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Assessment of water quality of some fresh water mountain springs in Naini lake basin of Kumaun Himalaya

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Abstract
Kumaun region of the Himalaya is bountifully supplied by a variety of drinking water resources including lakes, rivers, streams, springs, brooks, etc. Fresh water springs are important sources in rural as well as in urban areas of the mountain regions and are the natural sources of the ground water. They are generally managed by community and are not owned privately. As such they are considered to be the common sources of drinking water. In general, the springs are supposed to be uncontaminated, however, the probability of contamination by humans and wildlife is always there. The purpose of this study was to assess the physico-chemical and microbial quality of some springs in the Naini lake basin of Kumaun Himalaya. Seventeen springs located in the lake basin of Nainital were selected for the study. The water samples were collected thrice during 2017. In total, sixteen parameters were analysed viz; DO, pH, total hardness, Mn, Fe, total coliform, B.O.D., T.D.S., Ca, F, PO_4-P, NO_3-N, NH_3- N, NO_2-N, Cu and Zn. The results were compared with the Indian Standard Specification for drinking water. It was found that water qualities with regard to physico-chemical properties of almost all springs were either within the acceptable or within permissible limit of I.S.I. for human consumption; only six springs showed no coliform bacteria.

Keywords: springs, water quality, Naini lake basin, Kumaun Himalaya, mountain

1. Introduction

It will not be an exaggeration if we say that water is life. All human systems and natural ecosystems depend on water. When we go back in the history of civilization we find that all major human civilizations developed near the water bodies. The importance of water can also be understood from the fact that reduction in humans weight by 30 to 50 % due to hunger may not affect the human health seriously but only 10% loss of weight due to dehydration may adversely affect the physiology of humans. Because of this several Indian saints and philosophers have written the importance of water in their books. Although the water is so important, the statistical data throughout the world display a different scene. Worldwide, a large population of humans do not get regular safe drinking water. Moreover, a large number of people in developing countries go for miles to fetch a bucket of water. Not only this, many of humans lack access to adequate sanitation because of unavailability of water. According to a report, so many children are killed by the water borne diseases in developing countries like India. A report of W. H.O. (1973) [1] states that in developing countries 80% of all diseases and deaths are related with water borne diseases. This has attracted the attention of politicians, scientists, social workers and world bodies such as World Health Organisation. Many policy makers, water managers and social workers have attempted to suggest recognition of water as a human right.

When we consider the distribution of water on the earth, we find that water is most widely distributed and abundant in nature, but most of the water is not usable for drinking purposes because more than 97% is in the sea which is undrinkable due to high salinity. Only less than 3% is fresh water. Out of this, only 1% is available for drinking purposes. The important resources of fresh water include rivers, lakes, reservoirs, streams, brooks, springs, etc. These resources are also used for irrigation purposes and for producing electricity. In most of the rural areas of the plains wells are the important resources of drinking water which are owned by individuals. But in hilly region, springs constitute the important sources of natural drinking water and are managed and maintained by community. Locally, the springs are called ‘Dharas’ and ‘Naula’. They occur where slopping grounds and impermeable strata join the ground water table. A search on literature indicates that in abroad a good amount of work has been carried out on the water quality of mountain springs (e. g., Viviroli *et al* 2011, [2] Afiukwa and Eboatu, [3] 2013, Singh *et al*, 2014, [4] Zebreen and Ghanem, 2015, [5] Tripathi *et al* 2015), [6] but very little work has been done on Kumaun Himalayan springs.

The present research was carried out on the springs in Nainital lake basin of Kumaun region of Uttarakhand with the main objective of determining the water quality of these springs for drinking purposes. The water of the most of these springs are being widely used for drinking and other domestic purposes.

