ASSESSMENT OF WATER QUALITY IN EDUCATIONAL INSTITUTES IN SOLAN DISTRICT OF HIMACHAL PRADESH

Thesis

by

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submitted to

Dr. YASHWANT SINGH PARMAR UNIVERSITY OF HORTICULTURE AND FORESTRY
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CERTIFICATE-I

This is to certify that the thesis titled, **"Assessment of Water Quality in Educational Institutes in Solan District of Himachal Pradesh"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science** in the discipline of **Environmental Science** of Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) – 173 230 is a bonafide research work carried out by **Miss Aarti Sharma (F-2017-12-M)** daughter of Sh. Ved Prakash under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

This assistance and help received during the course of investigations have been fully acknowledged.

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Dated :

(Dr. RK Aggarwal)
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CERTIFICATE-II

This is to certify that the thesis entitled, **"Assessment of Water Quality in Educational Institutes in Solan district of Himachal Pradesh"** submitted by **Ms. Aarti Sharma (F-2017-12-M)** d/o Shri Ved Parkash to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-173 230, Solan (HP), India in partial fulfilment of the requirements for the award of degree of MSc Environmental Science in the department of Environmental Science has been approved by the Advisory Committee after an oral examination of the student in collaboration with the external examiner.

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"Needless to mention errors and omissions are mine."

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CONTENTS

LIST OF ABBREVIATIONS

APHA	:	American Public Health Association
BIS	:	Bureau of Indian Standards
BOD	:	Biological Oxygen Demand
CD	:	Critical Difference
COD	:	Chemical Oxygen Demand
CPCB	:	Central Pollution Control Board
$dS\ m^{-1}$	:	Decisiemens per meter
DWAF	:	Department of Water Affairs and Forestry
EC	:	Electrical Conductivity
ICAP	:	Inductively Coupled Plasma of Atomic Emission Spectroscopy
MPN	:	Most Probable Number
mgl^{-1}	:	Milligram per litre
NTU	:	Nephelometric Turbidity Units
NDWQS	:	National Drinking Water Quality Standard
ppm	:	Parts per million
TDS	:	Total Dissolved Solid
WHO	:	World Health Organization
WQI	:	Water Quality Index

LIST OF TABLES

Chapter -1

INTRODUCTION

Water is one of the most essential and important natural resources for human beings, animals and plants. It is difficult to imagine an environment without water. Man can live only three or four days without water. Potable and drinking water play an important role in the development of the good health of a nation. Water should be suitable for drinking and food preparation (Tihansky, 1974). Water is a good solvent and picks up impurities easily and thus changes its taste, colour and odour. It is a well-known fact that when water is polluted, its normal functioning and properties are affected (Trivedi *et al*., 2010).

The water plays a central role in economic and social development. Total amount of water is constant worldwide, its quantity and distribution are unequal. To execute this task, accurate and adequate information must be available about the quality of this natural resource. Although our planet has nearly 71 per cent of water, only 3 per cent of it is fresh (Dugan, 2012). The demands of water supply have been increasing tremendously due to increasing industrialization on one hand and exploding population on the other. Moreover, due to sewage, industrial waste and a wide range of synthetic chemicals, a considerable part of the water are polluted.

Freshwater, which is a valuable and limited vital resource, needs to be protected, conserved and used judiciously. But unfortunately, this has not been the case, as the polluted lakes, rivers and streams throughout the world testify. However, poor water quality continues to pose a major warning to human health worldwide. Globally, waterborne diseases are the cause of death and suffering of millions of people, especially, children in developing countries (Schafera *et al*., 2009). Worldwide 250 million cases of waterborne diseases have been reported (Esrey *et al*., 1985).

The World Health Organization states that water contains many types of impurities from various sources, causes different types of water - borne diseases and due to unsafe drinking water supplies each year, millions of people suffer from such diseases. Due to water - borne diseases, four hundred children in developing countries including India, die every hour (Asati and Choudhari, 2012).

The availability of safe drinking water is decreasing rapidly. For last few decades, the rapid increase in the human population, increasing anthropogenic activities, land-use changes, discharge of sewage and municipal waste into water bodies have degraded water quality (Meitei *et al*., 2004). Water sources are becoming unsafe for human consumption as well as for other activities like irrigation and industrial needs. The severe contamination of water around urban areas indicates that industrial and domestic sectors contribute significantly to water pollution in our country.

Water plays a vital role in the dispersal of various organisms, bacterial and viral diseases. Dangerous diseases like dysentery, typhoid, cholera, hepatitis, and diarrhea can be spread by fecal polluted drinking water. It is reported that about 70 per cent of the surface water sources have already contaminated (Rao and Mamatha, 2004). Water is a good solvent and picks up impurities easily and thus, changes its taste, colour and odour. Groundwater is usually assumed to be a very good source of potable water due to the purification property of soil (Odeyemi *et al*., 2011).

The pressure on water resources is increasing and per capita availability of water is reducing day by day with a rapid growing population and improving living standards (Sampath *et al*., 2003). The climate change is further expected to affect the quality of surface and groundwater sources and thus, water availability is also degenerate because of increasing pollutant loads from the point and non-point sources.

Solan district of Himachal Pradesh has also come up as a hub for various types of industries. Presently, it has about 38 small scale and 6 large-scale industries. The state is having 56 urban and suburban habitations, which are further growing rapidly and releasing about hundreds of tons of solid waste to the environment. Various anthropogenic activities like construction of roads, the establishment of industries and educational institutes, deforestation, change in the cropping pattern and excessive use of chemical fertilizers and pesticides for higher crop yield have degraded the water quality (Rana *et al*., 2016).

Therefore, there is an urgent need for monitoring quality parameters of water like biological oxygen demand, chemical oxygen demand, suspended solids, pH, electrical conductivity, hardness, toxic metals pesticides, oil and grease, and total coliform. The present study aims to analyze the quality of drinking water in different educational institutions in Solan District of Himachal Pradesh so that appropriate preventive and remedial measures could be undertaken.

The physico-chemical and biological parameters monitored for the assessment of water quality are expressed in a single form called water quality Index (WQI). Use of a water quality index (WQI) is one of the most effective approaches to communicate information to decision makers. It promotes the understanding of water quality issues by integrating complex data and generating a score that describes water quality status (Reza and Singh, 2010). Keeping this in view, the present study entitled “The Assessment of water quality in Educational Institutes in Solan District of Himachal Pradesh” was undertaken with the following objective:

i. To assess the physical, chemical and biological parameters of water sources

Chapter -2

REVIEW OF LITERATURE

Water is of paramount importance to the livelihood and health of the inhabitants. The problem of water pollution has further been worsened by the rapid population explosion, leading to congestion, increased waste generation and extreme pressure on the available water resources. The cohesiveness in representation of the related research has been analyzed in the present investigation entitled **"Assessment of Water Quality in Educational Institutes in Solan District of Himachal Pradesh.''** under following headings:

