Survey of natural water sources of Tawang region and studies of their physico-chemical and bacterial contamination of water

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Abstract- Water quality survey and analysis of water sources is mandatory before deciding the suitability of any source for human consumption. Main criteria in determining the quality of water are physico-chemical and microbial parameters. This paper deals with study of physico-chemical and bacterial parameters of different water sources as river, stream and lake of Tawang district in Arunachal Pradesh, India. The study was carried out in the month of September 2017. Standard methods were used for carrying the analysis of collected water samples. Results were compared for water collected from different sources and it was found that contamination level with respect to physico-chemical parameters was within standard limits except bacterial contamination which was above standard limit in nearly all the samples. Maximum Iron concentration was observed in Shungatser Lake i.e 0.36ppm well above the desirable level. Bacteria and turbidity was found to be in excess than permissible limit. Hence it is recommended that the water should be properly treated for turbidity and bacteria for any natural water source and for Iron also in case of closed water bodies before consumption.

Index Terms- Physico-Chemical parameters, bacteria, Tawang district, lake, river

I. Introduction

Water is one of the most important neccessity of human life and availability of quality water to all has become one of the prime mandate for the government of any country. In the last several decades reports of water pollution with a variety of contaminants has become very common. The contaminants range from heavy metals, microbes, organics, agricultural and industrial byproducts etc (B.K. Mandal et al, 2002; A. Chauhan et al, 2017; WHO, 2018) [1–3]. Hence different international and national standards have been made for drinking water quality such as WHO, EPA and BIS etc (IS, 2012; B. Behera et al, 2012; WHO, 2009; WHO, 2016) [4–7].

With passing decades water demand has increased several times due to population explosion and depleting fresh water sources. Generally for human consumption water is extracted either from ground or is taken from surface water sources such as river, lakes ponds etc. Groundwater is considered as less contaminated compared to surface water due to natural filtration through soil but with time its quality is getting deteriorated due to different natural and anthropogenic causes. Natural causes may be leaching from rocky soil underneath and among the anthropogenic causes fertilizers and insecticides being used for increasing crop yield as well as other industrial effluents. Consumption of contaminated water leads to several water borne diseases in human population (X. Qu et al, 2013) [8]

Tawang is an administrative district in the state of Arunachal Pradesh. Tawang town is the district headquarter. The area of the Tawang district is approximately 2172 sq km., bordered by Tibet in the north, Bhutan in the south west and Sela range separate west Kameng district in the east. Tawang lies roughly between 27.45 N and 90.15 E at the north east extremity of Arunachal Pradesh. Elevations range between 6,000 to 22,000 feet. The river system of the district is a part of the Brahmaputra river basin. The prominent rivers are Tawang-Chu and Nyamjang-Chu. Most of the rivers and streams are perennial. In the hilly terrain the rivers have deep narrow gorges along their courses (TERI, 2018; Tech Report CGWB 2013) [9,10].

Due to its location at high altitude it may have been assumed that natural water sources do not have any type of contamination. Therefore water quality survey of Tawang have not been carried out separately but some documents mention that the chemical quality of spring water in the district is fresh and potable and can safely be used for domestic and industrial purposes (H. B. Das et al 1996)[11]. In this view it was a thought of interest to study the physico-chemical and bacterial parameters of surface water sources as only a few physico-chemical parameters have been reported in previous studies (I. M. Umlong et al 2020) [12].

Hence, in this study we have carried out the analysis of physico-chemical and bacterial properties of river, stream and lake water collected from a maximum altitude of 4300m. The water from different sources was compared for assessing its quality with respect to pH, TDS, turbidity, conductivity and salinity, along with metallic and bacterial contaminants like iron and *E.coli* respectively.

II. Experimental

A total of 22 water samples were collected from different locations (Fig 1) of Tawang district of Arunachal Pradesh in the month of September 2017. Prior to sample collection all the plastic bottles were thoroughly washed and dried. The bottles were rinsed with water sample to be collected at the time of collection. Proper

labeling was done after collection. Parameters like temperature and dissolved oxygen (DO) were measured at the sampling site itself using a thermometer and portable DO meter.

During samples collection, the latitude, longitude and altitude of all the sampling sites along with the source were recorded [Table I] using a GPS system (Model: Garmin GPS 72H). Sampling location map is made by google earth 6.1 and QGIS 2.12 software (Fig. 1).

