International Research Journal of Natural and Applied Sciences
Vol. 3, Issue 2, Feb 2016 IF- 2.818 ISSN: (2349-4077)
© Associated Asia Research Foundation (AARF)
Website: www.aarf.asia Email : editor@aarf.asia , editoraarf@gmail.com

ASSESMENT OF GROUND WATER QUALITY IN AND AROUND OF THURAIYUR TALUK, TRICHY DISTRICT, TAMILNADU.

R. Sudha.

PG and Research Department of Zoology, Nehru Memorial College (Autonomous), (Accredited with 'A' Grade by NAAC) Puthanampatti-621 007, Tiruchirappalli District, Tamil Nadu, India.

ABSTRACT

The ground water quality in Thuraiyur taluk was monitored for a period of 3 months from January to March – 2014. Samples were collected at 4 sampling stations namely Thuraiyur (S1), Keerambur (S2), Sorathur (S3) and Puthanampatti (S4). Quality of water samples were assessed by analyzing various parameters such as phosphate, silicate, total hardness and hydrogen sulphide. The multivariate analysis was performed by SPSS (Ver. 16.0) software. In these parameters phosphate ranged from 0.33±0.06 to 5.11±0.10 in S4 and S2 respectively, Silicate from 0.89±0.01 to 0.99±0.04 in S2 and S1 respectively. Total hardness was high in (593.47± 28.18) S4 when compared to other stations. Hydrogen sulphide varied from 3.19± 0.77 to 8.32±0.47 in S1 and S4 respectively.

KEYWORDS – Thuraiyur taluk, Ground water quality, Phosphate, Silicate, Total hardness, Hydrogen sulphide.

Introduction:

Ground water is a valuable and important water resource for domestic, agricultural, and industrial in both rural and urban places. Almost one fifth of all the water obtained from ground water in world wise (Muthukumar *et al*., 2011). Ground water quality, particularly, concentration of dissolved ions, solids and minerals, are directed by ground water flow, geochemical reactions, solubility of salts and human activities (Bhatt and Salakani 1996; Karanth, 1997; and Jain *et al*., 2005). Due to scarcity of surface water, nowadays people using ground water for their daily requirements, so it is important to assess the quality of

ground water (Chaudhari *et al*., 2004 and Pandian *et al*., 2006). When run off fertilizers and pesticides, leaking off septic tank system and sewer lines, pollutants and industrial effluents reach the unsaturated zone of ground water affect the quality of water (Milway, 1969; Olimax, and Sikorska, 1975; Piecznska *et al*., 1975 Vollenweidre, 1986; Mahananda et al., 2010 and National Academy of Science). Quality of ground water may determined by the chemical composition of water. If the chemical composition of ground water is in definite limits, it is safe to use. Studies of ground water quality are becoming more important in nowadays. Soluble minerals and sedimentary rocks come in contact with ground water and make it rich in soluble constituents (Water watch, 2005). In most ground waters, 95% of ions are Na+, K+, Ca2+, Mg2+, Cl-, So4-, HCO3- and NO3-. These ions are adding together and responsible for the salinity of water and hence called total mineralization. The chemical concentration of some of the ions are very important in the ground water quality like Ca, Mg, Na, K, Cl, Co3, HCo3, SO4, PO4, H4SiO4. High mineral content of water referred to as hard water, which is determined by the level of multivalent cations (Ca2+ and Mg2+) in water and this may due to sedimentary rocks and run off from soli (Rai *et al*., 2012). High concentrations of these cations are responsible for the accumulation of insoluble salt deposits in storage tanks or plumbing. The aim of this paper is to review the ground water quality parameters in and around the Thuraiyur (Tk). The data collected from the study area from January to March, 2014. Thuraiyur taluk of Trichy district is considered as very dry and salt water area, where surface water resources are very rare; with the result ground water has become a major source of supply to the population of Thuraiyur taluk. Supply of water to this population is often by bore well or dug well.