2.1 Physico-chemical and biological parameters of water sources

2.2 Water Quality Index (WQI)

2.1 Physico-chemical and biological parameters of water sources

Al-Saleh and Iman (1996) observed the simple method for the spectro-chemical analysis of water samples by inductively coupled plasma atomic emission spectroscopy. Samples from 32 schools in drinking water coolers in Riyadh,Saudi Arabia were assemble at a specific time and analyzed for Al, Be, Cd, Co, Cr, Cu, Fe, Mn, molybdenum Mo, Ni, Si, strontium (Sr), vanadium (V) and Zn to assess the water quality. The analysis of drinking water in some cases showed high concentrations of metals that exceeded the guideline limits prescribed by WHO. Lokeshwari and Chandrappa (2006) studied was undertaken for assessing the level of heavy metals such as iron, zinc, copper, nickel, chromium, lead and cadmium in water, water hyacinth and sediment samples of Lalbagh tank, Bangalore. The results revealed that by large all metals are present in all the samples, except cadmium in the sediment samples. The average concentrations of iron in water and sediment samples, and lead in water hyacinth were found exceeding the limits of Indian Standards. In general, the concentrations of iron and zinc were found more, followed by lead, chromium, copper, nickel and cadmium concentration was low. Adekunle *et al*. (2007) observed that the most rural settlements in Nigeria, access to clean and potable water were a great challenge, resulting in water borne diseases. The aim of study was to assess the levels of some physical, chemical, biochemical and microbial water quality parameters in twelve hand-dug wells in a typical rural area of southwest region of the country. They have also examined the seasonal variations and proximity to pollution sources. All parameters were detected up to 200 m from pollution source and most of them increased in concentration during the rainy season over the dry periods, pointing to infiltrations from storm water. Coliform population, Pb, NO_3 and Cd in most cases, exceeded the World Health Organization recommended thresholds for potable water. The qualities of the well water samples were therefore, not appropriate for human consumption without adequate treatment. Regular monitoring of groundwater quality, abolishment of unhealthy waste disposal practices and introduction of modern techniques was recommended. Chan *et al*. (2007) conducted the study on the water samples collected before and after filtration treatment was given. Five types of filtered drinking water and five types of unfiltered tap water were chosen randomly from houses in Klang Valley for analyses. The purpose of the study was to determine the quality of filtered drinking water by looking into the microbiological aspect and several physicochemical analyses such as turbidity, pH and TSS. The microbiological analyses were performed to trace the presence of indicator organisms and pathogens such as *Escherichia coli*, *Streptococcus faecalis* and *Pseudomonas aeruginosa*. All of the water did not comply with the regulations of Food Act as consisted of more than 103-104 cfu ml^{-1} for total plate count. However, the total coliforms and *E. coli* were detected lower than 4 cfu ml^{-1} and not exceeding the maximum limit of Food Act. While the presence of *S. faecalis* and *P. aeruginosa* were negative in all samples. The pH value was slightly acidic (pH<6.5) compared to the range in the regulations. The TSS for the samples was low (1.0x10-4 - 2.2x10-3 mg l^{-1}) and the turbidity for all the samples were recorded below 1 Nephelometric Turbidity Units (NTU) thus, complying with the regulations. Ojo *et al*. (2007) observed that water samples were collected from Lagos State University, Ojo Campus. The water samples were immediately subjected to both chemical and microbiological analysis in order to evaluate the quality of potable water in circulation within the university and identify its sources of contamination. Levels of iron, calcium and magnesium appreciable in the circulating drinking water were far below the WHO recommended limits. This explains the high percentage of water-borne diseases such as Dysentery, Diarrhea and Typhoid fever within the university population. Meanwhile, other microorganisms detected were *E. coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, yeasts and moulds. The pH of potable water in circulation falls within recommended limits (6.0-8.0) but for faculty of arts and social sciences that had pH of 5.5 which suggested a high degree of public health concern. Akoto *et al*. (2008) studied the water samples from five sampling points on four rivers, Owabi, Akyeampomene, Pumpunase and Sukobri. Heavy metals (Zn, Cu, Mn, Cu, Pb and As) concentrations and some physical parameters of the water samples were determined. EC and pH of waters from all the streams were found to be within the acceptable limits of the (WHO). All the streams showed high turbidity values above WHO limits. The heavy metals determine in the water samples, Fe, Mn, Zn and Cu concentrations in all the streams were within the acceptable WHO limits, whiles Pb and As appeared to be higher than the acceptable limits in all the streams. There was a statistically significant positive correlation between pH and some metals at all the sample points ($p = 0.05$). The results showed that all the streams were polluted and must be treated before consumption. Ilyas *et al*. (2008) studied forty samples of water, collected from different sources available at schools Ghulam Mohammad Abad, Faisalabad were examined for chemical composition. The analysis included total hardness, total dissolved solids, chlorides, carbonates, bicarbonates, nitrates, calcium and magnesium. Results showed that Water and Sewerage Authority (WASA) water as direct supply, water stored in schools tanks and that available in schools coolers had calcium less than the WHO permissible limits. Total hardness, total dissolved solids, chlorides, carbonates, bicarbonates, nitrates and magnesium were within the safe limits. However, analysis of ground water showed that chlorides, total dissolved solids, carbonates bicarbonates, calcium and nitrates exceeded the WHO limits. Kar *et al*. (2008) studied the surface water samples collected from river Ganga in West Bengal during 2004-05 was analyzed for pH, EC, Fe, Mn, Zn, Cu, Cd, Cr, Pb and Ni. The maximum mean concentration of Fe (1.520 mg l^{-1}) was observed in summer, Mn (0.423 mg l^{-1}) in monsoon but Cd (0.003 mg l^{-1}) and Cr (0.020 mg l^{-1}) exhibited their maximum during the winter season. Fe, Mn and Cd concentration also varied with the change of sampling locations. A significant positive correlation was exhibited for conductivity with Cd and Cr of water but Mn exhibited a negative correlation with conductivity. Tikoo *et al*. (2008) carried out water analysis of Bichlari Nala at Banihal and Ramban (Jammu and Kashmir, India) for determining presence of Ca, Mg, K, Na, Fe, Mn, Cu, Ni, Zn and Pb. The analysis revealed that all cations were below the permissible limits except Fe, Mn and Ni. They also reported that bicarbonates, sulfates and nitrates, total hardness and pH values were within safer levels while turbidity values were higher. Sahato and Kazi (2009) reported that the temperature in January and August was 18 and 33^{0}C, pH in September and June was 7.3 and 8.9, alkalinity in July and January was 160 and 240 mg l^{-1}, minimum chlorides (30 mg l^{-1}) in September and maximum (85 mg l^{-1}) in December, conductivity (320 dS m^{-1}) in September and 496 dS m^{-1} in December, total dissolved solids were 240 mg l^{-1} in September and 391 mg l^{-1} in October, turbidity was 30 NTU in December and 78 NTU in May, dissolve oxygen was 7.0 mg l^{-1} in January and 9.0 mg l^{-1} in July, calcium (50 mg l^{-1}) in July and September and (78 mg $l^{-1)}$ in October, magnesium (21 mg l^{-1}) in August and September, and 35 mg l^{-1} in June of water samples of Keenjhar lake and concluded that the variation in parameters were due to rain and flow of river Indus in Keenjhar Lake, District, Thatta, Sindh, Pakistan.