The bottles were then taken to the laboratory in an icebox to avoid unusual change in water quality and stored at 4ºC for further analysis of turbidity, TDS, conductivity, salinity, iron, and bacteria as per standard procedures used for water analysis (APHA ,2005) [3]. AR grade reagents, deionized water and borosil glasswares were used for preparation of solutions. pH was estimated by digital pH meter (EuTech pH 610). TDS, DO, electrical conductivity and salinity were measured by using (Multiparameter EuTech CD 650). Turbidity was determined by using turbidity meter (EuTech TN 100). Iron was estimated via colorimetric method by using UV-Vis spectrophotometer (Analytikjena SPECORD 205). Bacterial contamination was determined by using standard plate count method.

III. Results and Discussions

Fig 1 shows the water collection area along with points of collection. The details of coordinates as well as information regarding source and altitude are shown in Table 1. Thus water samples were collected from three sources i.e. river, stream and lake. The range of altitudes varies from 1725 to 4300m.

Physico-chemical and bacterial analysis of all the collected water samples from different locations of Tawang was carried out and results are shown in Table 2 along with comparison with BIS standard values. The results obtained from this study are discussed below.

All the collected water samples were colorless and odourless. At the time of sample collection, the water temperature ranged between 13ºC to 24ºC.

Dissolved Oxygen (DO):

The dissolved oxygen is a measure of changes in biological parameters which occur as a result of aerobic or anaerobic phenomenon and signifies the condition of the river/streams water for the purpose of the aquatic as well as human life. The aquatic life gets disturbed if the DO values become very low. A range of 5–14 mg O_2/L is generally considered suitable for the natural waters depending on turbulence, temperature, salinity and altitude. As per the standards the range of DO should lie between 4 to 6 mg/L which ensures better aquatic life in the water body. In this study the value is DO is found to be in the range of 3.5 to 8.69mg/L.

pH:

The pH of any water body reflects its acidic or basic nature. It is considered as one of the important parameters of water quality since it controls the solubility of various metallic contaminants. Fluctuations in pH value of any water body are mostly due to discharge of industrial contamination or human waste in nearby vicinity or sometimes due to biological activity. If the pH of any water body changes due to any of the above mentioned reasons the physico-chemical parameters of water also show a change. If the pH becomes very high there are probabilities of formation of trihalomethanes which are very toxic. Alkaline pH value is witnessed due to presence of alkaline earth metals (Na, K) that interact with soluble CO forming carbonates and bicarbonates which result in shifting the pH up over 7. In the present study the value of pH is found to be normal for all sources ranging between 6.24 to 7.03.

Turbidity:

Turbidity of water shows how clean or cloudy it is. For any human it is an easiest measure of water quality as it is measured by human sense organ i.e. eye, although in the laboratory a turbidity meter is used for its measurement. The turbidity of any water body is affected by a number of factors. It is caused by particles which are dissolved or suspended in water that scatter light making it appear cloudy. Particulate matter generally includes clay and silt, phytoplanktons algae and other microscopic organisms, fine organic and inorganic matter etc (Das and Shrivastva, 2003) [13]. High turbidity indicates the presence of large amounts of suspended solids which reduce significantly the aesthetic quality of any water source (Verma et al. 2012) [14] It increases the cost of water treatment for drinking or any other application as food processing, pharmaceutical etc. Generally natural or human factors are responsible for causing turbidity. Natural factors include erosion from upland, stream channel movement etc. Human activities such as rock blasting or digging can also be a cause of erosion. Although the substances resulting in high turbidity may not be intrinsically harmful, but their effects may lead to serious consequences, since turbidity interferes with disinfection during water treatment and provides a medium for microbial growth. These microbes include bacteria, viruses and other parasites which cause symptoms such as nausea, cramps, diarrhea etc.

In this study the turbidity of collected water samples is in the range of 0.27 to 23.9 NTU which exceeded the permissible value. It is observed that river showed high turbidity compared to water collected from a stream which showed lowest turbidity. The high turbidity values of river may be due to vigorous turbulence of water during movement and presence of suspended particulate matter.