2. Study Area

The studied springs lie between the elevations of 1578 -2135 m above sea level in the Western Himalaya (Fig. 1). The climate of the area is sub- tropical and is mostly covered with forest and human settlement. With popularising of Nainital and expansion of infrastructure of tourism, a large number of tourists influx the town every year. The long cold and snowy winter and short summer characterise the climate of the area. The whole year can be divided into five seasons i.e. spring, summer, monsoon, autumn and winter. Spring season is characterised by mild cold in early parts, while the late spring is the intermediate between spring and summer. Minimum and maximum temperatures during spring season reach at 7ºĊ and 23º Ċ, respectively. Maximum temperature occurs in summer (May and June), sometimes reaching up to 31º Ċ. The minimum temperature during the summer is recorded at 15º Ċ. The monsoon season starts in the late June and continues till mid- September. July and August are the months when maximum rainfall occurs. Most of the rainfall (more than 80%) occurs during the monsoon months. Autumn follows the monsoon months. This is a mildly cold season. During this period temperature ranges between 14º Ċ and 23º Ċ. The winter starts from the late November and continues till February. Occasionally, during the winter the snowfall occurs. The minimum temperature during winter drops down to -3º Ċ while the maximum goes upto 15 º Ċ.

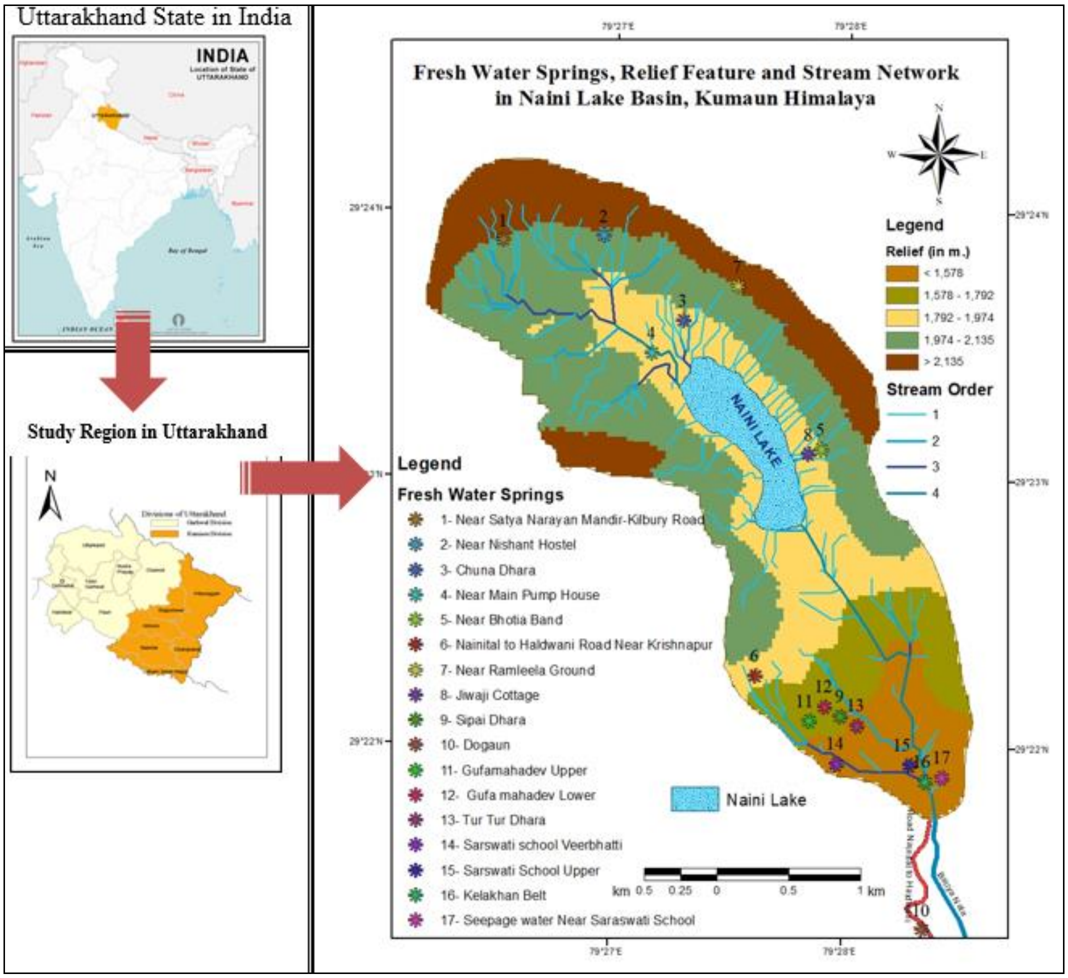

Fig 1: Showing the locations of springs in Naini lake basin. The stream order and relief features (elevation in m) are also depicted in the figure.