Shaikh and Mandre (2009) studied the physico-chemical parameters of drinking water in khed (lote) industrial area to analyzed the certain parameters like , pH, temperature , EC and chloride was found to under permissible limit in all ten different water samples. Parameters like TDS, DO, COD , BOD and hardness was found to beyond permissible limit in well water samples. In the present study concerned to seasonal change in parameter; there was no remarkable change of parameter as per season was found expect electrical conductivity, temperature and quite chloride. Agarwal and Rajwar (2010) studied the physico-chemical and microbiological characteristics of the water of Tehri dam reservoir in the Garhwal Himalaya of India. Total solids, total suspended solids, total dissolve solids, turbidity and sulphate values were maximum in rainy months. The alkalinity varied during different months. The pH, conductivity, hardness, calcium, dissolved oxygen and biological oxygen demand was higher during summer months. The chloride concentration was highest in the month of January and nitrate in the summer and early monsoon. The maximum number of total coliform and total plate count was during summer and rainy seasons and minimum during winter season. Joseph and Jacob (2010) studied some physico-chemical characteristics of a fresh water wet land were investigated. The analysis was carried out for a period of two years. Physical parameters such as colour, odour, temperature, (EC), (TSS), (TDS), (TS), turbidity and chemical parameters such as pH, alkalinity, hardness, (DO), (BOD), (COD), chloride, salinity, flouride, phosphate and nitrate were examined. The results indicated that water in Pennar River is highly contaminated and not safe for drinking. Uncontrolled use of chemical fertilizers and pesticides, unscrupulous dumping of domestic wastes are the major causes of deterioration of water. Poor quality of drinking water was recorded as the major risk factor for the large-scale water-borne diseases in the area. Quagraine and Adokoh (2010) assessed water quality in a dry season for the Cape Coast municipality in Ghana, which has been experiencing chronic water shortages. Fifteen different sampling stations four surface, five ground, and six tap water samples were analyzed for physicochemical and microbiological parameters during January to April 2005. Levels or trends in water quality that may be harmful to sensitive water uses, including drinking, irrigation, and livestock watering have been noted with reference to well established guidelines. Excess to some health-based drinking water guidelines included positive coliform for various water samples. The World Health Organization laundry staining Fe guideline of 0.3 mg l^{-1} was exceeded by

75 per cent of surface water, 44 per cent tap water, and 53 per cent groundwater samples. The corresponding Mn guideline of 0.1 mg l^{-1} was exceeded by all the water samples. Respectively, all surface water samples and also 75 per cent of the surface water exceeded some known Cu and Zn guideline for the protection of aquatic life. In several instances, tap water samples collected at the consumer's end of the distribution system did not reflect on the true quality of the treated water. Saxena and Gangal (2010) assessed the physico-chemical properties of drinking water in Brij region from Aligarh to Mathura and reported the concentration of pH, total dissolve solids, temperature, chlorides, calcium , magnesium, BOD and COD were in the range of 7.27 to 8.02, 313 to 760 mg l^{-1}, 29 to 32^0C, 28.4 to 485 mg l^{-1}, 25.2 to 42.4 mg l^{-1}, 80.3 to 98.4 mg l^{-1}, 6.8 to 12.8 mg l^{-1}, and 8.6 to 12.2 mg l^{-1}, respectively. Sharma and Kapoor (2010) assess the physical parameters of lake water of Patna Bird Sanctuary revealed that depth, pH, temperature, turbidity and light penetration of various experimental sites. As far as chemical parameters were concerned, BOD, COD and DO fluctuated from 14.01±0.007 to 44.04±0.002 ppm; 47.03±0.028 to 98.02±0.004 ppm; and 2.04±0.028 to 6.05±0.004 ppm, respectively. The Biological indicators i.e. phytoplankton and zooplankton attained lowest and highest population in different seasons of 2004-05 and 2005-06. In present investigations, the lake water was most favorable for higher fish production during rainy as well as winter season. Ali *et al*. (2011) determine the water quality of different reservoirs at schools of District Peshawar. Nineteen schools were selected for sampling of water. Thirty two drinking water samples were collected and analyzed for total coliform bacteria, fecal coliform bacteria and *E. coli*. The data revealed that out of 32 samples 15 were fit for human consumption. Positive results for total fecal coliform bacteria were found in 37 per cent samples, while E. coli was present in 18 per cent samples. Highest contamination of total coliform bacteria (TCB) was >1100 MPN ml^{-1} and lowest was 9 MPN ml^{-1}. Hamad *et al*. (2011) analyzed the six water samples collected from various schools and six bottled water brands collected from local supermarkets and food stores in North Central of akaka city, Saudi Arabia in respect to chlorine, manganese, nitrate, chromium, sulfate, iron and copper concentrations to ascertain their suitability for human consumption. With respect to manganese concentration, two of the analyzed bottled water samples failed to meet drinking water guidelines of Saudi Arabia Standards Organization (SASO), but were below the limit set by WHO. All tested schools water samples failed to meet drinking water guidelines of SASO, but were below the limit set by WHO. Comparison of the study results with the reported label values indicated good agreement with most components but considerable variation for Manganese in the second brand. Low sulfate variations were found

in all brands. Puri (2011) studied the water pollution with heavy metals in Nagpur City, Maharashtra, India. The levels of the occurrence of heavy metals like (cd), (Fe), (Zn), (As), (Hg), (Pb)and (Cr) were estimated in Futala, Ambazari, Gandhisagar and Gorewada lake, within Nagpur city, for the session January to December 2008. The monitoring was made over a period of one year comprising of three seasons; summer, winter and rainy season respectively. The yearly variation in the concentration of heavy metals had definite upward trends. In this study revealed that dissolved constituents of Fe, Pb, Zn and Cr were above ranges of unpolluted water indicating their contamination throughout the season in cases of Pb, Fe and Zn and occasional for As and Hg. The metals Zn, Fe, Cd, Ni almost remained in natural level while arsenic (As) was always below the detection limit of 0.0001 ppm. Wogu and Okaka (2011) studied the surface water samples from Warri river in Delta State of Nigeria were analyzed quantitatively for the concentration of nine heavy metals, namely: Cadmium, Chromium, Copper, Iron, Lead, Manganese, Nickel, Vanadium and Zinc, using Atomic Absorption Spectrophotometer. (Fe) recorded the highest mean value of 1.9304 mg l^{-1} while (Pb), had the least mean concentration of 0.0001 mg l^{-1}. Cadmium, Chromium, Manganese and Nickel had higher concentrations than values in standard guidelines for potable water, pointing to the existence of risks to public health. Yadav and Srivastava (2011) studied physico-chemical properties of River Ganga at Patthar Ghat, Bada Mahadeva Ghat, Dadari Ghat, Collector Ghat and Chitnath Ghat during September 2005 to August 2007 and found depletion in the dissolved oxygen, and increase in temperature, total solids, electrical conductance, pH, biochemical oxygen demand, chemical oxygen demand, chloride, acidity, total alkalinity, total hardness, calcium, phosphate, nitrate, sodium and potassium. Durmishi *et al*. (2012) the objective of this study was the assessment of physical, chemical and bacteriological quality of the drinking water in the city of Tetova and several surrounding villages in the Republic of Macedonia for the period May 2007-2008. A total of 415 samples were taken for chemical, physical and bacteriological analysis. They had used the Canadian Drinking Water Quality Index (DWQI) for the quality assessment of drinking water. The results showed that the highest water quality was recorded at the South East European University (SEEU) (DWQI = 92.69), whereas the lowest quality at Shipkovica (DWQI = 63.18).The study strongly recommended the immediate correction of these issues to protect the health of population from water borne diseases as well as regular monitoring of the drinking water quality in the region. Jadhav *et al*. (2012) to assess the Borewell water quality for suitability for drinking and domestic purposes were carried out from Ajara Tahsil. The ground water quality was assessed by examining various physico-chemical parameters. Borewell water samples were collected from 51 villages from Ajara Tahsil during April 2011. The physico-chemical parameters like temperature, pH, EC, total alkalinity, total hardness, Ca and Mg hardness, chlorides and dissolved oxygen have been analyzed. The results were compared with WHO and BIS drinking water standards. On the basis of hardness, out of 51 borewell samples, 48 samples were within the permissible limit and safe for drinking purpose. Sujitha *et al*. (2012) reported the water quality parameters (salinity, TDS, DO, BOD, turbidity, pH, temperature, alkalinity, hardness and dissolved nutrients) of surface water and sediments of Karamana river. The highest temperature was 31.0ºC during pre monsoon period and there was no influence of salinity. In the monsoon period, high DO (5.4 mg l^{-1}) was noticed. TSS (17 mg l^{-1}) at Manakatukadavu, 40 mg l^{-1} at Thiruvallam during pre monsoon and 24 mg l^{-1} at Manakatukadavu, 60 mg l^{-1} at Pallichal during monsoon were reported. TDS in water samples increased from 56 mg l^{-1} at station 1 to 28 mg l^{-1} at station 5 during pre monsoon and from 41mg l^{-1} at station 1 to 112 mg l^{-1} at station 5 from March to July. Total alkalinity observed in well was within the prescribed standards of drinking water (>120 mg l^{-1}). High hardness (12 mg l^{-1}) was recorded at Karamana at Siva temple during pre monsoon period. Thakur *et al*. (2012) studied the water becomes contaminated with enteric pathogens and to measure the extent of drinking water contamination with the pathogenic microorganisms. Water samples were collected from different areas of Solan city in Himachal Pradesh. MPN test was performed to detect the coliforms in water samples collected from surface water sources, hand pumps, taps, roof top storage tanks and aqua-guards. Chlorination of some water samples was done to see the effect of chlorine on bacteria. The indicator organisms isolated were *E. coli* and *Enterobacter aerogenes* were the characteristic of intestinal tract of man and animals. The study revealed that surface water and roof top storage tank water was more liable to contamination whereas, ground water and aqua-guard water was safer for human consumption. Chlorine was effective in removing these bacteria from water.

