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Assessment of potable water quality of surface water (*tuikhur*) and hand pumps in Siaha, southern Mizoram

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The present study focused on the physico-chemical characterization of potable water from hand pump (groundwater) and sub-surface (*tuikhur*) water in Siaha, Mizoram, during pre-monsoon season of 2017. pH, total dissolved solids (TDS), electrical conductivity (EC), turbidity, total alkalinity (TA), total hardness (TH), iron (Fe), magnesium (Mg), calcium (Ca), nitrate (NO_3), sulphate (SO_4) and chloride (Cl) and their mean values obtained were 7.1, 67.72 mg/L, 103 mg/L, 1.8 NTU, 43.9 mg/L, 45 mg/L, 0.30 mg/L, 6.24 mg/L, 7.21 mg/L, 0.23 mg/L, 3.27 mg/L and 9.51 mg/L respectively. The results revealed that all these water samples were well within permissible limits established by World Health Organization (WHO), and Bureau of Indian Standards (BIS). Hence, they are suitable for drinking purposes. However, Iron contents at few sites are found exceeding the permissible value of 0.3 mg/L.

Key words: Siaha; Physico-chemical parameters; rock-water interaction; standard levels.

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Introduction

In Mizoram, the need for safe and sufficient drinking water is ensured from its sources and through Public Health Engineering Department (PHED), its supply to long distance or remote areas particularly, which are inaccessible.[1-3] Potable water has been declining due to increasing human population, use of fertilizers, pesticides, manures, anthropogenic activities, etc.[4,5]

Drinking water is derived from a variety of sources such as surface water (rivers, lakes, reservoirs and ponds), groundwater (hand pumps, seepage and well) and rain water.[6,7] Rain water may not be recommended for direct domestic purposes as it contains minerals impurities. There may have a chance for interaction between surface and sub-surface water with the rocks, soils and organisms on the earth as well as below the earth's surface.[8,9] As a result, requisite minerals get included which are required for health to human beings. However, sometimes some toxic contents are being received by water in the form of heavy metals such as viz. arsenic, cadmium, nickel, etc.

Siaha is the headquarters of the southernmost district of Mizoram, India (Fig. 1). The district is bounded by Lunglei district on the north, Lawngtlai district on the south and on the south and east by Myanmar. The area under study is situated in Siaha town and its exact coordinates are 22.48°N and 92.97°E with an elevation of 2391 ft.

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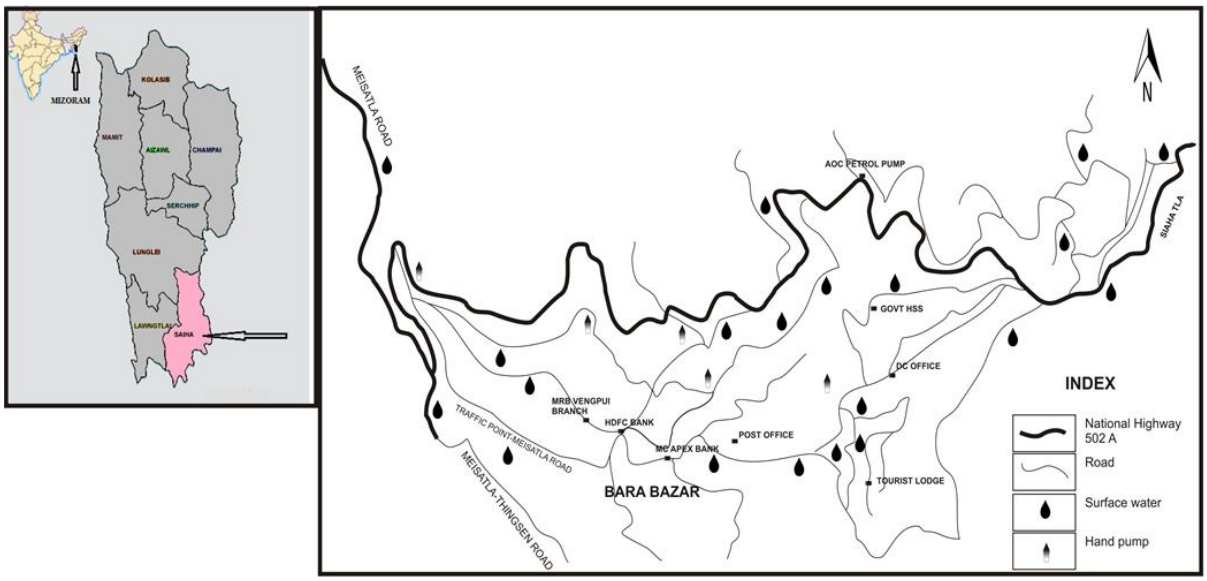

Fig. 1 | Location map of the study area.