Study area:

Thuraiyur is a town and municipality in Trichy district of Tamilnadu. Thuraiyur had a population of 31,005 (15,530 male and 15,475 females). Thuraiyur Taluk Head Quarters is Thuraiyur town. It is located 46 KM towards North from District Head Quarters Trichy, 325 KM from capital Chennai towards North. Thuraiyur Taluk is bounded by Uppiliapuram Taluk towards Northh, Tattayyangarpettai Taluk towards west, Musiri Taluk towards south, Manachanellur Taluk towards south. Perambalure City, Thammampatti City, Lalgudi city are the nearby cities to Thuraaiyur.

Materials and methods:

The water samples were collected from open and bore wells in study area using well sterilized and pre-cleaned dried polyethylene container and preserved as per (Trivedy *et al*., 1987 and APHA, 1995) for a period of 3 months (January to March – 2014). The collected samples were immediately transferred and water quality parameters were analyzed in lab. Four sampling stations were selected for collecting ground water samples; those were Thuraiyur main (S1), Keerambur (S2), Sorathur (S3) and Puthanampatti (S4). In each sampling station 5 locations were selected to collect samples. In each location considerable numbers of samples were collected to obtain concurrent values. The parameters analyzed were phosphate, silicate, total hardness and hydrogen sulphide. Phosphate estimation carried out by Stannous chloride method (APHA, 1998, "a"), Silicated estimated by Molybdosilicate method (APHA, 1998, "b"), total hardness titrated by EDTA method (APHA, 1998, "c") and hydrogen sulphide measured by iodometric methods (APHA, 1980).

Results and discussion:

The rule of water quality attracted a great deal of attention. Quality of ground water is depending on the availability of minerals and types of pollutant found at particular zone of bore well in that area. The dominant role of ground water resources is clear, in rural areas of USA, ground water resources supplied to 96% of domestic uses (Todd, 1980). Several literatures explained the decline of ground water quality (Sinha and Kamala Kant, 2003 and Anuraag Mohan et al., 2006, Gupta et al., 2009). The variation in parameters of ground waters of 20 samples have been summarized in the table 1, 2, 3 and 4.

Table 1. Parameters studied in ground water samples at 5 different locations of Thuraiyur area (S1).

Sl. No.	Parameters	East	West	North	South	Center
1	Phosphate (mg/l)	2.008	9.741	1.176	1.950	1.283
2	Silicate (mg/l)	1.061	0.938	0.934	0.843	0.813
3	Total hardness (mg/l)	444.02	442.5	441.3	443.4	445.3
4	Hydrogen sulphide (ppm)	1.05	4.3	2.2	5.4	3

Table 2. Parameters studied in ground water samples at 5 different locations of Keerambur area (S2).

Sl. No.	Parameters	East	West	North	South	Center
1	Phosphate (mg/l)	8.608	5.016	4.225	3.433	4.266
2	Silicate (mg/l)	0.857	0.885	0.902	0.923	0.880
3	Total hardness (mg/l)	97.84	95.40	97.08	96.01	97.6
4	Hydrogen sulphide (ppm)	5.69	5.10	6.01	4.25	5.63

Table 3. Parameters studied in ground water samples at 5 different locations of Sorathur area (S3).

Sl. No.	Parameters	East	West	North	South	Center
1	Phosphate (mg/l)	3.866	1.791	4.425	2.833	3.966
2	Silicate (mg/l)	0.927	0.987	0.940	0.930	0.956
3	Total hardness (mg/l)	395.01	394.99	396.2	396.66	396.5
4	Hydrogen sulphide (ppm)	4.65	5.75	6.68	5.18	5.25

Table 4. Parameters studied in ground water samples at 5 different locations of Puthanampatti area (S4).