Asadullah *et al*. (2013) investigated the physico-chemical quality of 780 water samples collected from 490 educational institutes located in various areas of Karachi, during the period of May to September 2005. The parameters include pH, turbidity, total dissolved solids, hardness and conductivity that were varied from 3.2 to 8.7, 0.2 to 3.1 NTU, 79 to 1066 ppm, 69 to 558 ppm and 96 to 1775 dS m^{-1}respectively. On the basis of pH 6 per cent, taste 2.1 per cent, turbidity 0 per cent, TDS 2.5 per cent and hardness 1.3 per cent, of the samples were found out of acceptable limits of World Health Organization guidelines. Moreover, the conductivity of the studied waters was found to be the multiple of 0.6001 to that of TDS when regression model was established. Bichi and Bello (2013) studied the Tatsawarki River, which was one of the major tributaries of the Kano River, received all domestic and industrial waste waters of Kano metropolis from the southern part. The samples of surface water were collected from three different points along the river and ground water samples were collected from three irrigation areas along the river. Control samples were collected from locations away from the river. The water samples were analyzed for physico-chemical parameters (Temperature, pH, TDS, Turbidity, Electrical conductivity, Hardness, Nitrates, and Nitrites) and heavy metals (Pb, Cr, Co, Cd, Zn, Cu, Fe and Mn). These results showed the higher values than the WHO guideline. The concentrations of the heavy metals in the irrigation water were also found to be higher than the FAO guideline values with the exception of Fe and Pb, which were found to be below the FAO guideline values. All irrigation water samples were also found to have higher metals level in comparison with the levels obtained in control sample with the exception of Pb. Samie *et al*. (2013) assessed the physical and chemical quality of several borehole water sources, used by rural schools in Greater Giyani Municipality Mopani district, South Africa, to determine their safety for human consumption. Atomic absorption spectroscopy and ion chromatography were used to determine the chemical quality of water sources. The pH of the water samples varied between 5.29 and 8.3 and tended to be higher in winter and lower in summer. The turbidity values varied between 6.17 and 44.7 NTU in some of the schools. The concentration of calcium and magnesium were high. Anions such as chloride and sulphate were within the recommended. The concentrations of nitrates were high obtained from all schools except in Nyanisi high school. In all schools there were no fluorides and phosphates. Heavy metals like arsenic, iron, cadmium and lead were within the prescribed DWAF limits. The results indicated that the water from the studied boreholes was not suitable for human consumption based on hardness and nitrate content and may cause a serious threat to the health of the consumers and therefore call for urgent intervention in order to reduce such chemicals and preserve the health of the children. Bakir *et al*. (2014) the main aim of this study was to investigate the drinking water quality in primary schools of a metropolitan area in Ankara. Water samples in a metropolitan area of 31 primary schools of Ankara were collected to determine the quality of drinking water. The physical and chemical parameters were within acceptable limits, except cadmium and lead levels. More than 30-year-old school buildings, which were 24.1 per cent of all 54 buildings, had higher and statistically significant averages of lead (0.016 ± 0.013 mg l^{-1}) levels compared to the others (0.006 ± 0.01 mg l^{-1}). In old school buildings lead contaminated plumbing materials should be treated and drinking-water quality monitoring should be continually maintained. Gupta *et al*. (2014) study on surface water quality from different land uses and under different seasons of Parwanoo area of Solan district of Himachal Pradesh was conducted during, winter, summer and rainy seasons under different land uses. Samples of surface water from different sources under different land uses (agriculture, forest and urban) were collected and analyzed for quality parameters viz. pH, temperature, electrical conductivity, total dissolved solids, BOD, COD, Ca, Mg, NO_3^- and Cl contents. The contents of all the elements were within permissible limits except Ca (>75 mg l^{-1}). Rahmanian *et al*. (2015) analyzed the drinking water quality was in suspected parts of Perak state, Malaysia, to ensure the continuous supply of clean and safe drinking water for the public health protection and to analyze the parameters such as pH, turbidity, conductivity, total suspended solids, TDS and heavy metals such as Cu, Zn, Mg, Fe, Cd, Pb, Cr, As, Hg, and Sn were analyzed for each water sample collected during winter and summer periods. The values of each parameter were found to be within the safe limits set by the WHO and NDWQS. Overall, the water from all the locations was found to be safe as drinking water. Sharma (2015) observed the safe drinking water to evaluate the physical and chemical qualities of tap water of Chandigarh. Tap water samples were collected from various sites in Chandigarh and were determine for physico-chemical parameters like colour, odour temperature, pH, turbidity, electrical conductivity, total dissolved solids, dissolved oxygen and salinity. The water samples studied present the value of various parameters to be within BIS and WHO guidelines. It was achieved that the quality of water samples studied were acceptable from the various physico-chemical parameters. Obi *et al*. (2016) observed the microbiological and physico-chemical analysis of randomly selected borehole waters used by staffs, students and pupils in twenty private schools in Umuahia Abia State. The physic-chemical parameters were within acceptable limit except for nitrate whose range fell between 10-53 mg l^{-1} above WHO guidelines of 10 mg l^{-1}. The findings showed that 16 of the borehole water samples from the 20 private schools met with WHO standards for drinking water while the water samples from four schools that did not meet with the WHO standards for drinking water and pose serious health threats to the pupils and teachers who drink the water. Shrestha *et al*. (2017) conducted the study to assess drinking water quality, sanitation, and hygiene (WASH) conditions among 708 school children and 562 households in Dolakha and Ramechhap districts of Nepal. A flame atomic absorption spectrophotometer was used to test lead and arsenic content of the samples.The values of water samples for pH (6.8–7.6), free and total residual chlorine (0.1–0.5 mg l^{-1}), mean lead concentration (0.01 mg l^{-1}), and mean arsenic concentration (0.05 mg l^{-1}) were within national drinking water quality standards. The presence of domestic animals roaming inside school children's homes was significantly associated with drinking water contamination.

