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Impact of Climate Sensitive Variables on Water Quality in Solan District of Himachal Pradesh

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Abstract

This study is an attempt to access water quality and the human health impacts associated with it. The area for the study is the Solan district of Himachal Pradesh, India. Key water quality parameters and their health issues are discussed. Surface water samples were collected from Ashwini and Giri rivers. These samples were assessed for physiochemical parameters like pH, turbidity, Total Hardness, color, Calcium, Magnesium, Total Alkalinity, Iron, Total Dissolved Salts, Chloride, Sulphate E. Colli, Total Coliforms and Fluoride. Microbial testing for Legionella and Vibrio Cholerae is done. Parameters were compared with BIS standards and are found to be within agreeable limits. Groundwater sampling was done from six locations for assessing Physiochemical parameters. It was found that the parameters at all sampling sites are within acceptable limits. For accessing the waterborne disease burden of the area, a health survey was also done in 12 blocks of Solan District by collecting data from the Chief Medical officer's office. Data shows a rise in a number of cases of enteric fever from 2040 to 2929 from the year 2014 to 2018, a decrease in a number of cases of jaundice and viral hepatitis from the year 2014 to 2018. The number of cases of acute diarrheal disease and gastroenteritis shows a rise in the number of cases from 29923 to 44615.

Keywords: Climate change; Health impacts; Parameter; Physiochemical; Solan; Temperature; Vulnerability; Water borne diseases

Introduction

Water is the most important part of environment and sustenance of life on the planet earth is due to its availability [1,2]. Earth's surface consists of 71% of water for which it is often called as blue planet. Increase in population, Industrial growth leading to shift in population for employment from rural to urban areas, high energy consumption, increase in consumption of water in agriculture and industry, fresh water is scarcely available [3].

Second factor that is creating a burden on water resources is change in climatic conditions. It is a change in the distribution of the patterns of weather if those changes take longer (e.g., decades to millions of years). Water quality and human health can be directly linked to each other. Around 1.8 billion people drink feces-contaminated water, putting them at risk of developing cholera, dysentery, typhoid, hepatitis A, and polio (WHO and UNICEF report).

According to statistics, almost 1 billion people do not have access to safe drinking water, and 5 million people die each year as a result of water-related diseases. The Inter-national Panel for Climate Change (IPCC) has research that the global surface temperature has increased by 0.74°C during 1906-2005 [4]. Climate change show changes in weather patterns, which affect temperature, wind patterns, weather, etc. These changes impact humans by increasing the occurrence of natural disasters, misery, diseases and other health related serious issues. The quality of water and water ecosystems can be altered directly or indirectly through various biochemical processes that can occur due to Climate change [5-11].

Furthermore, the specific effects will depend on topography, types of water bodies [7,8]. Waterborne illness is caused when a pathogen enters a water supply by drinking water or indirectly from eating contaminated food. Outbreaks of water-borne diseases generally occur after a major weather event like rain and snowfall. Anthropogenic activities are the main cause of climate change, which is known as global warming. Organic compounds like oil and pesticides also endanger water quality [9].

Climate change increases the severity and frequency of certain important weather events, people mostly in developing countries can face the risk of diseases. Pathogens like, protozoa's viruses and bacteria, water-soluble radioactive substances, ions like NO^{3-}, $PO4^{3-}$, $SO4^{2-}$, F^{-}, Ca^{2+}, Mg^{2+} and inorganic pollutants like salts, acids and toxic metals are considered as the major water pollutants [10-19].

In the lowlands of the Himalayan region, incidents of water borne diseases such as dysentery, typhoid, Shigellosis, cholera and hepatitis continue to be regularly reported. The present study is done to access water quality parameters in Surface and ground water and to access its impact on human health.

Studies show that there is a considerable increase of the stress of Water borne diseases resulting from climate changes and particularly from droughts, floods, increase of temperature with regards to factors as cyan toxins, microbial pathogen and chemicals [20]. There is a link between diarrhea and temperature, according to studies. With changes in climatic circumstances, heavy rainfall, drought, flooding, and meteorological events will become more common [21,22].

Solan district of Himachal Pradesh situated in north side of India is rapidly urbanizing. Due to widespread presence of industries in whole districts, there is a burden of gastroenteritis, hepatitis, waterborne

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diarrheal disease in the area [16]. So, there is a need to do assessment of the quality of water sources of the region. According to World Health Organization, Monitoring and surveillances play an important role in determining epidemiology of water borne diseases [17].

In this study, an attempt was made to assess Surface water samples collected from Ashwini and Giri rivers for physiochemical and Microbial parameters Legionella and Vibrio Cholerae. Parameters were compared with BIS standards. Groundwater sampling was done from six sampling sites for assessing physiochemical parameters. Lastly, a health survey was also done in 12 blocks of Solan District by collecting data from the Chief Medical officer's office to assess the disease burden of the area.

The impact of water quality parameters on health

Quality parameters are chemical, physical, and biological properties of water that can be monitored. Water quality parameters are classified into 3 types.