Sl. No.	Parameters	East	West	North	South	Center
1	Phosphate (mg/l)	0.447	0.162	0.374	0.438	0.245
2	Silicate (mg/l)	0.910	0.980	0.940	0.930	0.926
3	Total hardness (mg/l)	525.60	524.70	652.70	640.50	650.84
4	Hydrogen sulphide (ppm)	7.01	7.25	8.90	9.10	9.25

Presence of pollution, eutrophic condition (WHO, 1998), agricultural runoff containing fertilizers as well as waste water containing detergents are responsible for the high concentration of phosphate. The level of P in natural water sources is usually low, because it is used by aquatic plants by their immediate needs. If the P level is maximum might have encouraged the biological degradation of the organic matter. Mahananda *et al*., (2010) reported that the phosphate content of dug well ranged from a minimum of 1.65 ± 0.06 to a maximum of 2.37 ± 0.17 and bore well ranged from a minimum of 1.14 ± 0.09 to a maximum of 2.36 ± 0.03. The mean value of phosphate was 3.23±1.64, 5.11±0.10, 3.38±0.47 and 0.33±0.06 in Thuraiyur main, Keerambur, Sorathur and Puthanampatti respectively (Table 5). The phosphate content of > 0.2 mg/l perhaps considered as productive nature of water (Jhingram, 1977). The value for phosphate recorded in the present study indicates the non-productive nature of the water bodies. In the ground water most of the study areas crossed the maximum permissible limit prescribed by WHO & ICMR. The mean, standard deviation and standard errors of phosphate were given in table 5. The significance value, i.e., p-value, given in table 6. Since, the significance value 0.022 is less than 0.05 ($p<0.05$), the variance between different locations is significant. Therefore, we conclude that the levels of phosphate differ from each other in different stations significantly (Fig. 1).

Table 5. Descriptives statistics of Phophate at 4 different stations.

Descriptives

Phosphate (mg/l)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
S1	5	3.23160	3.658364	1.636070	-1.31086	7.77406	1.176	9.741
S2	5	5.10960	2.034252	.909745	2.58374	7.63546	3.433	8.608
S3	5	3.37620	1.060150	.474114	2.05985	4.69255	1.791	4.425
S4	5	.32780	.123558	.055257	.17438	.48122	.162	.447
Total	20	3.01130	2.651440	.592880	1.77039	4.25221	.162	9.741

Table 6. Significance of phosphate in Thuraiyur (Tk), Trichy (Dt).

ANOVA

Phosphate (mg/l)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	58.929	3	19.643	4.210	.022
Within Groups	74.644	16	4.665		
Total	133.573	19			

Silica is responsible for bone formation and increases bone mineral density and respect to decrease cognitive function (Gillette Guyonnet *et al*., 2007) and it may be the natural antidote to aluminium (Birchall and Chappel, 1988 and Doll, 1993). In this present study, the mean value of silicate was 0.99±0.04, 0.89±0.01, 0.95±0.01 and 0.94±0.01 in Thuraiyur main, Keerambur, Sorathur and Puthanampatti respectively (Table 7). The silicate levels of ground water samples of study areas do not pose any water quality problem. IS 10500, WHO and other similar agencies do not prescribe any permissible limit for silicate. So there is no guideline for S in drinking water. But the excessive ingestion this element is really dangerous. Chemical weathering of silicate minerals of rock and sediments will result in high concentration of dissolved silicate in water, because it makes up to 25% of earth's crust (Hem, 1970; Keller, 1975 and Jansen *et al.*, 2010). The significance value, that is p-value given in table 8. Significance value 0.213 is more than 0.05 ($p<0.05$), the variance between different locations is not significant. Therefore, we conclude that the levels of silicate were not differing from each other in different stations significantly (Fig. 1). The mean difference is not significant at the 0.05 level.

Table 7. Descriptives statistics of Silicate at 4 different stations.

