada, (c) Kunwarva, (d) Adhgam, (e) Tana, (f) Khasa, (g) Raner, (h) Motu Jampura, (i) Khariya, (j) Jakhel. These samples were collected, preserved and analyzed for physicochemical characteristics such as temperature, colour, odour, turbidity, electrical conductivity, pH, total dissolved solids, total alkalinity and concentrations of ions like chloride, fluoride, calcium,

magnesium, nitrate, sodium, potassium and sulfate by the standard methods described in the literature[12-22].

RESULTS AND DISCUSSION

Values of different physicochemical characteristics of water samples are shown in **Table-1**. Quality of these water samples is compared with the Indian Standard (IS: 10500) specifications for drinking water and guideline suggested by the World Health Organization (WHO: 1993). These agencies drew up directives for the purity of water intended for human consumption.

The standard or guideline prescribes the requirements for the essential and desirable characteristics to be tested for ascertaining the appropriateness of water for drinking purpose. IS: 10500(1991)– Drinking Water Specification was originally published in 1983 with the idea of assessing the quality of water resources and verifying the effectiveness of water treatment. Its first revision was published in 1991.Values of variables in excess of those mentioned under 'Desirable' make the water not acceptable, but still may be tolerated in the absence of alternative source. Beyond the 'Permissible limit in the absence of alternate source', the sample have to be rejected i.e. it is not fit for drinking purpose. Drinking water guideline of IS: 10500 (1991)(reaffirmed: 1993) and WHO(1993) are shown in **Table-2.**

Temperatures of these samples were in the range of 24.8°C to 25.7°C.

It was noted by direct observation that all the water samples were found colourless and clear. Odour is recognized as a quality factor affecting acceptability of drinking water and food prepared from it. Organic and inorganic chemicals contribute taste and odour. These chemicals may originate from waste discharges, natural sources such as rotting of vegetable matter related microbial activity. Direct inspection of the samples for odour was done and found that samples were odourless.

Turbidity in water is the reduction in transparency due to the presence of particulate matter such as slit, finely divided matter and microscopic organisms. The colloidal material exerts turbidity generates adsorption sites for chemicals that may create disagreeable taste and smell. Disinfection of turbid water is difficult because of the adsorptive nature of some colloids and because the solids may somewhat shield organisms from a disinfectant. Turbidity indicates dimness of water. High value of turbidity indicates presence of many suspended particles in water. If the value of turbidity is above 5 NTU (Nephelometric Turbidity Unit), consumer acceptance of such water decreases. It is an important feature for characterization of water. Clear water contains low turbidity level while grubby water contains high turbidity level. For all the water samples, turbidity was in the range of 1.5 to 1.9 NTU having standard deviation of 0.14. It indicates that suspended and colloidal matters were present in very negligible amount in the water samples. The look of water with a turbidity of less than 5 NTU is usually suitable to consumers, although this may vary with local circumstances. High values of electrical conductivity (E.C.) exhibits large amount of salts dissolved in water. This kind of property is not desired because it makes water inappropriate for drinking. Electrical conductivity of the water samples varied from 1109.23 to 1461 $\mu s\ cm^{-1}$ having standard deviation of 122.77 $\mu s\ cm^{-1}$.

pH is a measure of hydrogen ion concentration. The pH value of water is an expression of how acidic or basic the water is on the scale of 0 to 14. For pH values, general acceptable limit is 6.5 to 8.5. pH lower than 4 will produce sour taste and higher value above 8.5 bitter taste. Higher pH hastens the scale formation in water heating apparatus. pH below 6.5 starts corrosion in pipes, thereby releasing materials such as Zn, Cd, Cu, etc. pH values of water samples were found in the range of 7.74 to 8.54 having mean value 8.15 and standard deviation 0.25. pH values (>7) are indicative of alkaline nature of water. One sample (b) was slightly beyond the desirable limit of pH suggested by IS and WHO.