Parameters that are usually monitored to access quality of water are pH, temperature, turbidity, color, odor, taste, electrical conductivity, solids. Acidity, alkalinity, chloride, sulphate, nitrogen, fluoride, iron, manganese, hardness, sodium, potassium, lead, chromium, biochemical oxygen demand (bod), chemical oxygen demand (cod), bacteria, algae, viruses, and protozoa are all examples of dissolved oxygen (Figure 1).

Biological and Chemical reactions in water depends on temperature. Processes like BOD, COD, Solubility, viscosity etc. are temperature dependent. There is a limited Research on the impact of drinking cold or hot water on human health. Temperature of 23° C is suitable in all weather conditions for proper hydration of human body [23-25]. Pure water is clear and transparent.

Turbidity is due to presence of suspended materials in water. It can affect treatment processes by providing space for disease causing microorganism to hide from disinfection. Turbidity is measured by Turbidimeter.

The property of water to allow Electrical current to pass through it, is called Electrical conductivity. It is directly proportional to ionic concentration. Pure water is considered bad conductor. Sea water has high conductivity due to presence of salts in it. It is an important parameter in groundwater monitoring to identify saltwater intrusion, while in checking the freshwater quality it is also helpful. Measurement of the electrical conductivity of a solution is done by electrolysis.

Total suspended solids (TSS) and total dissolved solids (TDS) are two types of solids found in water (TDS). By passing water through filter paper, they may be quantified. Solids left on filter paper are Total suspended solids. Filtered water when evaporated, the solids obtained as residue are total dissolved solids. These parameters are of utmost importance in water treatment process. Values of Total dissolved solids not within prescribed limits will have adverse impacts on human health [12].

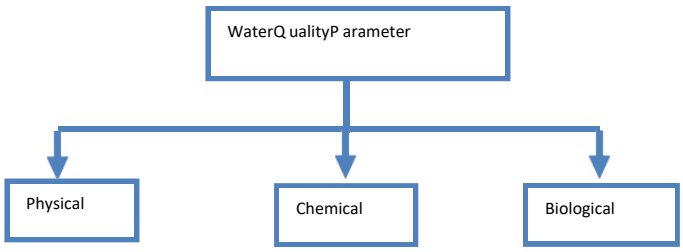

Figure 1: Classification of water quality parameters.

pH determines whether water is acidic or basic in nature. It ranges from 0 to 14. Value less than 7 indicates solution is acidic and more than 7 indicate solution is basic, while 7 is considered neutral. pH of 6.5-8.5 is considered safe for drinking water. Highly acidic and alkaline water lead to gastrointestinal, the irritation of skin, eyes [13]. Acidity led to corrosion; highly acidic water can easily dissolve heavy metals such as lead. High Alkalinity indicates presence of chemicals in water.

The chloride (Cl-) toxicity is not seen in humans [13] however high concentrations of chloride can taste salty to most people. The sodium content of table salt can cause heart and kidney diseases.

High concentrations of Sulphate ions may impart unwanted tastes or laxative effects, but impact on human health is not much evident.

Nitrogen is found in water and wastewater in the four forms. High nitrate in surface water degrades the water quality by stimulating the growth of the algae. It reacts with hemoglobin in blood and reduce its ability to carry oxygen thereby leading to methemoglobinemia or "blue baby syndrome".

Eutrophication is caused by an overabundance of phosphate and nitrogen in water, particularly due to runoff from the land. Fertilizer and livestock manure lead to dense plant growth and animal death owing to a shortage of oxygen. Algal blooms, fish fatalities, inedible shellfish, and blue algae were all caused by eutrophication, severely limiting the use of water for drinking, food harvesting, cleaning, and recreation. Small amount of fluoride in water help in preventing decay of tooth in children. Increase in amount of fluoride leads to dental fluorosis. Excess excessive iron results in high risk of carcinogenesis [13]. Impact of Manganese on human health is not evident expect it can impart bitter taste to water. Drinking hard water can lead to cardiovascular diseases, failure of reproductive system [24]. The concentration of Sodium greater than 20 ppm is not good [25]. Infants are more vulnerable to incorrect potassium ion excretion due to their inadequate renal reserve and immature kidney function [4]. High BOD means less availability of oxygen thus impacting aquatic organisms. Bacteria are unicellular organisms. Waterborne diseases like shigellosis, cholera, leptospirosis, paratyphoid fever, tularemia, and typhoid [15]. Protozoa are unicellular organisms [18]. They form lumps that cannot be treated by disinfection. Long-term high-level exposure can seriously harm the brain, reproductive system, and kidneys. Exposure is more in pregnant women, infants and young children. Chromium (Cr) can cause respiratory carcinogenicity, gastrointestinal disorders, genotoxic effects, cardiovascular shock, and mutagenicity [19].

Higher concentration of dissolved Oxygen indicates good quality of water. It is important factor in determining water quality [23]. Biochemical oxygen demand (BOD) is important factor in determining need for oxygen in water. Microorganisms present in water use organic substances for food [14] (Table 1).

Materials and Methods

Study area

Solan is situated in the outer Himalayas forming part of the Siwaliks and lies between 30° 54' 16.1496" N latitude and 77° 5' 48.2388" E longitude in the Solan district of Himachal Pradesh (Figure 2).