Descriptives

Silicate (mg/l)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
S1	5	.90880	.081374	.036391	.80776	1.00984	.813	1.016
S2	5	.88940	.024724	.011057	.85870	.92010	.857	.923
S3	5	.94800	.024566	.010986	.91750	.97850	.927	.987
S4	5	.93720	.026253	.011741	.90460	.96980	.910	.980
Total	20	.92085	.048556	.010858	.89812	.94358	.813	1.016

Table 8. Significance level of silicate in Thuraiyur (Tk), Trichy (Dt).

ANOVA

Silicate (mg/l)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.011	3	.004	1.672	.213
Within Groups	.034	16	.002		
Total	.045	19			

Sanjoy Meitei and Rakesh, (2013) reported that level of hardness in the ground water showed very wide variations and crossed the maximum permissible limit of WHO and ICMR. Hardness value below 300 mg/l is considered drinkable, if it crossing this limit produces gastrointestinal infection (ICMR, 1975). The total hardness content of ground water in study area ranged from a minimum of 96.79 ± 0.47 to a maximum of 593.47± 28.18 in Keerambur and Puthanampatti respectively (Table 9). Khopkar, (1993) classified water hardness into 5 categories on the basis of total ion content are known as soft (0 – 40 mg/l), moderately hard (40–100 mg/l), hard (100–300 mg/l), very hard (300–500 mg/l) and extremely hard (500-1000 mg/l). But Muthukumaravel (2010) classified as soft (0-60 mg/l), medium (60-120 mg/l), hard (120- 180mg/l) and very hard (>180mg/l). According to Khopkar, (1993), most of the study areas (Thuraiyur, Sorathur and Puthanampatti) have very hard ground water. Though as per IS: 10500-2012 the desirable limit and permissible limit for hardness is lies between 200 to 600 mg/l respectively. The results of ANOVA are given in table 10. Since, the significance value 0.000 is less than 0.05 ($p<0.05$), the variance of total hardness between different stations is significant. Therefore, we conclude that the levels of total hardness differ from each other in different stations significantly (Fig. 2).

Table 9. Descriptives statistics of total hardness at 4 different stations.

Descriptives

Total hardness (mg/l)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
S1	5	4.4330E2	1.51396	.67706	441.4242	445.1838	441.30	445.30
S2	5	96.7860	1.04680	.46814	95.4862	98.0858	95.40	97.84
S3	5	3.9587E2	.81300	.36358	394.8625	396.8815	394.99	396.66
S4	5	5.9347E2	63.00310	28.17584	515.2393	671.6967	524.70	650.84
Total	20	3.8236E2	187.21968	41.86359	294.7360	469.9790	95.40	650.84

Table 10. Significance level of total hardness in Thuraiyur (Tk), Trichy (Dt).

ANOVA

Total hardness (mg/l)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	650079.212	3	216693.071	218.142	.000
Within Groups	15893.756	16	993.360		
Total	665972.968	19			

The parameter of H2S is also very important because this may cause serious health effects (Department Of Health And Human Services, 2014). The taste and odour threshold for sulfides is about 0.2 mg/l (National Health and Welfare Canada, 1978) and 0.5 to 1 ppm smell musty and 1 ppm smell rotten egg (Mark Risse, 2014). In the guidelines of WHO, 1996 reported that the taste and odour thresholds for H_2S of water are estimated to be between 0.05 and 0.1 mg/l. Even 0.1 mg/l of H2s of water can detectable by smell by most people (Mark McFarland and Provin, 1998). The article of Scott Simonton and Morgan Spears (2007) reported that the concentration levels of H2S and their symptoms as 0-10 ppm causing irritation of eyes, nose, and throat, 2 ppm - bronchial constriction in asthmatic individuals, spontaneous abortion and 5-9.3 ppm - increased blood lactate concentration, decreased skeletal muscle citrate synthesis activity. EPA set the safe exposure level of H2S at 0.00014 ppm for sensitive people such as children and the elderly. But the hydrogen content of ground water in study area ranged from a minimum of 3.19± 0.77 to a maximum of 8.32±0.47 in Thuraiyur and Puthanampatti respectively (Table 11). Since WHO (1981) reported there were no international standards for H_2S. The results of ANOVA are given in table 12. Since, the significance value 0.000 is less than 0.05 ($p<0.05$), the variance of hydrogen sulphide between different stations is significant. Therefore, we conclude that the levels of hydrogen sulphide differ from each other in different stations significantly (Fig 1).