2.1 Vegetation around the springs

Hills around the springs are covered with Oak species namely, *Quercus leucotrichophora* and *Q. dilatata*. Coniferous trees such as *Cupressus torolusa,* and *Cedrus deodara* are also distributed in clumps. Other tree species include *Aesculus indica, Cornus macrophylla* and *Populus ciliata.*

3. Materials and Methods

An extensive survey of Kumaun region was made to find out the location and distribution of springs in Naini lake basin of the Kumaun Himalaya. The locations of springs are shown in Fig 1. Water samples from various springs were collected in clean 1 l polythene bottles in the month of April, September and November 2017. April represented the summer season, September the autumn season and the November represented the winter season. The water samples were transported to the laboratory as early as possible preferably on the same day. Samples collected at a particular date were analysed within 2-3 days. YSI Photometer (model 9300, USA make) was used to analyse the pH, total hardness, and concentrations of manganese, iron, calcium, fluoride, phosphate, nitrate, ammonia, nitrite, copper, total dissolved solids and zinc. This equipment is automated and uses its own reagent supplied by the manufacturer. The reagents are based on protocols of American Public Health Association (APHA, 1989) [7]. The concentration of dissolved oxygen was measured by YSI DO Meter (Optical D.O. Meter Pro-ODO U.S.A. make). Measurement of bio - chemical oxygen demand and total coliform count were done as per methods described in APHA (1989) [7].

4. Results and discussion

The various data on the physico-chemical parameters of water and coliform count of studied springs are contained in Table 1a & b. The data are means of three seasons (see Material and Methods).

Table 1a: Physico- chemical parameters of water quality and coliform count of various springs in the Naini lake basin of Kumaun Himalaya.

Sl. No.	Springs	DO mg/l	pH	T.hardness ($CaCO_3$) mg/l	Mn mg/l	Fe mg/l	Total coliform (MPN)	B.O.D mg/l
1.	Near Satya Narayan Mandir- Kilbury Road	2.5	7.0	230	0.15	0.01	1	1
2.	Near Nishant Hostel	2.6	7.5	515	0.01	0.20	2	1.5
3.	Chuna Dhara	2.1	7.0	480	0.01	0.0	1	0.8
4.	Near Main Pump House	2.2	7.2	520	0.01	0.01	1	1.5
5.	Near Bhotia Band	2.1	7.5	190	0.01	0.02	1	1.5
6.	Nainital to Haldwani Road Near Krishnapur	2.1	7.5	270	0.10	0.1	0	1
7.	Near Ramleela Ground	1.8	7.2	490	0.15	0.1	0	1
8.	Jiwaji Cottage	3.6	7.2	510	0.02	0.2	0	1
9.	Sipai Dhara	6.2	7.2	460	0.02	0.14	1	0.5
10.	Dogaun	6.31	7.0	150	0.01	0.20	0	0.8
11.	Gufa Mahadev Upper	6.5	7.5	420	0.015	0.21	1	0.5
12.	Gufa Mahadev Lower	4.15	7.5	370	0.012	0.15	0	0.6
13.	Tur Tur Dhara	8.2	7.5	520	0.013	0.12	1	1.0
14.	Saraswati School Veer Bhatti	8.5	7.0	450	0.011	0.0	1	1.5
15.	Saraswati School Upper	2.5	7.0	520	0.02	0.20	2	1.2
16.	Kelakhan Belt	2.6	7.0	490	0.01	0.01	0	1.2
17.	Seepage water, Near Saraswati School	2.8	6.5	520	0.01	0.01	1	1.3

Table 1b: Physico- chemical parameters of water quality of various springs in the Naini lake basin of Kumaun Himalaya.