Major parts of the Solan district are hilly and mountainous with highly dissected and undulating terrain. The area lies in the drainage basin of river Satluj; marked by the presence of alluvial deposits of quaternary age which are deposited in sets of terraces by the river Sirsa and the various seasonal tributaries of the river viz. Balad Nadi, Chikni Khad, Chota Khopta Nallah, Pula Nallah, Jattawala Nallah, Sandholi

Table 1: Permissible Limit of water quality parameters for drinking and domestic Purpose.

Parameters	Indian StandardIS: 10500-2012		Method of Test
	Acceptablelimit	Permissible limit	Indian StandardIS:3025
Odour	Agreeable	Agreeable	IS:3025 Part 5
Taste	Agreeable	Agreeable	IS:3025 Part 8
pH	6.5-8.5	No relaxation	IS:3025 Part 11
Turbidity, NTU	1	5	IS:3025 Part 10
Total hardness asCaco3 (mg/l)	200	600	IS:3025 Part 21
Chloride(mg/l)	250	1000	IS:3025 Part 32
Total alkalinity as $CaCO_3$, mg/l, Max	200	600	IS:3025 Part 23
Total Dissolvedsolids (mg/l)	500	1000	IS:3025 Part 21
Calcium as Ca, mg/l, max	75	200	IS:3025 Part 40
Flouride(mg/l)	1	1.5	IS:3025 Part 60
Sulphate(mg/l)	200	250	IS:3025 Part 24
Residual Free Chlorine, mg/l, Min*	0.2	1	IS:3025 Part 26
Nitrate (mg/l)	45	No relaxation	IS:3025 Part 34
Total Iron as Fe, mg/l, Max	0.3	No relaxation	IS:3025 Part 53
Total dissolved solids (TDS), mg/l,Max	500	2000	IS:3025 Part 16
Magnesium as Mg, mg/l, Max	30	100	IS:3025 Part 46

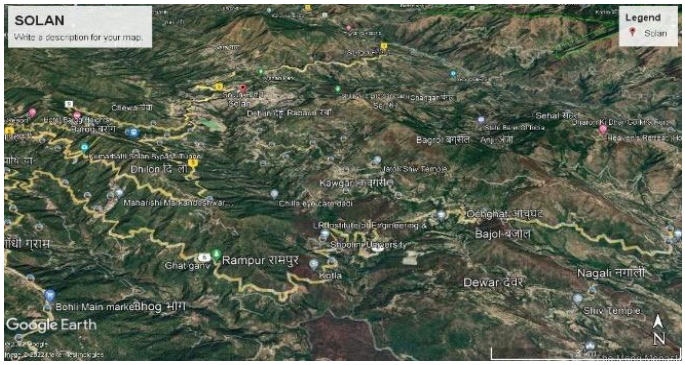

Figure 2: Solan district in Himachal Pradesh.

Nallah etc., have dissected these deposits into low-lying plains/flood plains. Solan is located 46 kilometers south of the state's capital, Shimla. Ashwani Khad enters District Solan upstream of Village Sadhupul. The catchment area in District Solan mainly comprises villages i.e., Kohari, Ded, Galai, Mathia, Shanbar, Andi, Sunnu Tikri, Bayela, Jalkhara, Dawarli and exits District Solan at Village Gaura near Yashwantnagar. The total stretch of Ashwani Khad in District Solan is approx. 22 Km. The Ashwani Khad meets River Giri at Village Gaura in Yashwantnagar. There is no industrial area in the entire stretch of Ashwani Khad in Solan District from Sadhupul till it meets River Giri at Yashwant Nagar. Yashwant Nagar falls in Sirmour district of Himachal Pradesh (Figure 3).

Giri River is also famous as "Giri Ganga" and is an important river that feeds the Yamuna River. Giri River originates from the hills of Kotkhai and drains at the parts of Himachal in the southeastern areas. It flows through the district of Sirmaur and further merges with the Yamuna River (Figure 4).

Sampling sites and collection of samples

Surface water sample of Giri river collected upstream of Drinking Water Works at Yashwant Nagar village near Solan and likewise water sample of Ashwani river collected upstream of Drinking Water Works near Shambar village which is 20 Km above the confluence Ashwani river with Giri river.

Groundwater sampling from 6 sampling sites was carried out in

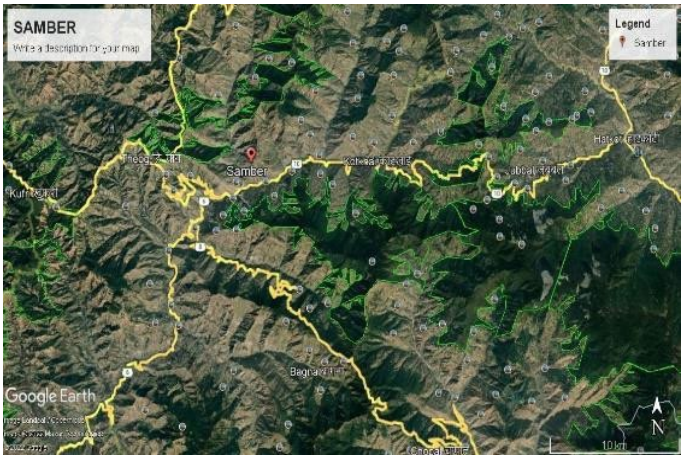

Figure 3: Sampling site for Ashwini River.