Total Dissolve Solids (TDS):

TDS is in general proportional to presence of all solids dissolved in water. It is also considered as an indicator of salinity of water. TDS comprises dissolved organic matter and inorganic salts (Ca, Mg, Na, K, HCO_3^-, Cl^- and SO_4^-) in water. Changes in pH strongly affect TDS as it affects solubility of suspended matter and may lead to precipitation of some of the solutes as well. Water containing more than 500mg/L of TDS is not considered desirable for drinking (BIS-2296, 1982; Shrinivasa Rao and Venkateshwaralu, 2000; Murhekar, 2011) [15-17]. In this study TDS of collected water samples varied from 9.78 to 139.0 mg/L which is within the permissible limit of BIS/WHO standards.

Electrical Conductivity (EC):

The ability of water to conduct electrical current is measured by EC which provides a general indication of water quality with respect to amount of total dissolved solids in the form of cations

and anions, their concentration and mobility etc. Thus with increase in the concentration of dissolved salts the electrical conductivity also increases. Changes in temperature also affect conductivity as solubility of salts responsible for ionic composition and hence conductivity varies with temperature. In the present study the conductivity of collected water samples is found to be in the range of 9.7 to 138.2 µS/cm.

Resistivity:

Resistivity is inverse of conductivity as it measures the resistance to electric conductivity. In the present study the resistivity of collected water samples is found to be in the range of 3.59 to 51 MΩ-cm.

Salinity:

Salinity of any water body gives information of its TDS and conductivity, since it indicates the presence of dissolved salts. Generally small amounts of dissolved salts exist in natural waters which are essential for the life of aquatic plants and animals but at the same time if the quantities become higher it may lead to severe health issues like increased blood pressure (BP) or hypertension leading way to cardiovascular diseases (CVD) (Mcmichael, 2003) [18]. The minimum salinity value was 18.29 mg/L and maximum 136.1 mg/L while the average value is 38.259 mg/L

Iron:

Iron is among one of the most abundant element of earth's crust. The cause of iron contamination in water may be geogenic or anthropogenic, the later due to industrial effluents and domestic waste. When iron contaminated water reacts with tea and coffee it appears blackish in colour. It also leads to staining of laundry and utensils. But iron is also an essential element for haemoglobin, myoglobin and a number of enzymes and its deficiency lead to anaemia and loss of well-being. At the same time its overload causes severe health problems in human beings such as liver cancer, diabetes, cirrhosis of liver, heart diseases and infertility etc. The presence of higher concentrations of iron changes colour, taste, odour of water, leaving stains on clothes and corrodes water pipelines (B. Behera et al, 2012) [5]. In the present study the iron concentration of collected water samples is found to be in the range of 0.05 to 0.36 mg/L.

Bacteria:

A wide variety of microorganisms exist in water bodies some of which may be pathogenic and some of which are non pathogenic. Some of the non-pathogenic microorganisms may lead to unpleasant taste and odour which may serve as an indicator. The main concern behind studying microbiological quality of water, however, is the potential of contamination by pathogens. Such pathogenic contaminants include bacteria, helminths, protozoa and viruses and most of these organisms are derived from feces (Amira A. A. et al 2011) [19]. Indicator organisms, usually bacteria, are generally used to analyze the microbiological quality of water. Among such indicators the most commonly used are thermotolerant (fecal) coliforms or *E.coli*. In addition to the above mentioned indicators of bacteriological water quality, the broader groups of coliforms known as total coliforms are also used in monitoring. In the present study the bacterial colony count of collected water samples is found to be in the range of 20 to 11680CFU/ml.

IV. Comparison of different water sources

River water

Samples 1-3 and 13 were collected from river, altitude varying from 2077m (sample no. 1) to 2318m (sample no. 3). pH for all the samples was observed to be within permissible limit varying from 6.5 for sample no. 13 and 6.99 for sample no. 2 respectively. Turbidity is in the range 1.30NTU for sample no. 1 to 23.9NTU for sample no. 11. The higher turbidity value for sample no. 13 may be due to its collection from a nearly plain area where all the sand, clay and other debris has flown. The presence of these particles leads to high turbidity value. When the sample was kept undisturbed for 24hr., the turbidity of the sample came drastically down (<1NTU). This shows that initially observed high turbidity values may be due to suspended impurities, mud etc which settled on keeping the samples undisturbed. Hence it can be assumed that turbidity of decanted water sample collected from low altitude was within desirable limit as per BIS standard. The TDS was observed to be in the range of 13.2mg/L to 139mg/L. Hence results show that water sample from the higher point of collection contains fewer quantity of dissolved matter which is reflected in its very low TDS value whereas samples from lower heights show higher quantity of dissolved impurities although both values are within the desirable limit as per BIS standard. With respect to Fe contamination, it was found in the range of 0.06 to 0.24mg/L which may be due to leaching from beneath the surface soil and rocks while water travels over it. Microbiological results showed the presence of bacteria with minimum 40CFU/ml and maximum 11,680CFU/ml. This shows that heavy load of microbial contamination is there in river water. All the physico-chemical analysis results show that maximum obtained values are within desirable limit or if exceed are still within permissible limit except turbidity which is much above the permissible limit of 5NTU. But after sedimentation and decantation the value was within desirable limit of <1NTU. Microbial contamination is a matter of concern, it being too high. Hence as per the results river water has to be treated for turbidity and bacteria before consumption.