2.2 Water Quality Index (WQI)

Gebrehiwot *et al.* (2011) the main objective of assessing suitability of groundwater quality for drinking purposes through WQI investigation of the different hand dug wells in the watershed. This was done by subjecting the 20 groundwater samples collected to comprehensive physico-chemical analysis using APHA standard methods of analysis. For calculating the WQI, 10 parameters have been considered: (pH, Na^+, K^+, Mg^{2+}, Ca^{2+},Cl^-, HCO_3^-, SO_4^{2-}—S and TDS). The WQI for these samples ranges from 54.41 to 86.24. All the groundwater samples estimated using the water quality index fall in the good water class and are all suitable for drinking purposes. Damo and Icka (2013) analyzed the quality of drinking water in the city of Pogradec, Albania. The samples were taken daily from six fixed points in the city. They were analyzed based on the standard methods for the following parameters: taste, odour, temperature, pH, EC, turbidity, NO^{3-}, NO^{2-}, NH^{4+}, chloride, and microbial load. The determination of water quality was made using the WQI of the Canadian Council of Ministries of the Environment (CCME). The calculated value of CCME WQI by 87.81 indicates that the drinking water quality in the city of Pogradec is "good," and that turbidity is the main problem in quality. Vatkar *et al*. (2013) aimed at evaluating the WQI for the drinking water of engineering colleges in Kolhapur city. This has been determined by collecting a monthly for period of one year from Feb 2011 to Jan 2012 of four engineering colleges of Kolhapur city and subjecting the samples to a comprehensive physico-chemical and biological analysis. For calculating the water quality index, nine critical parameters have been considered. The WQI for these fourty eight samples ranged from 66.26 to 98.80 with an average value of 84.14. The analysis reveals that the overall drinking water of the sampling sites, in general, can be considered fit for educational institutions of the student community and sampling sites B are slight to moderate water pollution and their water can be used for drinking purposes only after proper treatment thus the results that overall quality of drinking water is good at the sampling site. Shanbehzadeh *et al*. (2014) studied was carried out to examine heavy metals concentration in water and sediment of upstream and downstream of the entry of the sewage to the Tembi River, Iran. Samples were collected from upstream and downstream and were analyzed for Cd, Cr, Cu, Fe, Pb, Ni, and Zn by atomic absorption spectrophotometer. The results indicated that the average concentration of the metals in water and sediment on downstream was more than that of upstream. The mean concentration of Cu and Zn lies within the standard range for drinking water and the mean concentration of Mn, Zn, and Pb lies within the standard range of agricultural water. Batabyal and Chakraborty (2015) investigate the hydro geochemical parameters and addition of a WQI to assess groundwater quality of a rural tract in the northwest of Bardhaman district of West Bengal, India. Groundwater occurs at shallow depths with the maximum flow moving southeast during pre-monsoon season and south in post-monsoon period. The physicochemical analysis of groundwater samples shows the major ions in the order of HCO_3.Ca.Na.Mg.Cl.SO_4 and HCO_3.Ca.Mg.Na.Cl.SO_4 in pre-monsoon and post-monsoon periods, respectively. The groundwater quality is safe for drinking, barring the elevated iron content in certain areas. Based on WQI values, ground water falls into one of three categories: excellent water, good water, and poor water. The high value of WQI is because of high concentration of iron and chloride. The majority of the area is occupied by and poor water in post-monsoon and good water in pre-monsoon period.

Chapter -3

MATERIALS AND METHODS

The study entitled **"Assessment of Water Quality in Educational Institutes in Solan District of Himachal Pradesh"** was conducted during 2018-2019 in the Department of Environmental Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni (Solan), Himachal Pradesh. The details of materials used and methods employed during the present study are presented in this chapter.

3.1 Location

The study was conducted in Solan, Dharampur and Kandaghat blocks. Solan district is located between $30^o30"$ and $31^o50"$ N latitude and $76^o42"$ to $77^o20"$ E Longitude. The altitude of the district varies from 300 to 3,000 meters above mean sea level. The total geographical area of the district is 1936 sq km.

3.2 Climatic and weather conditions

The climate of the Solan district is sub-tropical to sub-temperate and semi-humid characterized by cold winters and having distinguished four major seasons in the year. The winter season commences from November to February, summer season from March to May followed by the monsoon season from June to September and autumn season from October to November. The higher reaches of the district receive snowfall during winter months.

3.3 Study sites and treatment details

a) **Study area:** Solan District

Number of blocks: 3

- Solan
- Dharampur
- Kandaghat

b) **No. of schools =** 3 in each block

c) **Seasons =** 2 (winter and summer)

d) **Total Treatment Combinations =** 3x3x2=18

e) **Replication =** 2

3.4 Collection and preparation of samples

Water samples were collected in acid washed plastic bottles of one liter capacity as per standard procedure (APHA 1998) from selected schools during two seasons i.e., summer and winter in two replications. Tap water samples were collected after running water for about five minutes as per standard procedure (Iqbal and Gupta, 2009). The colour, odour and temperature of water samples were determined at the time of sampling at the site itself. The temperature was recorded with the help of thermometer. All samples were adequately labeled, taken to laboratory and analyzed for pH, EC, TDS and BOD immediately and the remaining samples were stored in refrigerator at 4°C for performing subsequent analysis.

Table 3.1: Sampling details and sites

Sites	Schools	Latitude	Longitude
Solan	**S1**	30°54.547"N	077°06.066"E
	S2	30°52.137"N	077°08.140"E
	S3	30°52.003"N	077°10.211"E
Kandaghat	**S4**	30°55.943"N	077°07.917"E
	S5	30°57.843"N	077°06.092"E
	S6	31°00.620"N	077°05.412"E
Dharampur	**S7**	30°51.738"N	077°04.278"E
	S8	30°53.340"N	077°04.016"E
	S9	30°53.726"N	077°01.450"E

(S1 = Government Senior Secondary School (Girls) Solan, S2 = Government Senior Secondary School Oachghat, S3 = Government Senior Secondary School Shamror, S4 = Government Senior Secondary School Salogra, S5 = Government Senior Secondary School Kandaghat, S6 = Government Primary School Waknaghat, S7 = Government Middle School Anhech, S8 = DAV School Kumarhatti, S9 = Government Senior Secondary School Dharampur).