The average temperature ranges between 8° to 24°C in winter and it varies between 18 to 32° C in summer. Winter lasts from September and till January the next year. The area falls under the direct influence of south-west monsoon and heavy precipitation starts falling heavily from May to September. The soils type is generally the products of the weathered ferruginous sandstones, shale and limited alluvial and colluvial material transported by river/streams etc. They vary from sandy to load and clay to loam mixed with broken angular shape of varying size. The color of the soil varies from yellowish to brownish grey with varying depth.

The existing water for drinking purposes is mainly from those springs tapped through gravity drainage. Water supplied by the PHE department is not enough to meet the daily requirements of the people. Therefore, the people depend on secondary sources like rain water and surface water (*tuikhur*). Since these water are used without any treatment, the physico-chemical characterization needs to be studied in comparison to the standards specified by BIS and WHO, and to understand the sources of various contaminants in order to suggest remedies.

Materials and Method

The studies were conducted at Siaha town, Siaha district, Mizoram, India. The major native inhabitants are the Mara people. The water samples were collected in the pre-monsoon season in 2017 from the selected locations (Fig. 1). These samples have been taken for detailed hydrological and hydro-geochemical investigations. Various sources of potable water were identified. Out of 25 samples, 20 samples are from *tuikhur* and 5 samples are from hand pump. According to the recommendations of the APHA, AWWA and WEF, samples of potable water to be analyzed are representatives of the source from which water is drawn for different purposes. Before collection of the water samples, polythene bottles should be cleaned thoroughly, rinsed with distilled water and again rinsed with representative water samples.[10]

Two bottles of 250 ml each for each location, one acidified with 2-4 ml of diluted HNO_3 and non-acidified were collected. In situ testing of the water samples was done immediately at the site to find out the physico-chemical properties like pH, turbidity, total dissolved solids (TDS), electrical conductivity (EC) and iron (Fe). Digital

Table 1 | Water analyses results (physico-chemical characteristics) at Siaha.

Samples	Location	pH	EC	TDS	TURB	TA	TK
TK-01	Vaipih-I	7.2	69	51	2.6	42.21	39.16
TK-02	Vaipih-II	7.3	73	48	2.1	37.71	41.21
TK-03	Medical Vaih-I	6.8	102	79	2.5	42.18	37.32
TK-04	Medical Vaih-II	6.7	105	80	3.1	52.19	34.67
TK-05	MRP Land	7.2	125	75	1.7	44.43	43.62
TK-06	Siaha Tla	7.2	126	83	2.0	45.35	40.22
TK-07	Siaha Tla, road to Tlapih	7.1	87	48	1.2	56.46	35.34
TK-08	N.Siaha, OlaTKi	7.1	102	72	1.3	26.65	37.53
TK-09	New Siaha E	7.3	122	81	1.2	32.32	39.62
TK-10	New Siaha W	7.2	86	54	1.4	76.38	50.25
TK-11	Chho Chho Paw	6.9	92	53	1.3	37.68	54.32
HP-12	KeimoTKi	7.3	110	83	2.1	62.67	44.62
HP-13	New Colony-I	7.6	109	74	1.3	71.24	43.31
TK-14	New Colony-II	7.1	112	64	2.1	37.43	54.42
HP-15	Golden Street, New Siaha	7.3	123	92	2.0	39.56	55.37
TK-16	Meisa Vaih	7.1	107	64	2.1	34.78	46.62
HP-17	College Vaih	7.2	128	80	1.2	38.64	40.13
TK-18	Circuit Vaih	6.7	97	73	1.5	32.43	51.27
TK-19	Council Vaih-I	6.9	116	66	1.9	57.67	44.47
TK-20	Council Vaih-II	7.2	97	58	1.1	37.12	36.43
TK-21	Meisa tla-I	6.8	96	54	2.2	32.66	42.26
HP-22	Meisa tla-II	7.2	127	86	2.3	35.37	63.14
TK-23	PWD, New Siaha	6.8	131	92	1.5	46.54	64.26
TK-24	A.R Viah	7.1	68	40	1.6	40.11	44.28
TK-25	Chakma Vaih	7.3	86	43	1.7	37.67	43.23
MEAN		7.1	103.84	67.72	1.8	43.9	45.09
WHO	PREMISSIBLE LIMITS	6.5—8.5	600	500	--	--	500
BIS	PERMISSIBLE LIMITS	6.5—8.5	2000	2000	5	600	600