Sl. No	Springs	TDS mg/l	Ca mg/l	F mg/l	Phosphorus (PO_4-P) mg/l	Nitrate (NO_3-N) mg/l	Ammonia (NH_3-N) mg/l	Nitrite (NO_2-N) mg/l	Total copper (Cu) mg/l	Zinc (Zn) mg/l
1.	Near Satya Narayan Mandir- Kilbury Road	198	190	0.08	0.06	0.128	0.02	0.00	0.00	0.01
2.	Near Nishant Hostel	185	102	0.12	0.09	0.238	0.71	0.001	0.06	0.01
3.	Chuna Dhara	561	101	0.46	0.11	0.880	0.71	0.003	0.10	0.01
4.	Near Main Pump House	397	165	0.53	0.20	0.860	0.11	0.000	0.06	0.01
5.	Near Bhotia Band	421	106	0.32	0.12	0.550	0.32	0.009	0.00	0.01
6.	Nainital to Haldwani Road Near Krishnapur	236	33	0.33	0.10	0.332	0.05	0.000	0.08	0.015
7.	Near Ramleela Ground	420	31	0.45	0.12	0.477	0.45	0.001	0.08	0.015
8.	Jiwaji Cottage	379	55	0.39	0.34	0.496	0.15	0.003	0.04	0.015
9.	Sipai Dhara	224	54	0.42	0.07	1.010	0.07	0.003	0.08	0.012
10.	Dogaun	415	55	2.60	0.05	0.48	0.21	0.004	0.12	0.012
11.	Gufa Mahadev Upper	276	112	0.36	0.08	0.327	0.15	0.00	0.08	0.01
12.	Gufa Mahadev Lower	263	66	0.33	0.16	0.640	0.07	0.001	0.16	0.01
13.	Tur Tur Dhara	351	43	0.37	0.14	0.407	0.37	0.001	0.06	0.015
14.	Saraswati School Veer Bhatti	505	65	1.13	0.16	0.540	0.28	0.003	0.24	0.01
15.	Saraswati School Upper	475	85	0.73	0.17	0.545	0.17	0.062	0.06	0.01
16.	Kelakhan Belt	263	190	1.02	0.06	0.310	0.33	0.000	0.04	0.01
17.	Seepage water, Near Saraswati School	250	31	1.47	0.11	0.267	0.36	0.007	0.14	0.15

4.1. Dissolved oxygen (DO)

The concentration of dissolved oxygen in the springs varied from 1.8 mg/ l - 8.5 mg/l. No specification of DO for drinking water has been set by Bureau of Indian Standard (B.I.S.) [8].

4.2. Hydrogen ion concentration (pH)

The measurement of pH in drinking water and aqueous solution is one of the most frequently performed tests. The pH values of the springs varied from a minimum of 6.5 to a maximum of 7.5. Thus, the waters were either slightly acidic or slightly alkaline. As per the norms of Indian Standard for drinking water quality (Table 2) the acceptable limit for pH of drinking water is 6.5-8.5. Thus, the water can be regarded as safe with reference to pH.

Table 2: Indian standard for drinking water –specification for various parameters (Second Revision to 2012 specification). Modified from Bureau of Indian Standard specification tables.

Sl. No	Characteristic	Requirement (Acceptable limit) mg/l	Permissible limit in the absence of alternate source mg/l
1.	pH	6.5-8.5	No relaxation
2.	Total hardness	200	600
3.	Fluoride	1.0	1.5
4.	Phosphorous	-	-
5.	Nitrate	45	No relaxation
6.	Ammonia	0.5	No relaxation
7.	Nitrite	-	-
8.	Copper	0.05	1.5
9.	Zinc	5	15
10.	T.D.S.	500	2000
12.	Ca	75	200
13.	Fe	0.3	No relaxation
14.	Mn	0.1	0.3
15.	Total coliform bacteria*	0/100 ml	No relaxation
16.	D.O.	-	-
17.	B.O.D.*	0.75	1.5

*WHO specification

4.3. Total hardness (as $CaCO_3$)
Water hardness is caused by the presence of calcium and magnesium salts. The hardness is defined as contents of divalent metallic ions which react with sodium soaps to produce solid soaps or scummy residue, and which react with negative ions when the water heated with boilers to produce solid boilers scales (Todd, 2007)[9]. High hardness of drinking water causes gastroenteritis in humans. The total hardness in studied springs varied from 150 mg/l to 520 mg/l. On the basis of hardness level, the springs could be divided into three categories: there were six springs (Sl. No. 2, 4, 8, 13, 15 and 17) which showed more than 500 mg/l of total hardness. These could be called as very hard water springs. There were only two springs (Sl. No. 5 and 10) which had less than 200 mg/l hardness in their waters. They could be designated as low hard water springs. The total hardness in the water of remaining nine springs was between 200 and 500 mg/l. These springs could be referred to as medium hard water springs. Thus 35 % of the springs were having very hard water. The acceptable limit of hardness as per Indian Standard norms is 200 mg/l, while the permissible limit in the absence of alternate source is 600 mg/l. Thus, the total hardness of the water of only two springs was under acceptable limit and water of all springs was under the permissible limit with regard to total hardness

4.4. Manganese (Mn)
The concentration of manganese ranged from 0.01 - 0.15 mg/l in all springs' water. In most of the springs, the water contained limited amount of manganese i.e., under the acceptable limit. Only in three springs (Sl.No. 1, 6 and 7) the concentration exceeded the acceptable limit. However, it did not cross the permissible limit of 0.3 mg/l.