Stream water

Samples 4-10, 14-16 & 20-22 were collected from different streams. pH of stream water was observed to be in the range of 6.37 to 7.03. Turbidity was also in the range 0.27 to 10.46 NTU. TDS ranged from 13.8 to 78.13. Even in stream the bacteriological count seems to be out of the acceptable value with values between 20 and 2010 CFU/ml.

Lake Water

Five samples are from Lake i.e sample number 11,12,17,18 and 19. Sample number 17 i. e. Shungatser Lake shows highest Iron Contamination (0.36 mg/ml) but other parameters are well within the range. The High value of Iron may be due to the depository effect over time. This observation is very interesting looking into the altitude and oxygen level at the lake. At the same time bacteriological count also seems to be out of the acceptable value with range between 30 and 200 CFU/ml.

V. Conclusion

In the present study the values for different physico-chemical parameters in most of the collected water samples were found within the desirable or permissible limit as prescribed by BIS standards. The water samples collected from river and stream showed high turbidity values which came down after leaving them undisturbed overnight. TDS for nearly all the samples was within desirable limit. Iron was found in concentration above desirable limit for closed water body such as lake. All the water samples showed presence of bacteria the range being very wide from 20CFU/ml to 11680CFU/ml. Hence it is recommended that the water should be properly treated for microbes and also for Iron in case of closed water bodies before consumption.

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Table 1: Details of sampling sites and sources of collected water samples

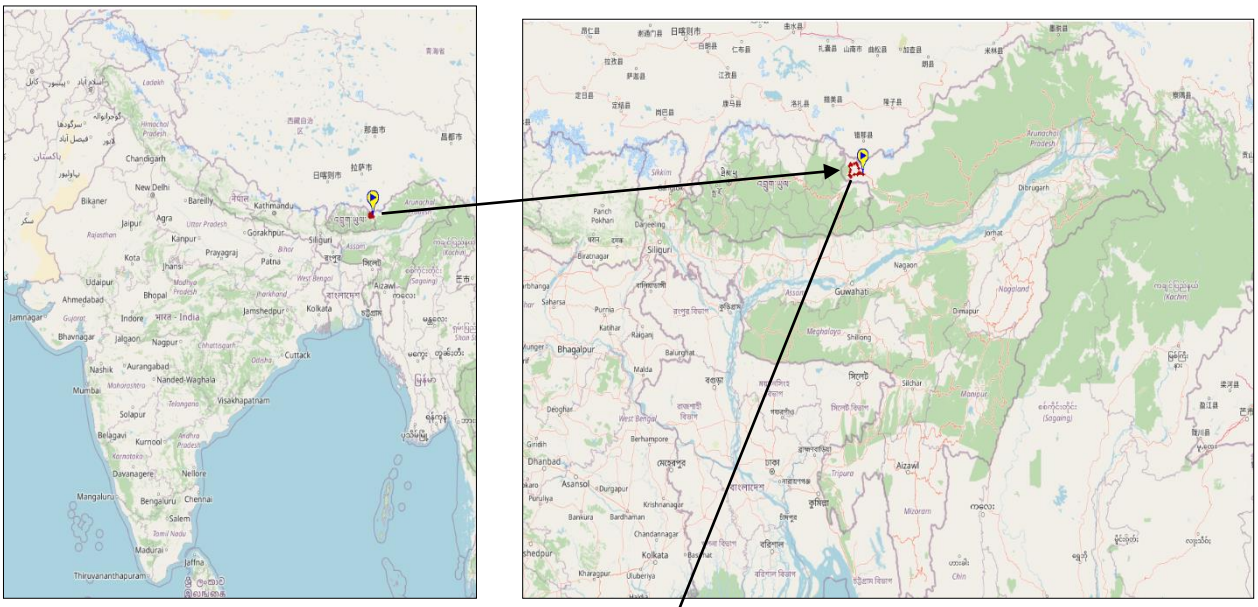
Sample No.	Name of the place	Sample Source	Latitude	Longitude	Altitude(m)
1	Jung Waterfalls	River	27.577643	91.946225	2077.1
2	Sappire	River	27.572888	91.850153	2307.1
3	Satteng	River	27.580038	91.794137	2318.5
4	Gutra	Stream	27.545801	91.734927	2350.4