* TK= Tuikhur; *HP= Hand pump

instruments made by Eutech Instruments were used to test the in situ values of pH, TDS and EC. Turbidity values of the samples were measured using the Digital Nephelo Turbidity Meter-132 (Systronics) using formazine as standard. Total Fe was measured using the Water Testing Kit made by Transchem Agritech Limited. Total hardness, Ca, Mg, total chloride, total alkalinity and sulphate were analyzed by titrimetric method. The determination of NO_3 concentration in the samples was done by UV-spectrophotometric method.

Results and Discussion

Results of all the potable sources in the study area have been classified into physical and chemical properties and presented in the Table 1 and 2 respectively.

It was seen that the pH varied from 6.7-7.6 (Table 1), which are found to be well within the acceptance limit for drinking water (6.5-8.5) as specified by the BIS[11] and WHO[12]. The electrical conductivity values varied from 68-131 μS/cm. The lower values of EC may be due to the presence of lesser amounts of dissolved salts indicative of less solubility of minerals and ions from the host rock and has insignificant rock-water intercalation. Further, it characterizes dominance of more silica content in the host rock. However, the Environmental Protection Agency (EPA) considers electrical conductivity as a secondary maximum contaminant level (SMCL); it does not have a direct impact on health.[13] The

Table 2 | Water analyses results (physico-chemical characteristics) at Siaha.

Samples	Location	TCl	Fe	Ca	Mg	SO_4	NO_3
TK-01	Vaipih-I	6.21	0.02	5.11	4.21	1.15	0.12
TK-02	Vaipih-II	6.32	0.01	5.21	4.43	1.24	0.11
TK-03	Medical Vaih-I	7.21	0.01	6.13	6.28	2.32	0.31
TK-04	Medical Vaih-II	8.13	0.02	4.24	4.28	2.31	0.21
TK-05	MRP Land	7.58	0.02	6.31	3.49	3.23	0.15
TK-06	Siaha Tla	8.32	0.01	6.26	4.42	3.08	0.17
TK-07	Siaha Tla, road to Tlapih	9.24	0.01	9.03	5.65	3.12	0.22
TK-08	N.Siaha, OlaTKi	9.05	0.01	6.11	3.42	2.35	0.26
TK-09	New Siaha E	8.26	0.02	4.27	4.41	3.43	0.37
TK-10	New Siaha W	11.07	0.02	7.32	6.34	2.18	0.25
TK-11	Chho Chho Paw	9.44	0.03	8.76	7.18	3.28	0.21
HP-12	KeimoTKi	8.17	0.5	10.12	8.77	5.02	0.28
HP-13	New Colony-I	7.87	0.8	7.54	9.28	6.06	0.26
TK-14	New Colony-II	11.19	0.2	9.36	12.13	5.12	0.18
HP-15	Golden Street, New Siaha	12.54	1.7	8.44	11.31	4.68	0.24
TK-16	Meisa Vaih	13.21	0.04	5.42	5.23	2.14	0.35
HP-17	College Vaih	14.28	2.1	7.64	10.34	5.27	0.27
TK-18	Circuit Vaih	11.37	0.02	6.59	4.67	3.41	0.19
TK-19	Council Vaih-I	10.26	0.03	4.89	3.54	2.47	0.18
TK-20	Council Vaih-II	8.87	0.04	6.87	6.35	3.09	0.19
TK-21	Meisa tla-I	9.53	0.02	7.27	4.42	2.54	0.27
HP-22	Meisa tla-II	10.21	1.9	11.07	9.46	6.05	0.31
TK-23	PWD, New Siaha	12.12	0.02	11.35	6.62	3.19	0.27
TK-24	A.R Viah	8.24	0.01	8.27	4.67	3.11	0.22
TK-25	Chakma Vaih	9.21	0.02	6.85	5.28	2.13	0.16
MEAN		9.51	0.3	7.21	6.24	3.27	0.23
WHO	PREMISSIBLE LIMITS	200	0.1	75	30	250	50
BIS	PERMISSIBLE LIMITS	1000	0.3	200	100	400	45