Figure 4: Sampling site for Giri River.

March 2019 across the Solan district in Himachal Pradesh (Table 2).

Determination of different physicochemical parameters

Water quality is assessed for physiochemical parameters according to the standard methods outlined in IS 3025. the results obtained from

the physicochemical and microbiological attributes were compared with the drinking water guidelines set by the Bureau of Indian Standards (BIS) (Table 3).

Data collection

Data for waterborne diseases were collected from chief medical officer Solan, for 12 blocks in Solan from 2014 to 2018.

Results and Discussions

Surface water sampling

Surface water samples were collected from the Ashwini and Giri rivers. Physiochemical parameters such as pH, turbidity, color, Total Hardness, Calcium, Magnesium, Total Alkalinity, Iron, Total Dissolved Salts, Chloride, Sulphate E. Colli*, Total Coliforms*, Fluoride, and microbial testing for Legionella and Vibrio Cholera were assessed in surface water samples collected from the Ashwini and Giri rivers (Tables 4 and 5).

Samples collected from Ashwini River were compared with the limits of IS Code. The Value of pH is 7.31 which the agreeable limit as compared to limits of IS: 10500-2012. Water is found to be turbid-free. Total hardness is found to be 160 mg/l, calcium is found to be 40 mg/l, Magnesium is 14.40 mg/l, Total Alkalinity is 80 mg/l, Iron is below the detection limit, Total dissolved salts is found out to be 205 mg/l, Chloride is found to be 35.46 mg/l, Sulphate is 96.29 mg/l, E.Colli and total coliforms are absent, fluoride is nil. All the parameters are within acceptable limits. Microbial testing shows absence of Legionella and Vibrio Cholera (Table 6).

Table 3: Blocks for Monitoring Disease burden.

S.NO.	BLOCK
1	ARKI
2	CHANDI (Krishangarh)
3	DHRAMPUR (Solan)
4	NALAGARH
5	SYRI (Kandaghat)
6	DISTT.HOSPITAL
7	ARKI(Darlaghat)
8	CHANDI (BADDI)
9	DHARAMPUR (KASAULI)
10	NALAGARH (BADDI)
11	NALAGARH (RAMSHAHR)
12	CHANDI (KASAULI)

Samples collected from the Giri river were compared with the limits of IS Code. Samples collected from Ashwini River were compared with the limits of IS Code. The Value of pH is 7.31 which the agreeable limit as compared to limits of IS: 10500-2012. Water is found to be turbid-free. Total hardness is found to be 160 mg/l, calcium is found to be 40 mg/l, Magnesium is 14.40 mg/l, Total Alkalinity is 80 mg/l, Iron is below the detection limit, Total dissolved salts is found out to be 205 mg/l, Chloride is found to be 35.46 mg/l, Sulphate is 96.29 mg/l, E.Colli and total coliforms are absent, fluoride is nil. All the parameters are in acceptable limits. Microbial testing shows the absence of Legionella and Vibrio Cholerae (Table 7).

Ground water sampling

Groundwater sampling was done for assessing physiochemical parameters. Six sites were selected for sampling (Table 8).

It has been found that the pH values range between 6.80 and 7.47. Total dissolved solids are in the range of 224 mg/l to 282 mg/l, total hardness in a range of 226 mg/l to 250 mg/l, total calcium in range of 38.6 mg/l to 58.8 mg/l, magnesium in a range of 22.4 mg/l to 29.6 mg/l, total alkalinity in a range of 230 mg/l to 289 mg/l, Chloride in a range of 12.6 mg/l to 14.9 mg/l, Sulphate in a range of 12.4 mg/l to 14.4 mg/l, Iron in a range of 0.12 to 0.14 mg/l, Zinc, Nitrate, Chromium, Manganese, Mercury, Cadmium, Fluoride, Selenium, Residual Chlorine are Not Detectable(ND) at all sites. E.coli is absent at 4 sites, Not Detectable (ND) at 2 sites and Total coliform is <2 at 4 sites and Not Detectable (ND) at 2 sites (Figure 5).

It has been found that the pH values range between 6.80-7.47. The lowest value of pH has been recorded at location 5, which is agreeable according to Indian standards. Highest value was recorded at location 4 which is acceptable for drinking purposes (Figure 6).

Highest value of TDS of 282 mg/l is at Site 2 and lowest value is 224 mg/l at site 3. All values are within acceptable limits (Figure 7).

Concentration of Calcium is within acceptable limits for drinking purpose. Highest concentration of 58.8mg/l is at site 4 and lowest concentration of 38.6 mg/l at site 2 (Figure 8).

The Concentration of chloride as Cl at all sampling sites is within acceptable limits.

The Concentration of Sulphate at sampling sites ranges between 12.4 mg/l to 14.4 mg/l. All values are within permissible limits (Figure 9-13).

Table 4: Physiochemical parameters of samples of Ashwini River.