Table-1: Values of physicochemical parameters

Parameter	a	b	c	d	e	f	g	h	i	j	Mean	S.D.
Temp. ^{0}C	25.5	24.8	24.8	25.0	25.3	24.9	25.2	25.3	25.7	25.0	25.10	0.32
Colour	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	Cl	-	-
Odour	Ol	Ol	Ol	Ol	Ol	Ol	Ol	Ol	Ol	Ol	-	-
Turbidity (NTU)	1.5	1.9	1.8	1.8	1.8	1.6	1.7	1.7	1.8	1.6	1.69	0.14
E.C. ($\mu s\ cm^{-1}$)	1218.03	1461.10	1394.04	1298.86	1415.91	1118.14	1201.01	1109.23	1329.35	1223.11	1276.87	122.77
pH	7.93	8.54	8.43	8.21	7.74	8.10	8.28	7.85	8.34	8.21	8.15	0.25
TDS(mg/l)	849	1016	965	927	1029	770	821	789	932	828	892.60	93.56
Cl^{1-} (mg/l)	105.79	143.07	231.11	94.79	146.62	77.39	123.54	122.12	183.18	160.11	138.77	45.13
Total Alkalinity (mg/l)	303.13	366.01	287.02	357.68	381.82	344.1	245.74	354.02	261.7	408.56	324.60	46.89
F^{1-} (mg/l)	0.95	1.28	1.35	1.30	1.01	0.83	1.21	1.03	1.10	1.36	1.15	0.19
Ca^{2+} (mg/l)	12.60	11.40	19.41	9.82	12.80	15	10.20	9.82	11	8.41	12.05	3.20
Mg^{2+} (mg/l)	3.12	8.76	7.92	7.08	9.36	5.04	7.44	10.08	9.12	6.48	7.44	2.13
NO_3^{1-}(mg/l)	30.38	23.56	16.12	29.14	19.22	24.18	40.31	37.82	45.58	39.68	30.63	9.97
Na^{1+}(mg/l)	198.49	225.4	214.59	181.47	214.36	186.99	181.7	190.9	220.11	250.70	203.87	24.27
K^{1+}(mg/l)	0.39	1.95	1.95	3.51	2.34	1.17	0.78	1.95	3.12	2.73	1.99	0.10
SO_4^{2-}(mg/l)	36.48	33.12	19.2	35.52	29.28	54.24	62.41	34.56	45.12	37.44	38.74	17.02

Temp.: Temperature, **Cl :** Clear, **Ol :** Odourless, **S.D.** : Standard Deviation.

Table-2: Drinking Water Specifications

Parameter	Drinking Water Guideline		
	Indian Standard(IS): 10500(1991)		World Health Organization(WHO)'s Guideline (1993)
	Requirement (Desirable limit)	Permissible limit in the absence of alternate source	Acceptable limit
Odour	Unobjectionable	-	-
Turbidity(NTU)	Less than 5 NTU	10 NTU	Less than 5 NTU
E.C.($\mu s\ cm^{-1}$)	-	-	250
pH	6.5 to 8.5	No relaxation	6.5 to 8.5
TDS(mg/l)	500	2000	-
Cl^{1-} (mg/l)	250	1000	-
Total Alkalinity (mg/l)	200	600	-
F^{1-} (mg/l)	1.0	1.5	1.5
Ca^{2+} (mg/l)	75	200	-
Mg^{2+} (mg/l)	30	100	-
NO_3^{1-} (mg/l)	45	-	50(Total nitrogen)
Na^{1+}(mg/l)	-	-	200
K^{1+}(mg/l)	-	-	-
SO_4^{2-}(mg/l)	200	400	-

As water is excellent solvent, it picks up many impurities. Total dissolved solids in water originates from various factors like minerals, sewage, natural sources, the nature of piping which is used to convey the water, agricultural runoff, etc. Many dissolved substances are undesirable in water. The value of TDS describes the general quality of water. TDS values for the samples varied from 770 to 1029 mg/l. For TDS, IS suggests 500 mg/l as the desirable limit while 2000 mg/l as the maximum

permissible limit in the absence of alternate source. Here, all the samples (a to j) showed TDS values which were exceeding the desirable limit. High TDS value reduces the quality and affects the taste of water. If drinking water contains high TDS, palatability decreases and may cause gastro intentional irritation. The presence of high levels of TDS may also be objectionable to consumers, owing to too much scaling in water pipes, boilers and domestic appliances.