* TK= Tuikhur; *HP= Hand pump

electrical conductivity values are generally higher for sub-surface water (*tuikhur* water) in comparison to the groundwater (hand pump). The value with 400 μS/cm of electrical conductivity at 25°C is considered fittable for human consumption, but more than 1500 μS/cm at the same temperature may cause corrosion of iron structure.[14] Since conductivity is related to the content of all cation and anion or total dissolved solid (TDS), it can be regarded as a crude indicator of water quality for many purposes. The geochemical rock-water intercalation may attribute the value of TDS higher due to the adding of a number of electrolytes to the water bodies.[15]

The TDS value obtained in the area ranged from 40-90 mg/L (Fig. 2A). According to WHO, the standard permissible limit for TDS is 2000 mg/l. Water at a TDS level of above 500 mg/l is unsuitable for flora and tastes unpleasant to drink. In the present study TDS values were found well within the standard permissible limit. Since total dissolved solids is directly proportional to conductivity, higher value of TDS in water indicates the presence of various kinds of minerals and ionized solute. For turbidity, it is observed that all the values of the stations have slightly higher than the desirable limit but still within the permissible limit of 5NTU. The hardness measured in the water samples were rather low, ranging between 34 mg/L and 64 mg/L. The measured were all below the WHO limit of 600 mg/L. Soft water less than 100 mg/L of hardness

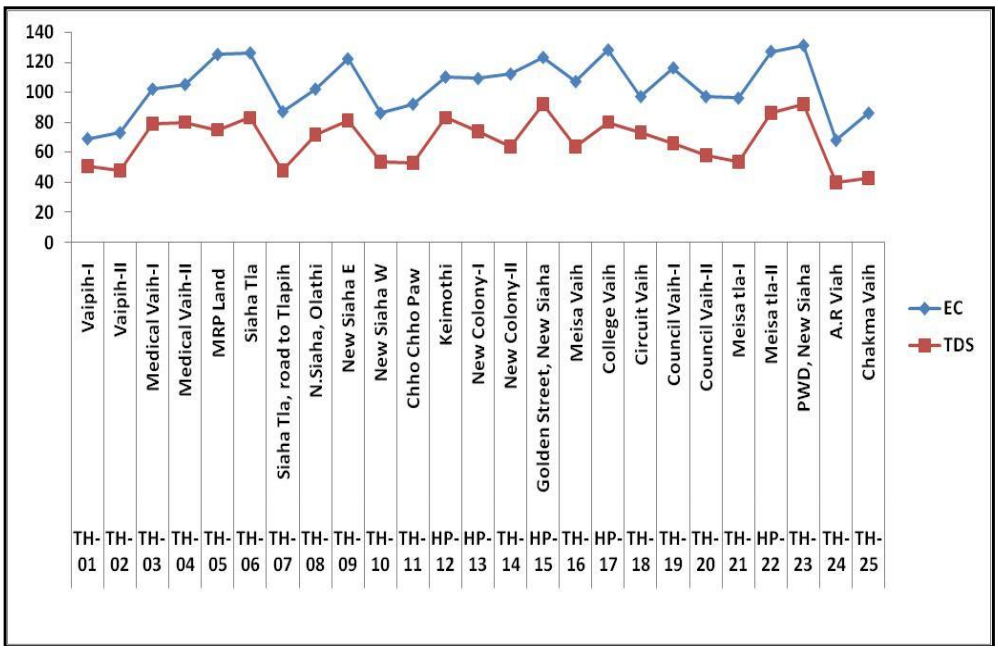

Fig. 2A | Plot of physical data (electrical conductivity and total dissolved solids).