4.5. Iron (Fe)
The concentration of iron varied from undetectable to 0.21 mg/l in all springs. Although iron is an essential element for the human health, its high concentration is not acceptable in drinking water. The acceptable limit for iron in drinking water has been set as 0.3 mg/ l by B.I.S [8]. No relaxation has been given for higher concentration (more than 0.3 mg/l) even in the absence of alternate source.

4.6. Total coliform (M.P.N.)
The total coliform bacteria count was between 0 and 2 in 100 ml of water. These values could be considered as very small. However, the drinking water should not contain any cell of coliform bacteria in 100 ml of water because acceptable limit is 0/100 ml. No relaxation has been given by B.I.S [8]. The 11 springs contained one or two coliform bacteria in 100 ml of water. It represents pollution, most likely from animals faecal matter such as monkeys, birds, langurs and other wild life animals. This demands the protection of spring water from contamination.

4.7. Biochemical oxygen demand (B.O.D.)
The bio-chemical oxygen demand ranged from 0.5 to 1.5 mg/l. The WHO's acceptable limit for B.O.D. is 0.75-1.5 mg/l (Table 2). Thus, the waters of all springs were within the WHO's highest acceptable and maximum permissible limit indicating the water to be of good quality.

4.8. Total dissolved solids (T.D.S.)
The concentration of T.D.S. in the studied springs ranged between 198 and 561 mg/l. The acceptable limit of T.D.S. set by B.I.S [8]. Is 500 mg/l, while the permissible limit is 2000 mg/l. There were only two springs in which the concentration of T.D.S. crossed the acceptable limit of B.I.S [8].

4.9. Calcium (Ca)
The concentration of calcium in springs' water varied from 31 -190 mg/l. The acceptable limit of calcium in drinking water has been set as 75 while the permissible limit has been fixed as 200 mg/l by B.I.S [8]. Thus, some spring waters fulfilled the acceptable limit while all were having the calcium concentration under permissible limit.

4.10. Fluoride (F)
Fluoride occurs naturally in some ground waters and is often introduced into drinking water for the prevention of tooth decay. However, excessive amount of fluoride are objectionable. Under excessive condition it can cause tooth discoloration. In recent past, contamination of natural waters with fluoride has received serious attention of health experts due to increasing causes of 'fluorosis', a disease caused by excessive consumption of fluoride. The concentration of fluoride in spring water is generally controlled by the climate of the area and the presence of accessary minerals in the rocks through which the ground water circulates. Its concentration in the present springs varied from 0.08 mg/l -2.60 mg/l. As shown in Table 1 b, only one spring (Sl. No.10) had more than 2.0 mg/l of fluoride in its water. There were three springs (Sl. No.14, 16 and 17) which had fluoride concentration between 1.0 and 1.5 mg/ l. The remaining 13 springs had less than 1.0 mg/ l fluoride concentration in water. As per Indian Standard specification, the acceptable limit of fluoride in drinking water is 1.0 mg/ l, while permissible limit in the absence of alternate source is 1.5 mg/ l.

4.11. Phosphorous (PO_4-P)
Phosphorous is essential for the human health as this is the raw material of ATP. However, it remains present in the drinking water in very low quantity. Phosphate can enter water courses through a variety of routes particularly domestic and industrial effluents and run off from agricultural land. Phosphate testing is an important process of monitoring drinking waters. The concentration of phosphate-phosphorous in the present springs varied from 0.05 mg/ l -0.34 mg/ l. No norms of phosphorous in drinking water is provided by the Bureau of Indian Standards (B.I.S) [8].