Table 11. Descriptives statistics of hydrogen sulphide at 4 different stations.

Descriptives

Hydrogen sulphide (ppm)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
S1	5	3.1900	1.71114	.76525	1.0653	5.3147	1.05	5.40
S2	5	5.3360	.68941	.30831	4.4800	6.1920	4.25	6.01
S3	5	5.5020	.76523	.34222	4.5518	6.4522	4.65	6.68
S4	5	8.3200	1.05392	.47133	7.0114	9.6286	7.10	9.25
Total	20	5.5870	2.13768	.47800	4.5865	6.5875	1.05	9.25

Table 12. Significance level of hydrogen sulphide in Thuraiyur (Tk), Trichy (Dt).

ANOVA

Hydrogen sulphide (ppm)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	66.426	3	22.142	17.368	.000
Within Groups	20.398	16	1.275		
Total	86.824	19			

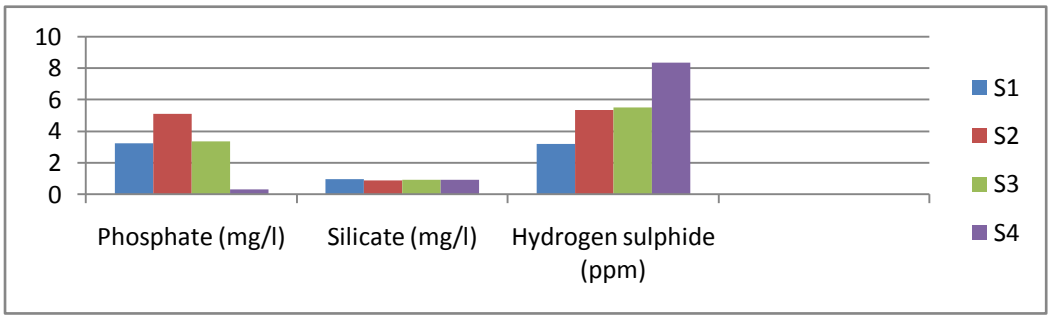

Fig.1. Multiple comparison of phosphate, silicate and hydrogen sulphide in different stations (S1, S2, S3 and S4).

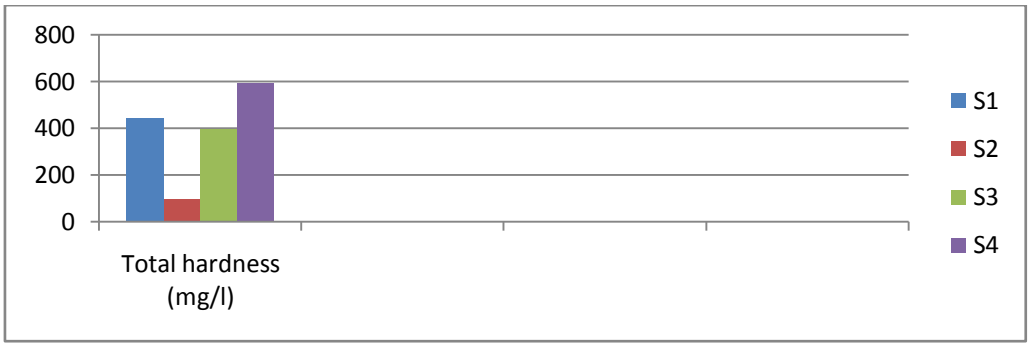

Fig. 2. Multiple comparison of total hardness in different stations (S1, S2, S3 and S4).