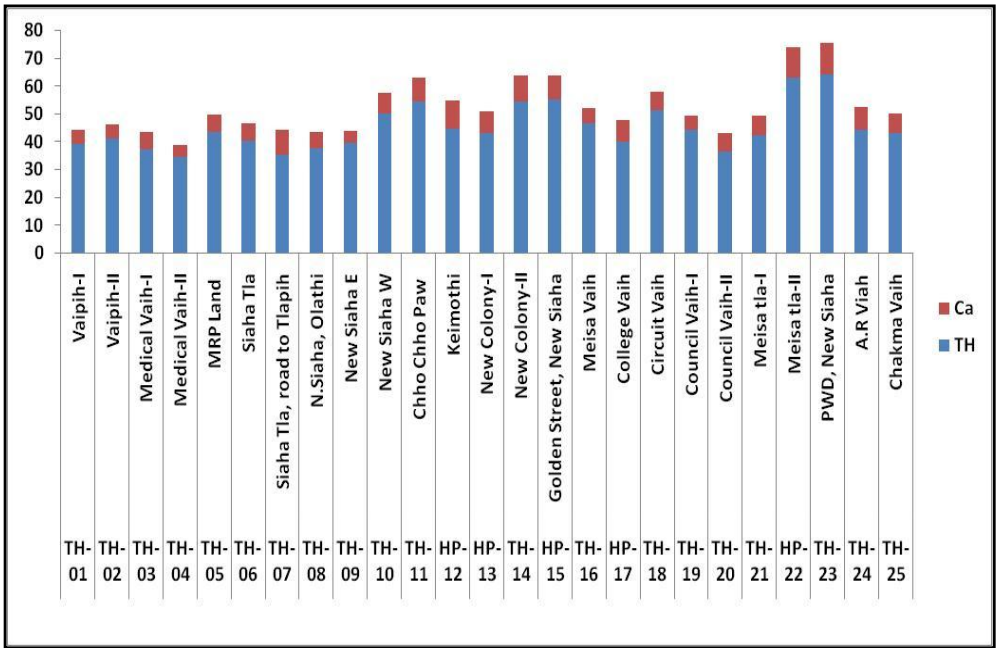

Fig. 2B | Plot of chemical data (calcium and total hardness).

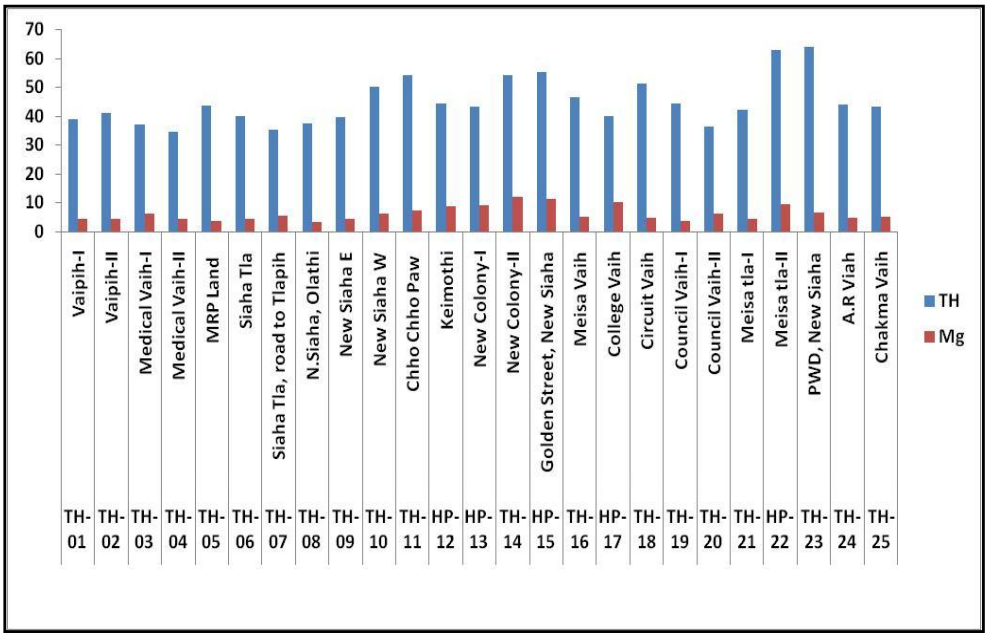

Fig. 2C | Plot of chemical data (total hardness and magnesium).