Cl^{1-} is one of the major inorganic anion of water. The salty taste is produced by the chloride concentration is variable and dependent on the chemical composition of water composition. High chloride may harm metallic pipes and growing plants. For, Cl^{1-}, IS suggests the limit 250-1000 mg/l. Beyond this limit taste, corrosion and palatability are affected. In the water samples, concentration of Cl^{1-} was from 77.39 to 231.11 mg/l having mean value 138.77 and standard deviation 45.13.

Alkalinity levels vary across India. If alkalinity value in drinking water is higher, the taste of the water becomes unlikeable. In the water samples, total alkalinity was from 245.74 to 381.82 mg/l having mean value 324.60 and standard deviation 46.89.

In water resources, concentration of fluoride is increasing due to geochemical dissolution of fluoride containing minerals, fast urbanization and modern industrialization. Fluoride concentrations in water differ with the type of rock from which water flows. Higher concentration of fluoride also causes respiratory failure, variation in blood pressure and general paralysis. Presence of large amount of fluoride (>1.5 mg/l) is associated with dental and skeletal fluorosis, while inadequate amount of fluoride (<1.0 mg/l) is associated with dental carries. Large population in India is affected by fluorosis. The F^{1-} concentration in samples was from 0.83 to 1.36 mg/l having mean value 1.15. No sample was violating permissible limit (1.0-1.5 mg/l) indicated by IS and WHO.

Hardness of water is caused by the presence of the multivalent cations and is largely due to calcium and magnesium ions. Calcium is a major constituent of different types of rocks. Similarly, magnesium salts are also important contributors in the hardness of water. Absolute soft water is tasteless. With the raise in hardness of water, its appropriateness decreases for cooking, cleaning and laundry jobs and if the concentration of magnesium is more than 300 mg/l, it is toxic [24]. Ca^{2+} and Mg^{2+} may combine with SO_4^{2-} causing stable hardness which cannot be removed by boiling. Such water may be softened by ion exchange process that is capable of exchanging Na^{1+} or H^{1+} for Ca^{2+} and Mg^{2+}. In the samples, Ca^{2+} concentration ranged from 8.41 to 19.41 mg/l, while Mg^{2+} content was found from 3.12 to 10.08 mg/l. So, the amount of Ca^{2+} present in the samples was within the desirable limit indicated for Ca^{2+} by IS. No sample was exceeding the maximum permissible limit indicated by IS for Mg^{2+}.

In groundwater, nitrate may result due to livestock facilities, agrochemicals and sewage disposal. Increasing presence of nitrate in water is a big threat to the public health. The nitrate rich water is not fit for drinking. Excess of nitrate in drinking water may become the cause of methemoglobinemia (blue baby syndrome). The nitrate values of the samples varied from 16.12 to 45.58 mg/l having mean value 30.63 and standard deviation 9.97. Hence, the observed values were not too high. Only in one sample (i), NO_3^{1-} concentration was 45.58 mg/l. Sodium is an essential mineral in our diet. It is generally found in the form of sodium chloride (salt). It dissolves easily in water and gives water a salty taste at levels greater than 180mg/l to 200 mg/l. All natural waters contain some sodium. High level of Na^{1+} is associated with excessive salinity and is found in many minerals in water. Concentration of Na^{1+} was in the range of 181.47 to 250.70 mg/l, having mean value 203.87 and standard deviation 24.27.

Potassium is present in rock and soil. Sources of potassium include fertilizer and erosion of potassium-bearing minerals like feldspar. In water, potassium has no smell or colour, but may give

water a salty taste. Potassium is vital for the body. Undesirable health effects from exposure to higher potassium in drinking water are unlikely in healthy people. Potassium and sodium maintain the body's water balance. Potassium is also associated with nerve function blood pressure. Concentration of K^{1+} was in the range of 0.39 to 3.51 mg/l, having mean value 1.99 and standard deviation 0.10. Sulfate is found in most mineral waters. It can cause a pungent odour and taste in water and may have a laxative effect. For SO_4^{2-} , is indicates 200 mg/l as desirable limit. Beyond this causes gastro intentional irritation when magnesium or sodium is present. Concentration of SO_4^{2-} was in the range of 19.2 to 62.41 mg/l, having mean value 38.74 and standard deviation 17.02.