S.NO	Parameter	Results	Acceptable Limits as per IS: 10500-2012	Method of Test
1	Color* Hz	1	Not more than 5 Hz	IS:3025 Part 4
2	Odor*	Agreeable	Agreeable	IS:3025 Part 5
3	pH	7.312	6.5-8.5	IS:3025 Part 11
4	Turbidity* NTU	nil	Not more than 1	IS:3025 Part 10
5	Total Hardness as $CaCO_3$ mg/l	160	Not more than 200 mg/l	IS:3025 Part 21
6	Calcium Ca mg/l	40	Not more than 75 mg/l	IS:3025 Part 40
7	Magnesium Mg mg/l	14.403	Not more than 30 mg/l	IS:3025 Part 46
8	Total Alkalinity $CaCO_3$ mg/l	80	Not more than 200 mg/l	IS:3025 Part 23
9	Iron Fe mg/l	BDL (DL 0.0 mg/l)	Not more than 1 mg/l	IS:3025 Part 53
10	Total Dissolved Salts TDS mg/l	205	Not more than 500 mg/l	IS:3025 Part 16
11	Chloride Cl mg/l	35.461	Not more than 250 mg/l	IS:3025 Part 32
12	Sulphate SO_4 mg/l	96.293	Not more than 200 mgl	IS:3025 Part 24
13	*E. Coli**	Absent	Absent	IS: 1622-1981, MPN Method.
14	Total Coliforms	Absent	Absent	IS: 1622-1981(RA2009), MPN Method.
15	Fluoride F	nil	Not more than 1.0 mg/l	IS:3025 Part 60

Table 5: Microbial parameters of Samples of Ashwini River.

S. NO.	Test Parameter	Observed Results
1.	Legionella/250 ml	Absent
2.	Vibrio Cholerae/250 ml	Absent

Table 6: Physiochemical parameters of Samples of Giri River.

S.NO.	Parameter	Results	Acceptable Limits as perIS: 10500-2012	Method of Test
1	Color* Hz	1	Not more than 5 Hz	IS:3025 Part 4
2	Odor*	Agreeable	Agreeable	IS:3025 Part 5
3	pH	7.201	6.5-8.5	IS:3025 Part 11
4	Turbidity* NTU	nil	Not more than 1	IS:3025 Part 10
5	Total Hardness as $CaCO_3$ mg/l	85	Not more than 200 mg/l	IS:3025 Part 21
6	Calcium Ca mg/l	27	Not more than 75 mg/l	IS:3025 Part 40
7	Magnesium Mgmg/l	4.23	Not more than 30 mg/l	IS:3025 Part 46
8	Total Alkalinity $CaCO_3$ mg/l	65	Not more than 200 mg/l	IS:3025 Part 23
9	Iron Fe mg/l	BDL (DL0.01 mg/l)	Not more than 1 mg/l	IS:3025 Part 53
10	Total DissolvedSalts TDS mg/l	180	Not more than 500 mg/l	IS:3025 Part 16
11	Chloride Cl mg/l	22.161	Not more than 250 mg/l	IS:3025 Part 32
12	Sulphate SO4 mg/l	62.622	Not more than 200 mgl	IS:3025 Part 24
13	*E. Coli**	Absent	Absent	IS: 1622-1981, MPN Method.
14	Total Coliforms*	Absent	Absent	IS: 1622-1981(RA2009), MPN Method.
15	Fluoride F	nil	Not more than 1.0 mg/l	IS:3025 Part 60

Table 7: Microbial testing (Samples of Giri River).

S.NO.	Test Parameter	Observed Results
1.	Legionella/250 ml	Absent
2.	Vibrio Cholerae/250 ml	Absent

Table 8: Water quality parameters for all sampling sites.

Parameters	Results						Acceptable Limit	Permissible Limit	Test Method
	GW1	GW2	GW3	GW4	GW5	GW6			
pH	7.221	7.022	7.232	7.471	6.802	7.172	6.5-8.5	No relaxation	APHA-4500H+, 23rd Edition - 2017
Total dissolved solids, mg/l	274	282	224	256	230	245	500 Max.	2000	APHA-2540C, 23rd Edition - 2017
Total Hardness (as $CaCO_3$), mg/l	250	236	239	226	229	236	200 Max.	600	APHA-2340B, 23rd Edition - 2017
Calcium (as Ca++), mg/l	38.6	42.8	57.6	58.8	40.0	40.7	75 Max.	200	APHA- 3500B, 23rd Edition - 2017
Magnesium (as Mg++), mg/l	24.6	22.4	24.2	29.6	25.0	23.6	30 Max.	100	APHA-2340B, 23rd Edition - 2017
Total Alkalinity (as $CaCO_3$), mg/l	230	280	294	289	235	240	200 Max.	600	APHA-2320B, 23rd Edition- 2017
Chloride (as Cl), mg/l	12.9	14.9	12.6	13.4	12.8	12.7	250 Max.	1000	APHA-4500B, 23rd Edition -2017
Sulphate (as SO4), mg/l	12.4	12.6	14.4	12.8	12.8	12.4	200 Max.	400	APHA-4500E, 23rd Edition -2017
Iron (as Fe), mg/l	0.12	0.13	0.12	0.14	0.12	0.12	1.0 Max.	No relaxation	IS: 3025(Part- 53), 2003
Zinc (as Zn), mg/l	ND	ND	ND	ND	ND	ND	5 Max.	15	APHA-3030D, 23rd Edition -2017
Nitrate (as NO3), mg/l	ND	ND	ND	ND	ND	ND	45 Max.	No relaxation	IS: 3025(Part- 34), 1986
Chromium (as Cr), mg/l	ND	ND	ND	ND	ND	ND	0.05 Max.	No relaxation	APHA-3111B, 23rd Edition -2017
Manganese (as Mn), mg/l	ND	ND	ND	ND	ND	ND	0.1 Max.	0.3	APHA-3030D & 3111B, 23rd Edition -2017
Mercury (as Hg), mg/l	ND	ND	ND	ND	ND	ND	0.001 Max.	No relaxation	APHA-3500 Hg-B, 23rd Edition-2017.
Cadmium (as Cd), mg/l	ND	ND	ND	ND	ND	ND	0.003 Max.	No relaxation	APHA-3030D & 3111B, 23rd Edition - 2017.
Fluoride (as F), mg/l	ND	ND	ND	ND	ND	ND	1.0 Max.	1.5	APHA 4500 F-D, 23rd Edition 2017 SPANDS Method.