5	Buka	Stream	27.551504	91.73034	2303.2
6	Jung	Stream	27.558539	91.720802	2116
7	Lumla	Stream	27.566326	91.698864	2170.8
8	BTR village	Stream	27.606316	91.714806	2068
9	Gerdum	Stream	27.638059	91.722298	1725.6
10	Zemithang	Stream	27.682146	91.707213	1960.8
11	Jerjang Tso	Lake	27.832614	91.575622	4100
12	Jerjang Tso	Lake	27.832256	91.593036	4300
13	Shakti	River	27.711956	91.728476	2202.3
14	Shakti II	Stream	27.689069	91.718993	2337.9
15	Gispu	Stream	27.69552	91.750723	3029.4
16	Sherwong	Stream	27.712092	91.792945	3016.4
17	Shungatser	Lake	27.721914	91.827148	3386.5
18	Tsokyo lake	Lake	27.691981	91.849736	4264.7
19	Nagula	Lake	27.654202	91.863022	4125.2
20	Gumgang	Stream	27.600078	91.87584	2996.2
21	Tesri udasri	Stream	27.584298	91.858344	2957.9
22	Manpath	Stream	27.592714	91.896457	2322.4

Table 2: Results of all physio-chemical parameters

Sample no.	**Water Temp (ºC)**	**DO (mg/L)**	**pH**	**TDS (mg/L)**	**Conductivity (µS/cm)**	**Turbidity (NTU)**	**Resistivity MΩ**	**Salinity (mg/l)**	**Iron (mg/l)**	**Bacterial Count CFU/ml**
BIS Standard (desirable - permissible)			6.5-8.5	500-2000		1-5			0.3-no relaxation	Nil in 100ml
1	14	8.05	6.68	56.01	55.11	1.3	8.969	57.67	0.06	11,680
2	15	8.1	6.99	27.19	26.9	5.54	18.43	32.59	0.15	510
3	15	8.4	6.96	13.2	12.22	1.66	41.18	20.4	0.09	40
4	18	8.56	7.03	26.6	26.44	6.69	18.8	32.03	0.05	1,620
5	14	8.25	6.9	21.78	21.73	0.9	22.92	28.07	0.2	340
6	14	8.15	6.78	28.55	28.46	10.46	17.52	33.81	0.07	430
7	14	7.29	6.8	78.13	77.69	4.3	6.371	78.55	0.06	30
8	15	8.69	6.55	26.75	26.65	6.69	18.63	32.39	0.21	590
9	24	7.85	6.68	13.8	13.62	0.53	36.49	21.53	0.15	1,020

10	15	8.42	6.71	18.86	10.82	0.68	46.01	19.28	0.13	150
11	18	6.65	6.68	11.66	10.16	0.93	41.12	20.11	0.19	60
12	16	6.85	6.98	13.76	10.16	0.98	43.12	22.11	0.23	80
13	14	8.25	6.5	139	138.2	23.9	3.596	136.1	0.24	460
14	14	8.1	6.96	23.05	22.94	5.26	21.59	29.22	0.14	1,280
15	16	6.55	6.7	13.09	13.37	0.54	38.31	20.92	0.28	20
16	14	7.75	6.72	13.42	14.23	0.59	37.2	21.12	0.12	40
17	18	3.5	6.5	14.3	11.7	1.89	34.78	21.82	0.36	30
18	18	6.75	6.6	11.76	10.26	0.95	42.12	20.01	0.18	50
19	14	7.03	6.24	9.78	9.77	1.37	51	18.29	0.13	200
20	13	7.75	6.37	48.01	47.67	0.31	10.43	50.53	0.07	340
21	13	6.5	6.6	32.4	32.2	0.27	15.58	37.05	0.09	450
22	15	7.2	6.64	51.57	51.23	1.97	9.707	53.8	0.2	2,010
Min	13	3.5	6.24	9.78	9.77	0.27	3.596	18.29	0.05	20
Max	24	8.69	7.03	139	138.2	23.9	51	136.1	0.36	11680
Average	15.5	7.483	6.70	31.48	30.52	3.53	26.53	36.7	0.154	974.09