STATISTICAL ANALYSIS

Statistical analysis can be applied to represent the data of the water research work and useful in understanding the internal relations of various parameters used for the physicochemical analysis. Many research workers have applied statistical analysis to their results [25-37]. As initial part of statistical analysis, mean and standard deviation for the values of different parameters were calculated and are shown in **Table-1**.

Correlation is a broad class of statistical relationship between two or more variables. Hence, it can be considered as a normalized measurement of covariance. The correlation study is useful to find a predictable relationship which can be exploited in practice. It is used for the measurement of the strength and statistical significance of the relation between two or more water quality parameters. Hence, it is helpful for the promotion of research activities. It can put forward possible causal or mechanistic relationships of research work. The correlation coefficients(r) were calculated and correlation matrix was obtained. Here, r is a dimensionless index which is in the range of -1.0 to +1.0 inclusive 0. It exhibits the extent of a relation between variables. The values of r from 0 to 1 and its indications are shown in **Table-3.** The values of correlation coefficients for different variables are listed in **Table-4.**

Table - 3: Indications of values of coefficient r

Value of r	Indication of the relation
0 - 0.2	Very poor correlation
0.2 - 0 .4	Slightly significant correlation
0 .4 - 0.6	Moderate correlation
0 .6 - 0.8	High correlation
0.8 - 1	Very high correlation

Table - 4: Correlation Matrix for Various Parameters

Parameter	Temp.	Tur.	E.C.	pH	TDS	Cl^{1-}	T.A.	F^{1-}	Ca^{2+}	Mg^{2+}	NO_3^{1-}	Na^{1+}	K^{1+}	SO_4^{2-}
Temp.	1.000													
Tur.	-0.179	1.000												
E.C.	-0.307	0.247	1.000											
pH	-0.768**	0.415	0.387	1.000										
TDS	-0.307	0.252	0.980**	0.234	1.000									
Cl^{1-}	-0.360	0.020	0.572	0.360	0.498	1.000								
T.A.	-0.263	0.141	0.514	0.183	0.552	-0.202	1.000							
F^{1-}	-0.538	0.287	0.469	0.636*	0.368	0.547	-0.147	1.000						
Ca^{2+}	-0.257	0.205	0.270	0.062	0.242	0.403	0.038	-0.125	1.000					
Mg^{2+}	0.055	0.470	-0.473	0.071	0.437	0.440	0.089	0.276	-0.142	1.000				
NO_3^{1-}	0.232	-0.361	0.456	0.089	-0.494*	-0.095**	-0.255	-0.032	-0.731	0.077	1.000			
Na^{1+}	-0.554	-0.168	0.374	0.327	0.373	0.648	-0.134	0.500	-0.084	0.366	0.048	1.000		
K^{1+}	-0.357	0.130	-0.565	0.193	0.417	0.297	0.129	0.471	-0.287	0.523	0.137	0.498	1.000	
SO_4^{2-}	0.045	0.183	-0.330	0.107	-0.599	-0.532	0.244	-0.340	-0.371	-0.254	0.559	-0.358	0.347	1.00

Temp.: Temperature, E.C. : Electrical Conductance, Tur. : Turbidity, T.A. : Total Alkalinity.

*** Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).**

Very high positive correlation was found between TDS and E.C. High negative correlation was found between pH and temperature.

Very poor positive correlation was of –

Temperature with Mg^{2+}, SO_4^{2-},

Turbidity with Cl^{1-}, T. A., K^{1+}, SO_4^{2-},

pH with T. A., Ca^{2+}, Mg^{2+}, NO_3^{1-}, K^{1+}, SO_4^{2-},

T. A. with Ca^{2+}, Mg^{2+}, K^{1+},
Mg^{2+} with NO_3^{1-},
NO_3^{1-} with Na^{1+}, K^{1+}.

Very poor negative correlation was of –

Temperature with turbidity,
Turbidity with Na^{1+},
Cl^{1-} with T.A., NO_3^{1-},
T.A. with F^{1-}, Na^{1+},
F^{1-} with Ca^{2+}, NO_3^{1-},
Ca^{2+} with Mg^{2+}, Na^{1+}.