Disease burden of the area

Unchecked industrialization, growing urbanization, and agricultural chemicals and pesticides have resulted in a slew of gastroenteritis, diarrhea, and hepatitis outbreaks [14]. As a result, microbiological testing of indicator organisms, such as coliforms, in drinking water sources is required, as well as research into their association with waterborne diseases. Results of microbial testing of water from Ashwini River and Giri river, are given in Tables IV and VI. Water samples collected from these rivers were analyzed for Legionella and Vibrio Cholerae.

Furthermore, to access the burden of waterborne diseases in the district, data was collected from the Chief medical officer's office. Data of the spread of Enteric fever, jaundice/viral hepatitis, and acute diarrhoel disease of 12 blocks of Solan namely Arki, Chandi (Krishangarh), Dhrampur(Solan), Nalagarh, Syri(Kandaghat), district hospital, Arki (Darlaghat), Chandi (Baddi), Dharampur (Kasauli), Nalagarh (Baddi), Nalagarh (Ramshahr), Chandi (Kasauli) from 2014 to 2018 has been collected from Chief Medical officer's office (Table 9).

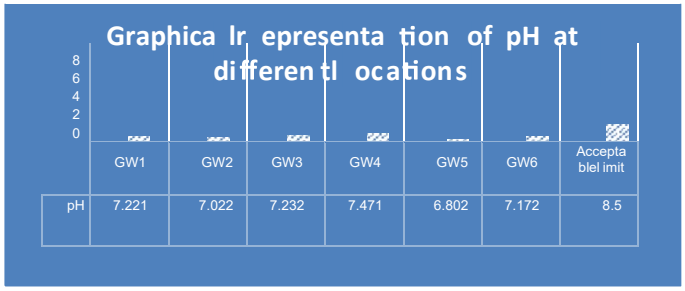

Figure 5: Comparison of pH at all sampling sites with acceptable limits.

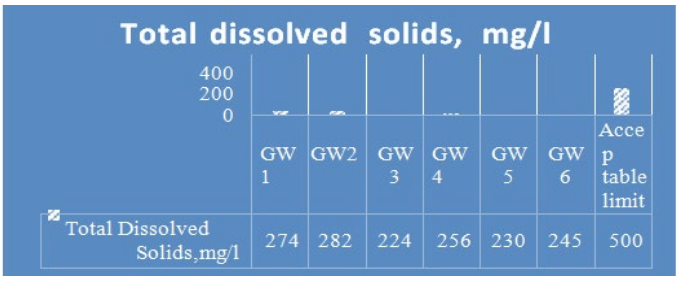

Figure 6: Comparison of total dissolved solids at all sampling sites with acceptable limits.

Figure 7: Comparison of total hardness at all sampling sites withacceptable limits.total hardness as $CaCO_3$ at all sites is slightly more than the acceptable limits but well within permissible limits.

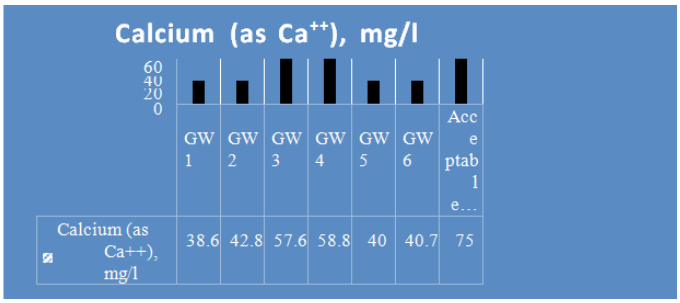

Figure 8: Comparison of Calcium at all sampling sites with the acceptable limits.

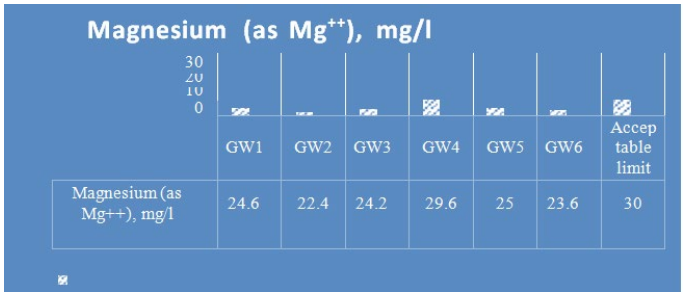

Figure 9: Comparison of Mg++ at sampling sites with the acceptable limit.