4.12. Nitrate-nitrogen (as NO_3-N)
Nitrogen is the raw material of protein and is required by humans in good quantity. Its requirement is mainly fulfilled through the food. However, it remains in water in very low quantity. It enters the water supplies from the breakdown of natural vegetation, the use of the chemical fertilizers in modern agriculture and from the oxidation of the nitrogen compounds in sewage effluents and industrial wastes. Drinking water containing excessive amounts of nitrates can cause 'methaemoglobinaemia'. In bottle fed infants the disease is also called 'Blue Baby Syndrome'. As per Indian Standard drinking water specification, the maximum acceptable limit of nitrate is 45 mg/ l, and no relaxation in permissible limit has been set. With regard to this, the waters of all springs were safe for drinking purposes and the concentration of nitrate was very low in water of all springs as compared to the permissible limit.

4.13. Ammonia (as total NH_3-N)
Pollution control programs routinely apply ammonia test to monitor drinking water supplies. The maximum acceptable limit of ammonia in drinking water is 0.5 mg/ l as per the specification of Indian Standard for drinking water. Even in the absence of alternate source, no relaxation has been given. In the present springs the concentration of ammonia -nitrogen varied from 0.02 mg/ l -0.71 mg/ l. There were only two springs (Sl.No 2 and 3) which had ammonia –nitrogen concentration greater than 0.5 mg/ l. The remaining springs had limited amount of ammonia –nitrogen.

4.14. Nitrite (as NO_2-N)
The concentration of nitrite-nitrogen in the waters of studied springs varied from undetectable to 0.062 mg/ l. Thus, the concentration of nitrite was very low in all springs. In general, high concentration of nitrite is considered to be undesirable and perhaps toxic in drinking water. However, no norms for drinking water has been provided by Bureau of Indian Standard (B.I.S.) [8].

4.15. Copper (Cu)
Living organisms require at least fourty naturally occurring elements. Of these, copper and zinc are of much significance for human health. However, the presence of copper in drinking water can give rise to discoloration or an astringent taste. The acceptable limit of copper in drinking water as per the norms of Indian Standard is 0.05 mg /l, while the permissible limit in the absence of alternate source is 1.5 mg/ l. The concentration of copper in the water of present springs ranged between undetectable and 0.24 mg/l. The concentration exceeded 0.05 mg/l in 13 springs. Thus in 75% springs, the concentration of copper was greater than the acceptable limit and only 25% of the springs had concentration under acceptable limit of the Bureau of Indian Standard (B.I.S.) [8].

4.16. Zinc (Zn)
Zinc is also required by humans in limited quantity. Most of human requirement of zinc is fulfilled by food. But drinking water is also a good source of it. Its high concentration in drinking water is objectionable. The concentration of zinc in the studied springs varied from a minimum of 0.01 to a maximum of 0.15 mg/ l. According to Bureau of Indian Standard for drinking water the acceptable limit of zinc in water is 5 mg/l and permissible limit in the absence of alternate source is 15 mg/ l. Thus, the concentrations of this metal in the waters of all springs were under the acceptable limit.

Neary *et al* (2009) [10] have stated that the most sustainable and best quality freshwater sources in the world originate in forest ecosystems. According to them the biological, chemical and physical characteristics of forest soil are particularly well suited to delivering high quality water to diverse aquatic habitats. Accordingly, the water of the springs in the mountains of the Himalaya must be considered very clean and suitable for drinking purposes. In general, studied springs had good quality of water except few ones which contained high concentration of fluoride and copper. However, the quality of water should not be determined only on the basis of physico-chemical parameters. The microbial parameters such as total coliform bacteria contained in water should also be considered to assess the quality of the water.

Springs' water is acknowledged as the best potable water especially if it is free from chemical contaminants because microbial contents can be eliminated by some level of treatment but removing chemicals from the drinking water is rather difficult. The sources of the spring waters can be protected by housing them and passing through PVC pipes in between the rock cavities and collecting the water into sedimentation tanks where liming disinfection and aeration can be done. The overflow of the treated springs water can then be passed through distribution pipes to household taps or public consumer taps. This will inhibit excessively the water from cavities in which animal droppings, dead vegetation run off and other forms of anthropogenic sources contamination can no longer affect (Afiukwa and Eboatu, 2013) [3].

5. Conclusion

This study suggested that the water qualities of almost all studied springs with regard to physico-chemical properties were either within the acceptable or within permissible limit of I.S.I. for human consumption; sixty four percent of the springs contained one or two coliform bacteria and the remaining thirty six percent were free from such contamination.

6. Acknowledgement

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