CONCLUSION

The present study has led to conclude that the quality of water samples studied were acceptable from the majority of the physicochemical parameters but as TDS values of all the samples were violating the desirable limit suggested by IS, the water should be treated properly before its usage as drinking water to avoid probable adverse effects. Therefore, public should be made aware of drinking water quality. Management of precious natural liquid asset is essential need of today's time. For the welfare of the human being, water quality should be assessed on the regular basis.

ACKNOWLEDGEMENT

The author is indebted to the University Grants Commission **(U.G.C.)** of India for the financial assistance to the Minor Research Project.

REFERENCES

1. O. Ombaka, J.M. Gichumbi, D. Kibara, Evaluation of Ground Water and Tap Water Quality in the Villages Surrounding Chuka Town, Kenya, *J. Chem., Biol. Phys. Sci.*, 2013, **3(2),** 1551-1563.
2. A. A. Hamidu, A. Umar, Determination of Physicochemical Characteristics of Water in Mubi South Local Government Area of Adamawa State, *J. Phys. Sci. Innov.*, 2012, **4,** 73-77.
3. E. Bearnard, N. Ayeni, Physicochemical Analysis of Groundwater Samples of Bichi Local Government Area of Kano State of Nigeria, *World Environ.*, 2012, **2(6),**116-119.
4. F. Konstantopoulou, S. Liu, L.G. Papageorgiou, P. Gikas, Water Resources Management for Paros Island, Greece, *Int. J. Sust. Water Environ. Syst.*, 2011, **2(1),** 1 - 6.
5. S. G. Daraigan, A. S. Wahdain, A. S. Ba-Mosa, M. H. Obid, Linear Correlation Analysis Study of Drinking Water Quality Data For Al-Mukalla City, Hadhramout, Yemen, *Int. J. Environ. Sci.*, 2011, **1(7),** 1699-1708.
6. F. M. Al-Ruwaih, J. M. Alhumoud, S. M. Al-Mutairi, Quality of Potable Water in Kuwait, *Am. J. Environ. Sci.*, 2010, **6(3),** 260-267.
7. M. Laurent, M. J. Marie, Groundwater Quality of South-eastern Brazzaville, Congo, *E-J. Chem.*, 2010, **7(3),** 861-869.
8. A. Shahbazi, A. Esmaeili-sari, Groundwater Quality Assessment in North of Iran, A Case Study of the Mazandaron Province, *World Appl. Sci. J.*, 2009, **5,** 92-97.
9. M. A. Nkansah, J. H. Ephrain, Physicochemical Evaluation of the Water From Boreholes Selected From E J and BAK Districts of the Ashanti Region of Ghana, *Thammasat Int. J. Sci. Technol.*, 2009, **14(3),** 64-73.
10. O. Akoto, J. Adiyiah, Chemical Analysis of Drinking Water from Some Communities in the Brong Ahafo Region, *Int. J. Environ. Sci. Technol.*, 2007, **4(2),** 211-214.