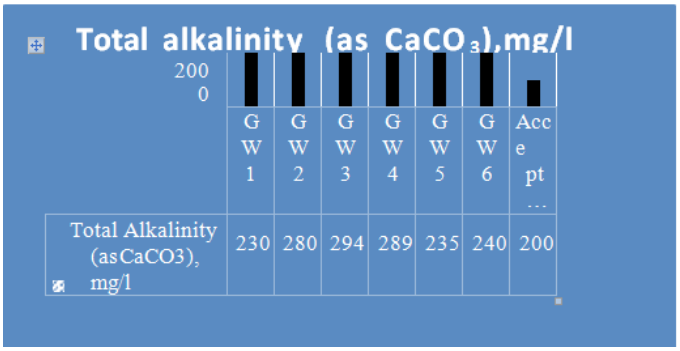

Figure 10: Comparison of total alkalinity at all sampling sites.

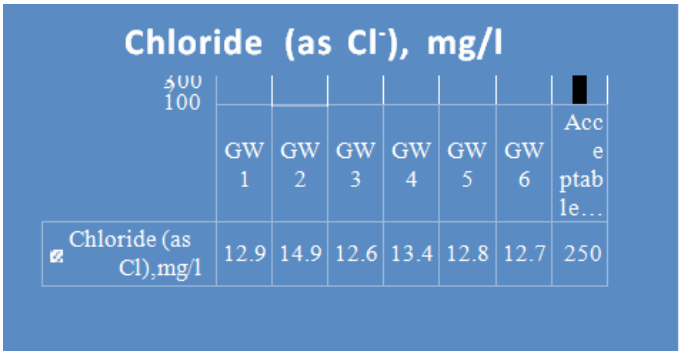

Figure 11: Comparison of Chloride at all sampling sites.

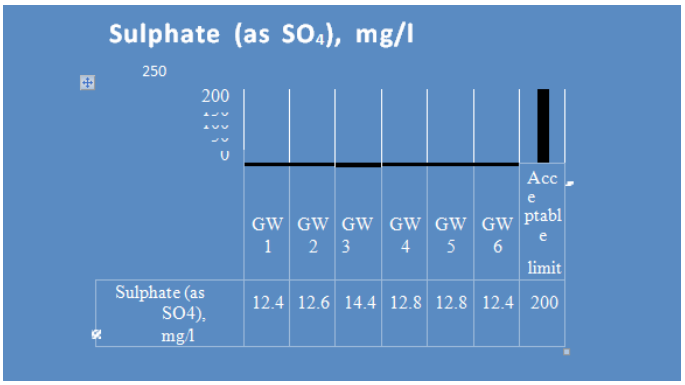

Figure 12: Comparison of Sulphate at all sampling sites.

Figure 13: Comparison of Iron at all sampling sites.

The number of cases of enteric fever has increased yearly. The lowest number of cases is recorded in 2014. The data shows a rise in number from 2040 to 2929, with an increase of 300 cases in 2018 from 2629 cases in 2017 (Figure 14).

358 cases of jaundice and viral hepatitis were reported in 2014.

Table 9: Enteric Fever in year 2014 to 2018.

BLOCK	2014	2015	2016	2017	2018
ARKI	229	276	429	303	261
CHANDI (Krishangarh)	32	24	5	19	9
DHRAMPUR (Solan)	681	719	410	534	701
NALAGARH	230	113	575	355	960
SYRI (Kandaghat)	85	122	92	284	155
DISTT.HOSPITAL	0	0	0	0	0
ARKI(Darlagh at)	2	4	20	22	32
CHANDI (BADDI)	32	5	260	167	292
DHARAMPUR (KASAULI)	729	856	576	888	413
NALAGARH (BADDI)	19	57	103	57	98
NALAGARH (RAMSHAHR)	0	0	0	0	2
CHANDI (KASAULI)	1	0	0	10	6
	2040	2176	2470	2629	2929

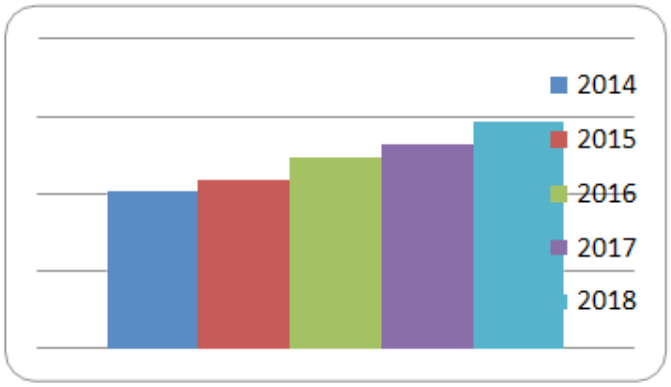

Figure 14: Cases of enteric fever from year 2014 to 2018.