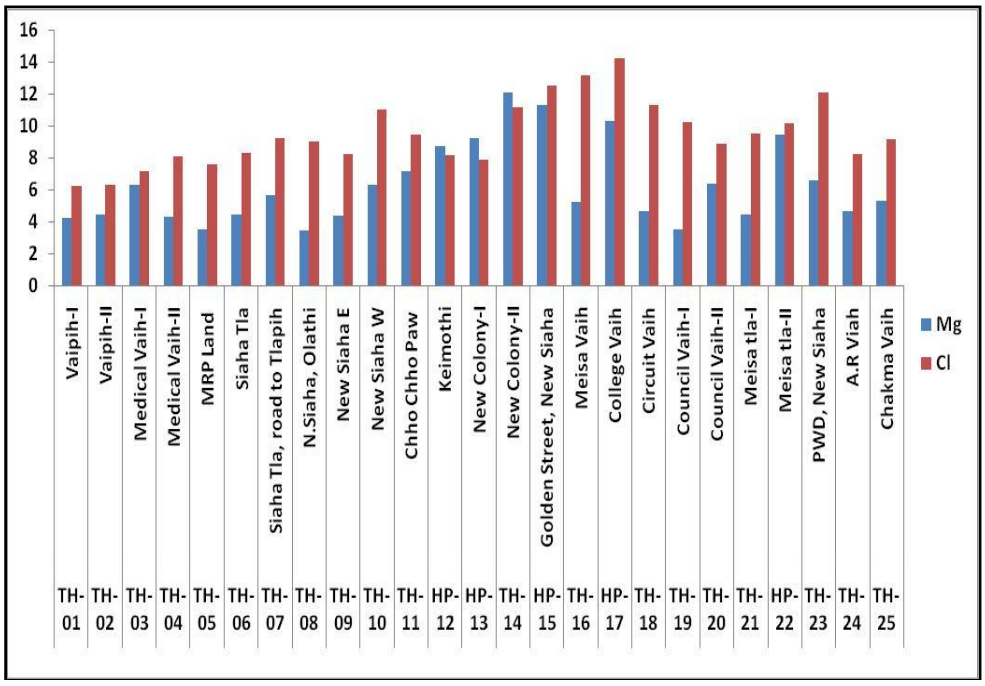

Fig. 2D | Plot of chemical data (magnesium and chloride).

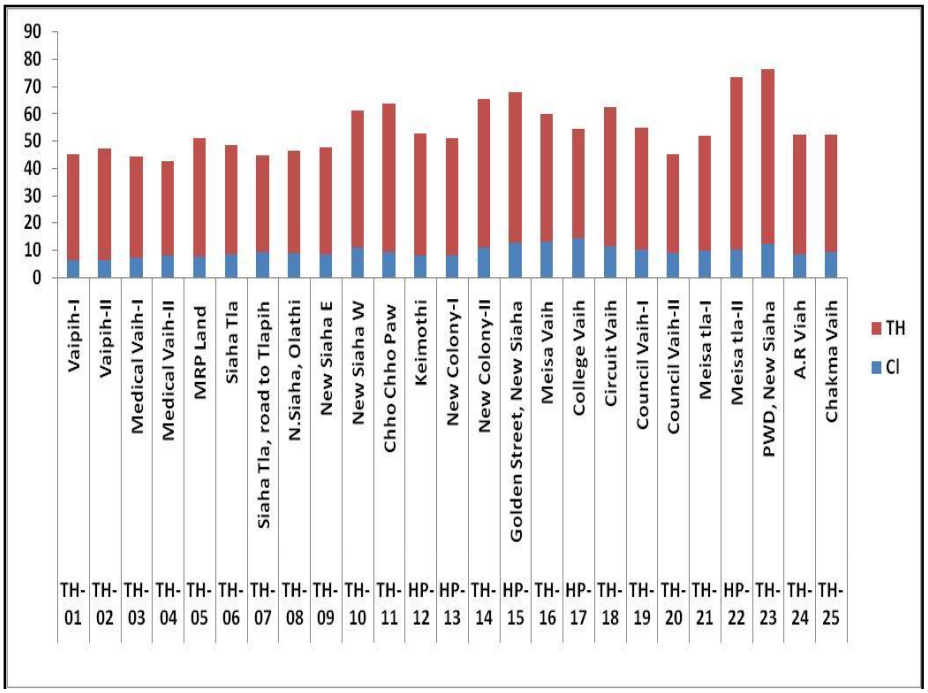

Fig. 2C | Plot of chemical data (total hardness and magnesium).