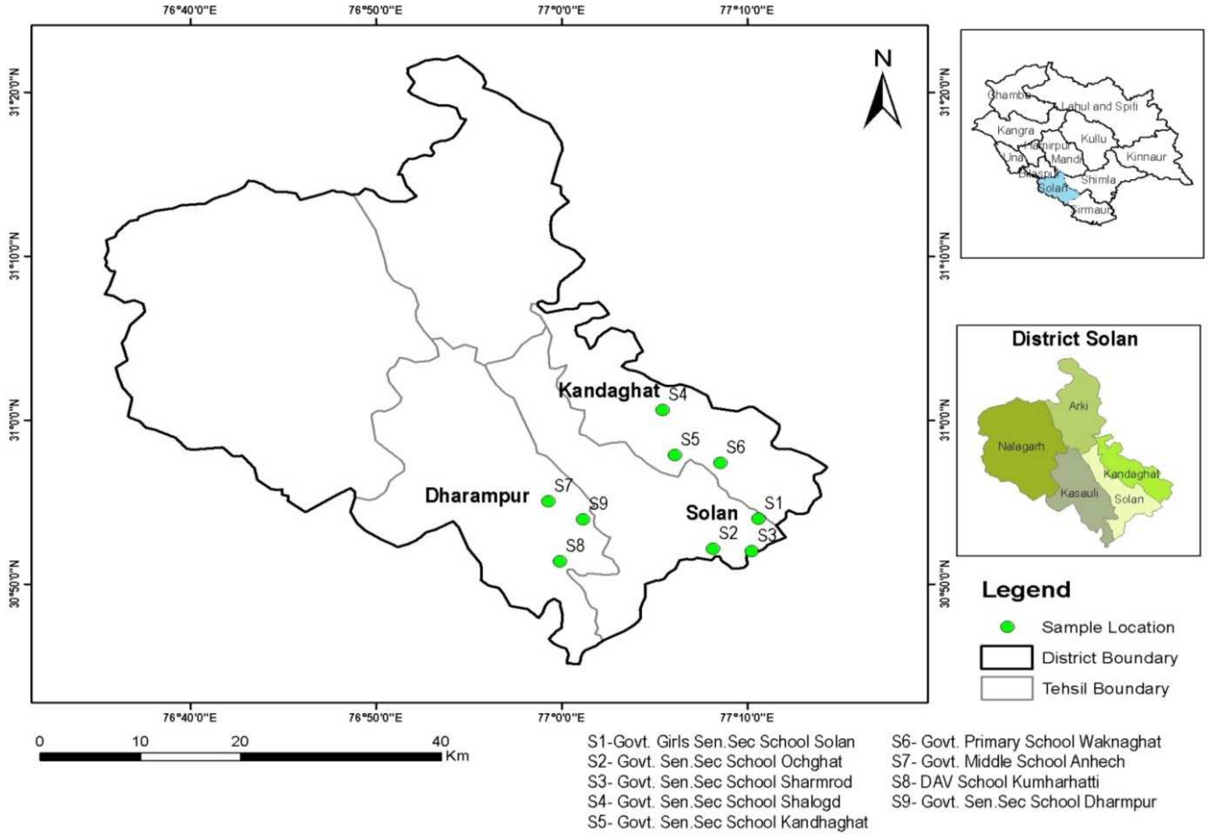

Fig. 3.1: Map showing study area

3.5 Water sampling and analysis

The water samples were then analyzed for the physical, chemical and biological parameters by applying the following procedures:

3.5.1 Physical Parameters

a) Colour

Colour was determined by visually seeing the colour of water with naked eyes.

b) Odour

Odour was determined by smelling the water samples.

c) Temperature (^{0}C)

The temperature of the water samples was recorded at the sampling site by using laboratory thermometer.

Table 3.2 Colour and odour of water samples according to CPCB classification

Colour code	1. Light brown	6. Dark green	Odour code	1. Odour free	6. Septic
	2. Brown	7. Clear		2. Rotten eggs	7. Aromatic
	3. Dark brown	8. Colourless		3. Burnt sugar	8. Chlorinous
	4. Light green			4. Soapy	9. Alcoholic
	5. Green			5. Fishy	10.Unpleasant

3.5.2 Chemical parameters

a) pH

The pH of the water was determined by using microprocessor based pH meter (Model-1013 of EIA make).

b) EC

The electrical conductivity (EC) was measured with microprocessor based conductivity TDS meter (Model-1601 of EIA make) and expressed dS m^{-1}.

c) TDS (Total Dissolved Solids)

The Total dissolved solid (TDS) was measured by using Microprocessor based conductivity TDS meter (Model-1601 EIA make) and expressed in mg l^{-1}.

d) Biological Oxygen Demand (BOD)

The BOD was estimated by using 5 day BOD test as per 5210B method (APHA, 2012). The pH of the water samples was adjusted between 6.5-7.5 ranges. Water sample (152 ml) was taken in BOD bottle and 5-6 drops of nitrification indicator inhibitor was added and stirred properly. Gasket was kept in BOD bottle and 3-4 drops of KOH solution was added and sensors were attached to the BOD bottle by using BOD system oxi-direct (Aqualytic make). Then BOD bottles were loaded in the system and kept in the incubator for five days at 20°C. BOD readings were recorded after five days and expressed as mg l^{-1}.

e) Chemical oxygen demand (COD)

The COD is the amount of oxygen in mg l^{-1} required for the degradation of organic compounds of waste water to occur. The COD test enabling the measurement of a waste in terms of total quantity of oxygen required for its oxidation to carbon dioxide and water was based upon the action of strong oxidizing agents under acidic conditions. Potassium dichromate ($K_2Cr_2O_7$) is the most commonly used oxidizing agent in this test. Chemical Oxygen Demand was estimated by oxidizing water sample with hot H_2SO_4 solution of potassium chromate with silver sulphate as the catalyst. The water samples were digested at 148^{o}C in the pre heated thermo-reactor (TR 320) for 120 minutes. In the system chloride was masked with mercury sulphate the concentration of Cr^{3+} ions was then determined photometrically by using Spectroquant Pharo 300 (Merk make) instrument and expressed as mg l^{-1}. The observed procedure is analogous to EPA 410.4 US Standard method 5220 D, and ISO 15705.

f) Heavy metals

The water samples were filtered with Whatman filter paper (No. 1) and heavy metals viz. As, Cd, Pb, Fe, Mn, Cu, Ni and Zn were estimated by using standard kits and Inductively Coupled Plasma of Atomic Emission Spectroscopy-6300 DUO (ICAP-6300 Duo) and expressed as mg l^{-l}.