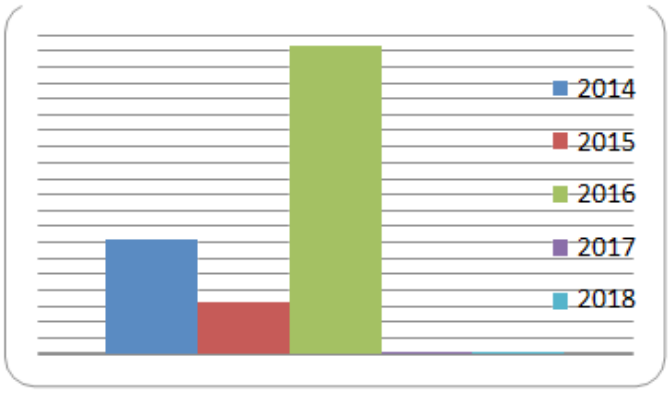

Figure 15: Cases of jaundice and viral hepatitis from year 2014 to 2018.

164 cases were reported in 2015. The data shows a rise in a number of cases to 966 in 2016. Only 4 cases are recorded in 2017 and 6 cases are reported in 2018 (Tables 10 and 11).

Cases of acute diarrheal disease and gastroenteritis were 29923 cases in 2014, 35932 cases in 2015, 37714 cases in 2016 and 45975 cases in 2017. The data shows a rise in the number of cases from 29923 to 44615 (Figure 15 and 16).

Table 10: Jaundice/Viral Hepatitis in year 2014 to 2018.

BLOCK	2014	2015	2016	2017	2018
ARKI	52	9	21	0	0
CHANDI (Krishangarh)	0	0	0	0	0
DHRAMPUR (Solan)	189	102	797	0	0
NALAGARH	5	5	25	0	0
SYRI (Kandaghat)	32	10	38	0	0
DISTT.HOSPI TAL	0	0	0	0	0
ARKI(Darlaghat)	2	1	0	0	0
CHANDI (BADDI)	42	2	0	0	0
DHARAMPUR (KASAULI)	34	27	84	4	6
NALAGARH (BADDI)	0	8	1	0	0
NALAGARH (RAMSHAHR)	0	0	0	0	0
CHANDI (KASAULI)	2	0	0	0	0
TOTAL	358	164	966	4	6

Table 11: Acute Diarrheal Disease in year 2014 to 2018.

BLOCK	2014	2015	2016	2017	2018
ARKI	5047	2490	1771	2034	1624
CHANDI (Krishan garh)	1029	1068	759	984	864
DHRAM PUR (Solan)	5048	5993	4928	5353	6525
NALAGARH	6822	3244	3430	3419	2475
SYRI (Kandaghat)	1412	1599	1310	1680	2071
DISTT.H OSPITAL	0	0	0	0	0
ARKI(Darlaghat)	409	608	424	475	937
CHANDI (BADDI)	1189	1499	953	1088	1064
DHARA MPUR (KASAULI)	5555	12842	16444	18088	13869
NALAGA RH (BADDI)	2085	4992	5812	10361	13918
NALAGA RH (RAMSHAHR)	445	532	312	474	492
CHANDI (KASAU LI)	882	1065	1571	2019	776
TOTAL	29923	35932	37714	45975	44615

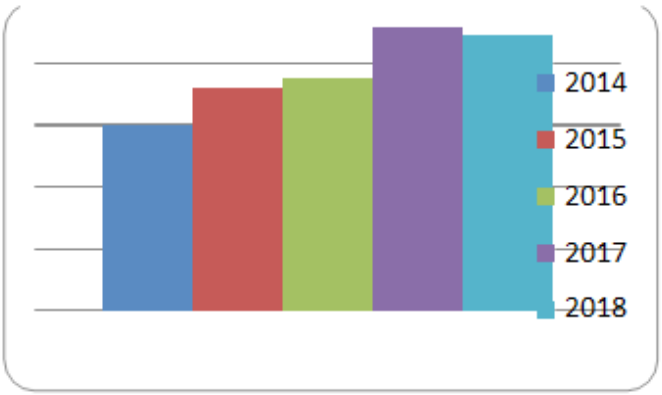

Figure 16: Cases of acute diarrheal disease and gastroenteritis from year 2014 to 2018.

Conclusion

The research provides information on a wide range of water quality factors. The physical, chemical and microbiological properties

of drinking water sources have been altered by water contamination owing to climate change and numerous anthropogenic activities. The utility of a health indicator, such as the disease incidence in the study area, was also investigated in this study. The parameters of water quality, as well as their health implications and allowable limitations, are discussed.

As a result, assessing the water quality of drinking water sources is critical for long-term human health management. Routine water sampling, seasonal microbiological assessments of water bodies, and giving information, education, and enhancing public awareness regarding water pollution have all been proposed to the administration, hygienic and sanitary conditions.

Climate change's effects on water quality should be quantified in future studies. Before consumption, the water must be purified further. Water quality of Areas near Industries should be accessed regularly. Health checkups and health surveys should be done regularly. People should be made aware of the safe use of water and minimize the wastage of water. This study should be considered as a stepping stone toward water management and related health risks.

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Conflict of Interest

The author(s) declares no conflict of interest.

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