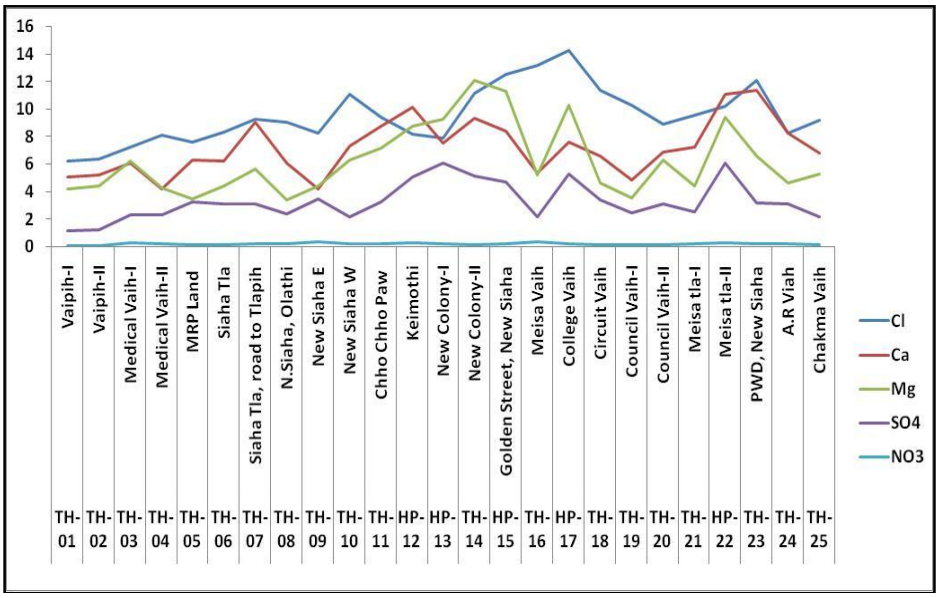

Fig. 2F | Plot of chemical data (chloride, calcium, magnesium, sulphate and nitrate).

may have low buffering capacity and more corrosive.[16]

In natural waters, alkalinity is due to free hydroxyl ions and dissolution of CO_2 in water.[17] In addition, it is a measure of the buffering capacity of water, or the capacity of bases to neutralize acids. It is used in determining the ability of stream to neutralize acidic pollution from rainfall or wastewater. In the samples analyzed, total alkalinity was found to be slightly low ranged from 26-76 mg/L. The values of total alkalinity having less than 200 mg/L are desirable for drinking and domestic purposes. Chloride in water is one of the major inorganic anions. The concentration of chloride which exceeds the level of 250 mg/L may produce salty taste; however, it does not cause any hazard to human health. The concentration of total chloride (TCl) in all the stations are much lower (6-14 mg/L) than the desirable limits value of 250 mg/L (Fig. 2D, 2E). Values of chloride ion in normal portable water are less than 30 mg/L, whereas higher values commonly indicate the admixture of mineralized waters or anthropogenic pollution.[18]

The standard level of iron prescribed by WHO is 0.3 mg/L. The concentration of iron in groundwater (hand pumps) samples is much more than the sub-surface water. All of the hand pumps samples were found exceeding the standard level of iron. The Environmental Protection Agency considers iron as a secondary contamination; declare that it does not have a direct impact on human health. The secondary maximum contaminant level of iron set out by the WHO is merely a guideline and not a federal standard. Idaho's groundwater (well) has exceeded quite amount of iron (15 mg/L), however the level is still not enough to cause physical harm.[19] The concentration of nitrate in all the samples is quite low ranged from 0.11-0.37 mg/L as compare to the standard level of 45 mg/L (Fig. 2F). The low concentration of nitrate indicates less use of nitrogenous fertilizers.[20] The major cations like calcium and magnesium are found to be in ranged of 4.24-11.35 and 3.42-12.13 mg/L having mean value of 6.87 and 5.28 mg/L respectively. In all the samples, it can be seen that all the values of these cations (Ca, Mg) are much lower than the standard value, but are well within the desirable limits (Fig. 2F). High level of Sulphate in drinking water may contribute to the corrosion of distribution system, and hence causes water a bad taste as well as purgative in humans.[21] The values of Sulphate were generally low, ranging between 1.15 mg/L-6.06 mg/L with a mean of 3.11 mg/L. The WHO permissible limit is 200 mg/L.

Conclusion

The present investigations indicate that all the physico-chemical parameters of the samples were within the permissible limits as per standards prescribed by WHO and BIS. Though Iron concentration in hand pump samples exceeded the standard level, it is considered as the secondary contamination which means that it does not have a direct impact on human health. It is concluded that all the tuikhurs and hand pumps are fit and suitable to serve as water source for human consumptions and household purposes.

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