11. R. Hurtardo Jimenez, G. Torrresdy, High Levels of Fluoride, Arsenic, and Selenium in Groundwater in Los-Altos De Jalisco, Mexico, *Fluoride*, 2005, **38(3)**, 234.
12. A. Narsimha, V. Sudarshan, P. Srinivasulu, B. Vishnu, M. R. Kumar, S. N. Kumar, Groundwater Quality and its Suitability for Drinking and Agricultural Purpose Around Chityal Area, Nalgonda District, Andhrapradesh, India, *Water Res. Dev.*, 2012, **2(3)**, 68 -75.
13. Food and Agriculture Organization (FAO), Chemical Analysis Manual for Food and Water, FAO, Rome, 1997, 20-26.
14. R. Reza, G. Singh, Physicochemical Analysis of Groundwater in Angul-Talcher Region of Orissa, India, *J. Am. Sci.*, 2009, **5(5)**, 53-58.
15. L.S. Clesceri, A.E. Greenberg, A.D. Eaton (Eds.), Standard Methods for the Examination of Water and Wastewater, American Public Health Association(APHA), American Water Works Association (AWWA), Water Environment Federation (WEF), Washington D.C., 20th edition, 1998.
16. S. Chakrabarty, J. Deka, H. P. Sarma, Water Quality Issues in Baihata Area of Kamrup(Rural) District, Assam, India, *Int. J. Chem. Sci.*, 2009,**7(4)**, 2914-2920.
17. N. F. Gray, Water Technology - An Introduction for Environmental Scientists and Engineers, Viva Books Pvt. Ltd., New Delhi (India), **1999**, 134-144.
18. S. Jain, M. Agarwal, Study of Physicochemical Characteristics of Groundwater of Various Villages Around Raiser, *J. Chem. Biol. Phy. Sci.*, 2012, **2(3)**, 1551-1555.
19. R. K. Trivedi, P. K. Goel, Chemical and Biological Methods for Water Pollution Studies, Environmental Publication, Karad (India), 1986, 1-112.
20. S. A. Abbasi, Water Quality, Sampling and Analysis, Discovery Publishing House, New Delhi(India), 1998, 1-12, 13-33, 51-57, 65-82, 102-110.
21. M. J. Barcelona, J. P. Gibb, R. A. Miller, A Guide to the Selection of Materials for Monitoring Well Construction and Groundwater Sampling, ICWS Contract Report 327, Illinois State Water Survey, Champaign, Illinois, 1983, 78.
22. V. P. Kudesia, Water Pollution, Pragati Prakashan, Meerut (India), 2007, 555-591.
23. T. Marimuthu, S. Rajendran, M. Manivannam, R. Nagalakshmi, N. Karthiga, Physicochemical Characteristics of Dye Effluent and Groundwater Samples in Karur District, Tamilnadu, India, *J. Chem. Biol. Phy. Sci.*, 2012, **3(2)**, 952 - 957.
24. K. S. Venkateswarlu, Water Chemistry - Industrial and Power Station Water Treatment, New Age International Pvt. Ltd., New Delhi (India), 1999, 7, 11.
25. J.Y. Lee, J.Y. Cheon, K.K. Lee, S.Y. Lee, M.H. Lee, Statistical Evaluation of Geochemical Parameter Distribution in a Groundwater System Contaminated with Petroleum Hydrocarbons, *J. Environ. Qual.*, 2001, **30**, 1548-1563.
26. D.M. Joshi, N.S. Bhandari, A. Kumar, N. Agrawal, Statistical Analysis of Physicochemical Parameters of Water of River Ganga in Haridwar District, *Rasayan J. Chem.*, 2009, **2(3)**, 579-587.
27. N. Jain, S. Saxena, R. K. Shrivastava, Correlation Coefficient of Some Physicochemical Characteristics of Groundwater of Jabalpur, *Ind. J. Environ. Prot.*, 2004, **24(1)**, 57-59.
28. J. Cohen, P.Cohen, S.G.West, L.S. Alken, Applied Multiple Regression/Correlation Analysis for the Behavioural Science, Hillsdale Lawrence Erlbaum Associates, 3rd edition, 2003.
29. R.O. Gilbert, Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold Co., New York, 1987, 320.
30. M.S. Mustaqeem, G.A. Usmani, Evaluation of Trends in Chemical and Physical Properties of Groundwater and its Modeling: A Correlation Regression Study, *Rasayan J. Chem.*, 2010, **3(2)**, 236 - 239.
31. G.F.P. Box, W.G. Hunter, J.S. Hunter, Statistics for Experiments, An Introduction to Design, Data Analysis and Model Building, John Wiley and Sons, Toronto, 1978, 653.
32. D. Chapman (Ed.), on the behalf of UNESCO,WHO, UNEP, Water Quality Assessments - A Guide to Use Biota, Sediments and Water in Environment Monitoring, F & F Spon, London, **1996**, Chapter-9.
33. R. N. Prasad, R. Chandra, K. K. Tiwari, A Correlation Study of Ground Water Chemistry of Bapi and Sundarsanpura Industrial Area of Dausa District, Rajasthan, *Poll. Res.*, 2010, **29(2)**, 359-363.