(c)

Figure 1 Location map of water collection points (a) Indian Map (b) North East Map (c) Tawang and nearby areas

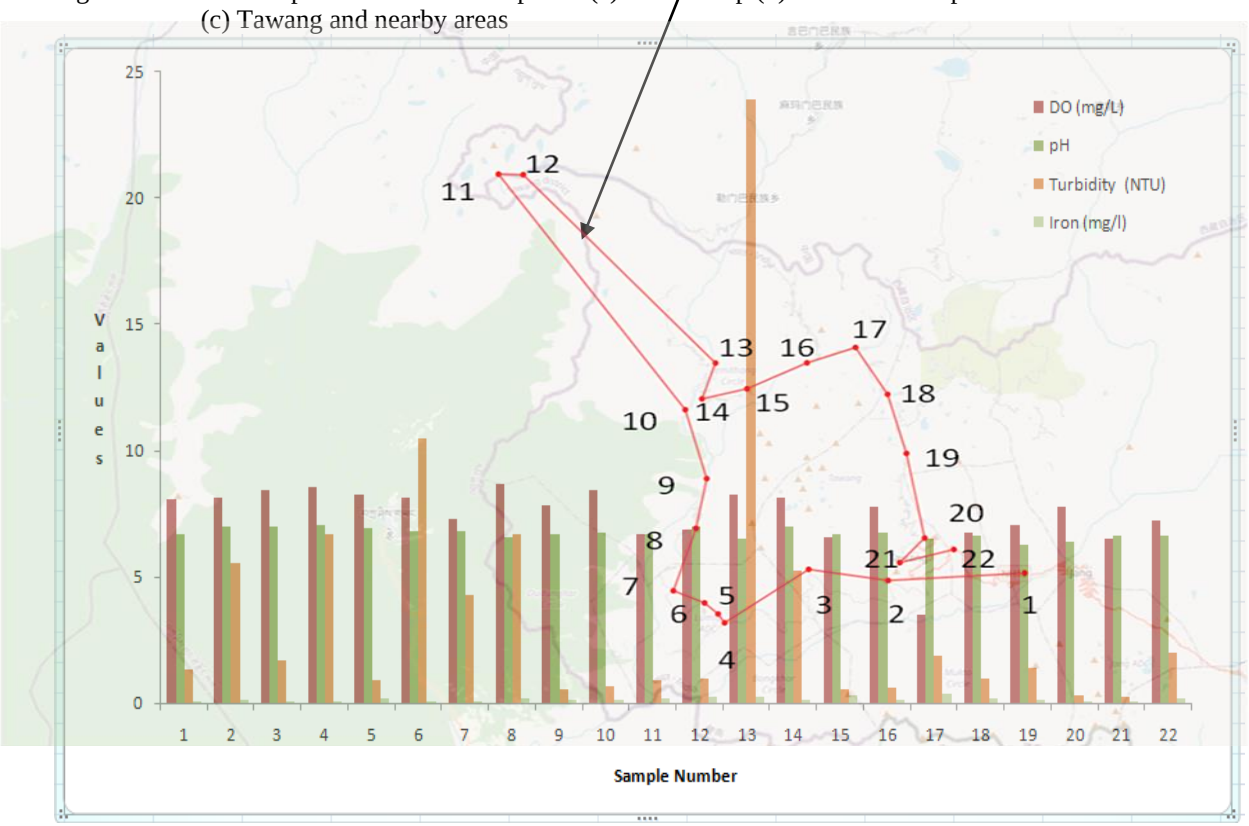


Figure 2 Variation of DO, pH, Turbidity & Iron for different samples

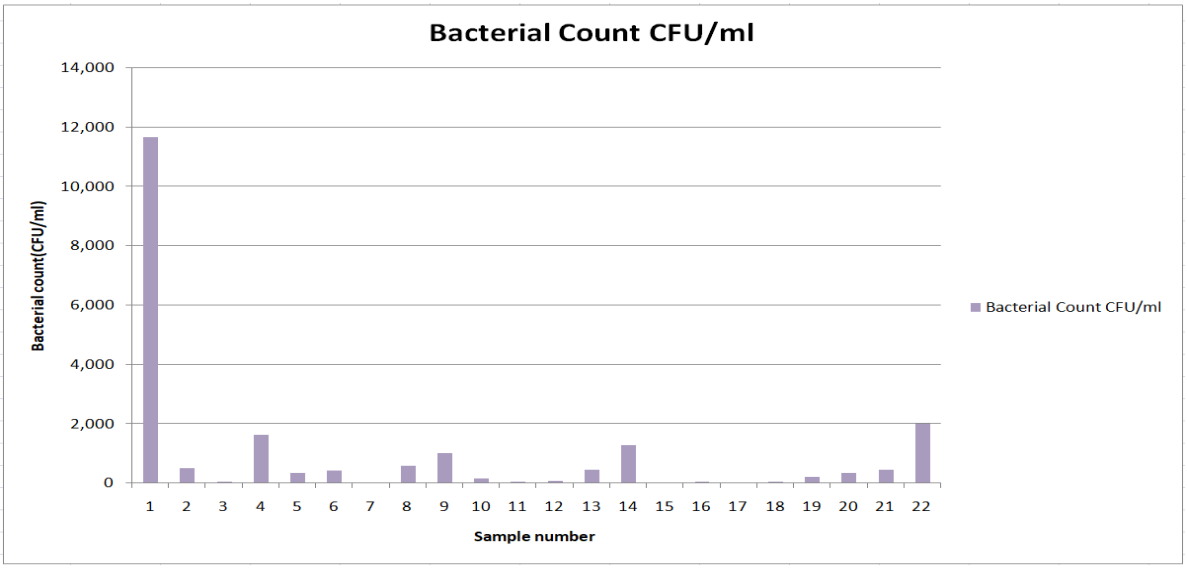


Figure 3: Variation of Bacterial Count for different samples