3.5.3. Biological Parameters

Total Coliform

The standard test for the assessment of number of the coliform groups may be carried out either by the multiple tube dilution tests (presumptive test, confirmed test, or completed test) and by the membrane filter technique followed by APHA (2012).

a) Presumptive stage

i. Use Mac-Conkey broth. Inoculate a series of fermentation tubes with applicable consistent quantities of the water to be tested. The concentration of nutritive ingredients in the mixture should be injected in double strength and 1 ml and its dilution should be injected into single strength medium.

ii. Incubate all tubes for 24 to 48 hours at 37°C. Check each tube at the end of 24±2 hours for gas production and if no gas has been formed reincubate for another 24 hours and at the end of 48 hours, check again. Note the presence of or absence of gas at each check of the tubes regardless of the amount.

iii. Formations of the gas in any amount within 48±3 hours, in the inner fermentation tubes complete a possible presumptive test. The absence of gas formation incubation constitutes a negative test at the end of 48±3 hours.

b) Confirmed stage – In confirmed test the medium used is brilliant green bile lactose broth (BGB).

i. Submit all primary fermentation tubes at the end of 24 hours showing any amount of gas incubation to the confirmed test. If additional primary fermentation tubes show gas at the end of 48 hours incubation, these too shall be acknowledging to the confirmed test. Sterile metal loop 3 to 4 mm in diameter are used to transfer one or two loopful of medium from the presumptive positive tubes to a tube of BGB' broth. When making such transfers, firstly shake the tube or mix by rotating. And at last incubate the inoculated tubes at 37°C for 48± 3 hours.

ii. The formation of gas in any amount in the Durham's tubes of BGB tube constitutes a positive confirmed test at any time within 48± 3 hours.

c) Completed test

i. Applied to positive BGB tubes. Shake the tube, and streak with the help of a loop as soon as possible on the Mac-Conkey agar plates in such a way so as to get distinct colonies. At 37°C for 24± 2 hours incubates the plates.

ii. Pick up typical or typical colonies from each plate and inoculate lactose broth and nutrient agar slants. Incubate for 24 to 48 hours at 37°C.

iii. For gram- stain nutrient agar slants can be used. If organisms are gram negative and non- spore forming bacilli and in lactose broth gas is produced the test is considered completed and the presence of coliform organisms is demonstrated.

iv. Gram-stain technique- Prepare a thin smear of the growth on a clean glass slide on the agar slant. Air dry, fix by passing the slide over a flame, and with ammonium oxalate-crystal violet solution stain for 1 minute. Wash the slide with water, blot dry; decolorize with ethyl alcohol for 30 second, using gentle agitation. Blot and envelope with counter stain for 10 seconds with safranin, then wash, dry and audit under oil immersion. Cells which decolorize and obtain the safran in stain are pink in colour and determine as gram-negative in reaction. Cells which are retain the crystal violet stain and do not decolorize, and are defined as gram-positive which are deep blue in colour.

3.6 Permissible limits

The permissible limits of various physico-chemical parameters and concentration of heavy metals in the drinking water recommended by different agencies has been summarized in Table 3.3.

Table 3.3: Permissible limits of drinking water parameters

Parameters	Desirable	Permissible limit	Reference
pH	6.5	8.5	BIS, 2012
EC (dS m^{-1})	0.75	2.25	WHO, 2011
TDS (mg l^{-1})	500	2000	BIS, 2012
BOD (mg l^{-1})	5.00	-	BIS, 2012
COD (mg l^{-1})	250.00	-	BIS, 2012
As (mg l^{-1})	0.01	0.05	BIS, 2012
Cd (mg l^{-1})	0.03	-	BIS, 2012
Zn (mg l^{-1})	5.00	15.00	BIS, 2012
Pb (mg l^{-1})	0.05	-	BIS, 2012
Fe (mg l^{-1})	0.3	-	BIS, 2012
Mn (mg l^{-1})	0.10	0.30	BIS, 2012
Ni (mg l^{-1})	0.10	0.30	BIS, 2012
Cu(mg l^{-1})	0.05	1.5	BIS, 2012

3.7 Water quality index (WQI)

Water quality index refers to a technique of rating that provides the composite influence of individual water quality parameter on the total quality of water. To get a comprehensive picture of total quality of surface and groundwater, the WQI was used. The Indian standard specified for drinking water (BIS, 2012) was used for the calculation of WQI (Table 3.4). Each of the 15 parameters (pH, temperature, EC, TDS, BOD, COD, As, Cd, Zn, Pb, Cu, Fe, Mn, Ni and total coliform) was assigned a weight (w_i) according to its relative importance in the overall quality of water for drinking purposes and the WQI was calculated by following method outlined by Batabyal and Chakraborty (2015) as mentioned below:

$$WQI = \sum S_{i\_n}$$

$$SI_i = W_i \times q_i$$

Where,

SI_i is the sub index of ith parameter;

W_i is relative weight of ith parameter;

q_i is the rating based on concentration of ith parameter, and

n is the number of chemical parameters.

$$w_i = \frac{w_i}{\Sigma w_i}$$

Where,

W_i is the relative weight,

w_i is the weight of each parameter, and

$$q_i = (C_i/S_i) \times 100$$

Where,

q_i is the quality rating,

C_i is the concentration of each chemical parameter in each water sample in mg l^{-1}, and

S_i is the Indian drinking water standard for each chemical parameter in mg l^{-1}.

Table 3.4 Water quality classification

Range	**Quality**
0-25	Excellent
26-50	Good
51-75	Bad
76-100	Very bad
>100	Unsuitable for drinking

3.8 STATISTICAL ANALYSIS

The data obtained from the physical, chemical and biological analysis was subjected to statistical analysis under the Factorial Completely Randomized Design by following the procedure suggested by Gomez and Gomez (1984) for each seasons of the study. The treatment means were compared by the means of critical difference (CD) at 5 per cent level of significance. The Analytical data was analyzed in OPSTAT online.

Chapter – 4

RESULTS AND DISCUSSION

The results obtained from the present investigation entitled **"Assessment of Water Quality in Educational Institutes in Solan district of HimachalPradesh"** are described in this chapter under the following headings:

4.1 Physical parameters

4.2 Chemical parameters and Heavy metals

4.3 Biological parameters

4.4 Correlation analysis of parameters

4.5 Water quality index (WQI)

4.1 PHYSICAL PARAMETERS

The physical parameters like, colour, odour, temperature of tap water were found to vary with seasons in Solan, Dharampur and Kandaghat blocks of district Solan.

4.1.1 Colour

Data presented in (Appendix I) revealed that tap water taken from selected schools was found to be colourless.

4.1.2 Odour

Data presented in (Appendix I) revealed that tap water taken from selected schools was found to be odourless.

4.1.3 Temperature

The data presented in table 4.1 revealed that the temperature of tap water ranged from 18.31 to 21.21^{o}C, whereas, season wise temperature was found to vary from 13.22 to 24.87^{o}C, which were within the permissible limits as prescribed by BIS. It was observed that the maximum (21.21^{o}C) temperature was found in Government Senior Secondary School Shamror followed by Government Middle School Anhech (19.60^{o}C), Government Primary School Waknaghat (19.06^{o}C), Government Senior Secondary School Oachghat (19.04^{o}C), DAV School Kumarhatti (18.72^{o}C), Government Senior Secondary School Dharampur

(18.56°C), Government Senior Secondary School Kandaghat (18.54°C), Government Senior Secondary School (Girls) Solan (18.38°C) and Government Senior Secondary School Salogra (18.31°C). The mean temperature was higher (24.87°C) in summer while lower (13.22°C) in winter. The interaction effect of school and season was also found to exert significant influence on the tap water. The results are conformity with the findings of Trivedi *et al*. (2010) and Rana *et al*. (2016) who observed maximum temperature in summer season.