References:

1. American Public Health Association. (1980), Standard methods for the examination of water and wastewater (15th ed.): Washington, D.C.
2. Anuraag Mohan, Kinty Pandey, Singh, R.K. and Vineet Kumar. (2006), "Assessment of Underground water quality in industrial area of Bareilly", *IJEP*, 26(2),pp.153-158.
3. APHA, AWWA, WPCF. (1995), Standard methods for the examination of water and waste water, 19th *Edn*. Washington D.C.
4. APHA. 1998. Standard Methods for the Examination of Water and Waste water. American Public Health Association / 20th *edn*. New York.
5. Bhatt, K.B. and Salakani, S. (1996), "Hydrogeochemistry of the upper Ganges River, India", *J. Geol Soc. India*, 48,pp.171-182.
6. Birchall, J.D. and Chappell, S. (1998), "The chemistry of aluminium and silicon in relation to Alzheimer's disease", *Clin Chem*; 34,pp.256-267.
7. Chaudhari, G.R., Deepali Sohani and Shrivastava, V.S. (2004), "Groundwater Quality Index near Industrial Area", *IJEP*, 24(1),pp.29-32.
8. Department Of Health And Human Services. (2014), Public Health Statement, Hydrogen sulphide. Public Health Service Agency for Toxic Substances and Disease Registry.
9. Doll, R. (1993), " Review: Alzheimer's disease and environmental aluminium. Age Ageing", 22,pp.138-145.

10. Gillette - Guyonnet. S., Andrieu, S. and Vellas, B. (2007), " The potential influence of silica present in drinking water on Alzheimer's disease and associated disorders", *The journal of nutrition, health and aging*. Vol 11 (2),pp.119 -124.
11. Gupta, D.P., Sunita and Saharan, J.P. (2009), "Physiochemical Analysis of Ground Water of Selected Area of Kaithal City (Haryana) India", *Researcher*, 1(2),pp.1-5
12. Hem, J.D. (1970), Study and Interpretation of the Chemical Characteristics of Natural Waters. Excellent Reviews of the Chemistry of Natural Water and of the Significance of Properties and Constituents Reported in Water Analyses. 2nd Edition. *US Geol Survey Water Supply Paper No. 1473*, 363.
13. I.C.M.R. (1975), Manuals of standards of quality for drinking water supplies. I.C.M.R. New Delhi.
14. IS: 10500-2012. Beuro of Indian Standards for Drinking water 2012.
15. Jain, P., Sharma, J.D., Sohu, D. and Sharma, P. (2005), "Chemical analysis of drinking water of villages of Sanganer Tehsil, Jaipur District", *Int. J. Environ. Sci. Tech.*, 2(4),pp.373-379.
16. Jansen, N., Hartmann, J., Lauerwald, R., Durr, H.H., Kempe, S., Loos, S., Middelkoop, H. (2010), "Dissolved silica mobilization in the conterminous USA. *Chem Geol*, 270,pp. 90-109.
17. Jhingram, V.G. (1977), "Fish and fisheries of India", 3rd *Edn*. Hindustan publishing Corporation Delhi (India).
18. Karanth, K.B. (1997), Groundwater assessment, development and management. Tata McGraw-Hill Publishers, New Delhi.
19. Keller, W.D. (1957), The Principles of Chemical Weathering. Columbia, Missouri: Lucas Brothers Publishers.
20. Khopkar, S.M. (1993), Environmental pollution analysis Wiley Eastern Ltd. N-Delhi.
21. Mahananda, M.R., Mohanty, B.P and Behera, N.R. (2010), "Physico-chemical analysis of surface and ground water of Bargarh district, orissa, india", *Ijrras* 2 (3) March,pp.284 – 295.
22. Mahananda, M.R., Mohanty, B.P. and Behera, N.R. (2010), "Physico-chemical analysis of surface and ground water of Bargarh district, Orissa, India". *IJRRAS* 2 (3). March,pp. 284 – 295.
23. Mark Risse, Dana Lynch, Kristine Uhlman. (2014), Your Household Water Quality: Hydrogen Sulfide and Sulfate. The University of Georgia is committed to principles of equal opportunity and affirmative action.