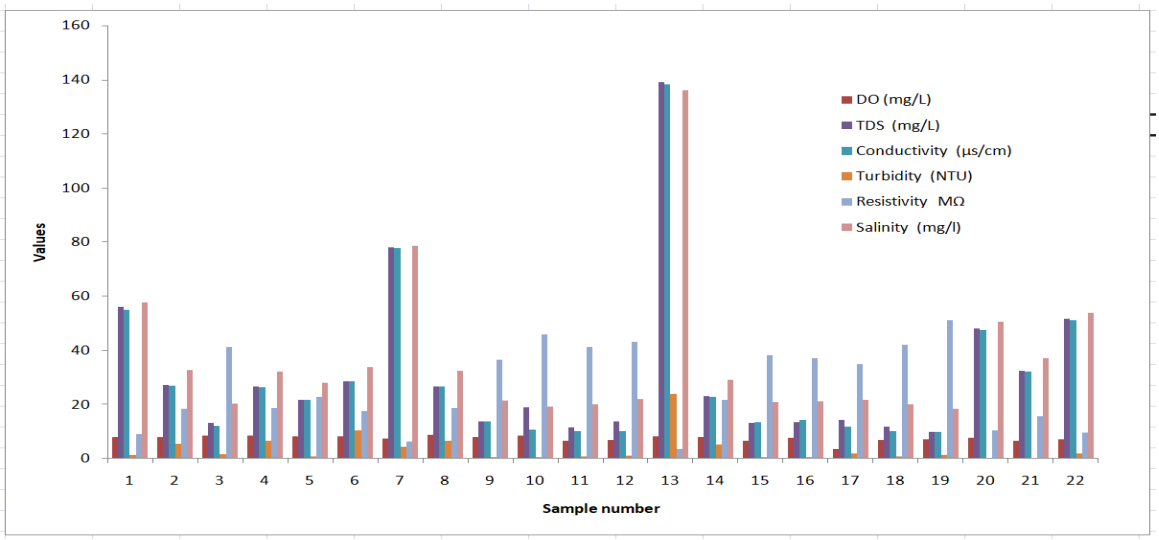


Figure 4 Variation of DO, TDS, Conductivity, Turbidity, Resistivity & Salinity for different samples

(a)

(b)

(c)

(d)

Figure 5: Some representative images of water sampling points (a) River (b) Lake (c) waterfall and (d) Stream