24. Mark, L., McFarland and Provin, T.L. (1998), Hydrogen sulfide in drinking water Causes and treatment alternatives. The Texas A&M University System, U.S. Department of Agriculture, and the County Commissioners Courts of Texas Cooperating.
25. Milway, C.P. (1969), Educational in large lakes and impoundments. Proc.*Upplasale Symp*. DECD *Paris.*
26. Muthukumar. S., Lakshumanan. C., Santhiya. G., Krishnakumar, P. and Viveganandann. S. (2011), "Assessment of water quality in Trichy City, Tamil Nadu, India". *Int. J. Environ. Sci.* Vol. 1 (7), pp.1841-1855.
27. Muthukumaravel, K. and *et al*., (2010), "Evaluation of Ground Water Quality in Perambalur", *Indian Journal of Environmental Sciences*, 14(1), pp.47-49.
28. National Academy of Science. Eutrophication causes consequences and correctives. *Nat.Acad. Sci. Washington, D.C.*
29. National Health and Welfare Canada. (1978), *Guidelines for Canadian drinking-water quality—supporting documentation.* Ottawa.
30. Olimax, T and Sikorska, U. (1975), "Field experiment on the effect of municipal sewage on macrophytes and epifauna in the lake littoral". *Bull. Acad. Pol. Sc. Clii* 23, pp.445-447.
31. Pandian, G.V., Kannan, N., Paulraj, K. and Paulrajan, S. (2006), "Effect of Industrial Pollution on ground water in Madurai Suburban Area" *IJEP*, 26(10), pp. 939-945
32. Piecznska, E., Usikorna and Olimak, T. (1975), "The influence of domestic sewage on the littoral zone of lakes", *Pol. Arch. Hydrobiol.* 22, pp.141-156.
33. Rai, A.A., Paul, B. and Kishor, N. (2012), "A study on the sewage disposal on water quality of Harmu River in Ranchi city Jharkhand, India", *Int. J. Plt. Animal. Environ. Sci*., 2(1), pp. 102-106.
34. Sanjoy Meitei, L and Rakesh, K.h. (2013), "A comparative study of the ground and surface water quality with reference to heavy metal concentrations in the Imphal valley Manipur, India", *International Journal of Environmental Sciences Volume 3 No.6, pp.*1857 – 1867.
35. Scott Simonton and Morgan Spears, P.E. (2007), " Human Health Effects from Exposure to Low-Level Concentrations of Hydrogen Sulfide. Occupational Health and Safty. https://ohsonline.com/articles/2007/10/human-health-effects-from-exposure-to-lowlevel-concentrations-of-hydrogen-sulfide.aspx.

36. Sinha, A.K and Kamala Kant. (2003), "Underground water quality and its impact on the health of its users in Sarani Block of Rae Bareli", *IJEP*, 23(9), pp.1017-1024.
37. Todd, D.K. (1980), "*Groundwater Hydrology".* 2nd edition, John Wiley, New York, 535
38. Trivedy, R.K., Goel, P.K., and Trisal, C.L. (1987), Practical methods in ecology and environmental science. *Environ-Media*, Publ. Karad, India.
39. Vollenweidre, R.A. (1986), "Scientific fundamental of the eutrophication of lakes and flowing waters with special reference to nitrogen and phosphorus, as factoring eutrophication". *O. E C. D. Paris.*
40. Water watch. (2005), Australian National Technical Manual. Module 6 Ground water Monitoring. Department of Environment and Heritage, Canberra.
41. World Health Organization. (1981), Hydrogen sulfide. Environmental Health Criteria No.19. Geneva.
42. World Health Organization. (1996), Guidelines for drinking-water quality, 2nd ed. Vol. 2. *Health criteria and other supporting information.* Geneva.
43. World Health Organization. (1998), Guidelines for Drinking Water Quality, 2nd Edition Geneva.