Table 4.1: Seasonal variation of temperature (°C) of tap water in selected Educational Institutes

Blocks	Schools	Seasons		Mean
		Winter	Summer	
Solan	Government Senior Secondary School (Girls) Solan	12.32	24.45	**18.38**
	Government Senior Secondary School Oachghat	12.56	25.53	**19.04**
	Government Senior Secondary School Shamror	14.87	27.55	**21.21**
Kandaghat	Government Senior Secondary School Salogra	12.34	24.28	**18.31**
	Government Senior Secondary School Kandaghat	13.83	23.25	**18.54**
	Government Primary School Waknaghat	12.56	25.56	**19.06**
Dharampur	Government Middle School Anhech	14.76	24.45	**19.60**
	DAV School Kumarhatti	12.56	24.88	**18.72**
	Government Senior Secondary School Dharampur	13.23	23.89	**18.56**
	Mean	**13.22**	**24.87**	

$CD_{0.05}$

School = 0.727

Season = 0.342

Schools × Season = 1.027

4.2 CHEMICAL PARAMETERS AND HEAVY METALS

In Solan, Dharampur and Kandaghat blocks of district Solan, the chemical parameters like, BOD,COD and heavy metals of tap water were found to vary with seasons.

4.2.1 pH

The data presented in table 4.2 revealed that the pH of tap water ranged from 6.95 to 7.13 whereas, seasons wise pH was found to vary from 6.99 to 7.07, which was within the permissible limits as prescribed by BIS. It was observed that the maximum pH (7.13) was found in Government Senior Secondary School Kandaghat followed by Government Middle School Anhech and DAV School Kumarhatti (7.09), Government Senior Secondary School

(Girls) Solan (7.04), Government Senior Secondary School Oachghat and Government Senior Secondary School Shamror (7.03), Government Senior Secondary School Salogra and Government Senior Secondary School Dharampur (6.96), whereas, minimum pH (6.95) was noticed in Government Primary School Waknaghat, The mean pH was higher (7.07) in summer while lower (6.99) in winters. The interaction effect of school and season was also found to exert significant influence on the tap water. The higher pH during summer season was because of more evaporation and less dilution as compared to other seasons (Salve and Hiware, 2006).

Table 4.2: Seasonal variation of pH of tap water in selected Educational Institutes

Blocks	Schools	Seasons		Mean
		Winter	Summer	
Solan	Government Senior Secondary School(Girls) Solan	7.03	7.05	**7.04**
	Government Senior Secondary School Oachghat	6.92	7.13	**7.03**
	Government Senior Secondary School Shamror	6.95	7.11	**7.03**
Kandaghat	Government Senior Secondary School Salogra	6.94	6.99	**6.96**
	Government Senior Secondary School Kandaghat	7.10	7.15	**7.13**
	Government Primary School Waknaghat	6.98	6.92	**6.95**
Dharampur	Government Middle School Anhech	7.02	7.15	**7.09**
	DAV School Kumarhatti	7.01	7.17	**7.09**
	Government Senior Secondary School Dharampur	6.98	6.95	**6.96**
	Mean	**6.99**	**7.07**	

$CD_{0.05}$

School	=	0.01
Season	=	0.00
School × Season	=	0.01

4.2.2 Electrical Conductivity (EC)

The data presented in table 4.3 revealed that the EC of tap water ranged from 0.24 to 0.51dS m^{-1} whereas, seasons wise EC was found to vary from 0.32 to 0.35 dS m^{-1}, which was within the permissible limits as prescribed by WHO. It was observed that the maximum (0.51 dS m^{-1}) EC was found in Government Senior Secondary School Dharampur which was significantly different from other EC values followed by Government Senior Secondary School Salogra (0.40 dS m^{-1}), Government Primary School Waknaghat (0.37 dS m^{-1}), Government Senior Secondary School Shamror (0.36 dS m^{-1}),DAV School Kumarhatti (0.31

dS m^{-1}), Government Senior Secondary School Kandaghat (0.30 dS m^{-1}), Government Middle School Anhech (0.29 dS m^{-1}), the minimum (0.24 dS m^{-1}**)** EC was found in Government Senior Secondary School (Girls) Solan which was statistically at par with Government Senior Secondary School Oachghat (0.25 dS m^{-1}). The mean EC was higher (0.35 dS m^{-1}) in summer while lower (0.32 dS m^{-1}) in winter. The interaction effect of school and season was also found to exert significant influence on the tap water. This is in confirmation with the findings of Jadhav *et al*. (2012).

Table 4.3: Seasonal variation of EC (dS m^{-1}) of tap water in selected Educational Institutes.

Blocks	Schools	Seasons		Mean
		Winter	Summer	
Solan	Government Senior Secondary School (Girls) Solan	0.23	0.26	**0.24**
	Government Senior Secondary School Oachghat	0.18	0.33	**0.25**
	Government Senior Secondary School Shamror	0.38	0.34	**0.36**
Kandaghat	Government Senior Secondary School Salogra	0.44	0.35	**0.40**
	Government Senior Secondary School Kandaghat	0.32	0.29	**0.30**
	Government Primary School Waknaghat	0.29	0.45	**0.37**
Dharampur	Government Middle School Anhech	0.26	0.32	**0.29**
	DAV School Kumarhatti	0.30	0.33	**0.31**
	Government Senior Secondary School Dharampur	0.50	0.52	**0.51**
	Mean	**0.32**	**0.35**	

$CD_{0.05}$

School = 0.04

Season = 0.02

Schools × Season = 0.06

4.2.3 Total dissolved solids (TDS)

The data presented in table 4.4 revealed that the TDS of tap water ranged from 107.90 to 194.02 mg l^{-1}, whereas, seasons wise TDS was found to vary from 133.83 to 143.77 mg l^{-1}, which was within the permissible limits as prescribed by BIS. It was observed that the maximum (194.02 mg l^{-1}) TDS was found in Government Primary School Waknaghat which was statistically at par with Government Middle School Anhech (190.97mg l^{-1}) followed by Government Senior Secondary School Kandaghat (152.10mg l^{-1}), Government Senior Secondary School Shamror (127.05 mg l^{-1}), Government Senior

Secondary School (Girls) Solan (126.22 mg l^{-1}), Government Senior Secondary School Oachghat (125.32 mg l^{-1}), Government Senior Secondary School Dharampur (116.80 mg l^{-1}) whereas minimum TDS was found in Government Senior Secondary School Salogra (107.90 mg l^{-1}) which was statistically at par with DAV School Kumarhatti (108.85 mg l^{-1}). The mean TDS was higher (143.77 mg l^{-1}) in summer while lower (133.83 mg l^{-1}) in winters. The interaction effect of school and season was also found to exert significant influence on the tap water. The present trend is in confirmation with the findings of Sharma and Kapoor (2010) and Rao *et al*. (2011).

Table 4.4: Seasonal variation of TDS (mg l^{-1}) of tap water in selected Educational Institutes

Blocks	Schools	Seasons		Mean
		Winter	Summer	
Solan	Government Senior Secondary School (Girls) Solan	145.60	106.85	**126.22**
	Government Senior Secondary School Oachghat	124.30	126.35	**125.32**
	Government Senior Secondary School Shamror	116.20	137.90	**127.05**
Kandaghat	Government Senior Secondary School Salogra	101.75	114.05	**107.90**
	Government Senior Secondary School Kandaghat	108.20	196.00	**152.10**
	Government Primary School Waknaghat	193.60	194.45	**194.02**
Dharampur	Government Middle School Anhech	189.95	192.00	**190.97**
	DAV School Kumarhatti	108.85	108.85	**108.85**
	Government Senior Secondary School Dharampur	116.05	117.55	**116.80**
	Mean	**133.83**	**143.77**	

$CD_{0.05}$

School = 5.083

Season = 2.396

Schools × Season = 7.189

4.2.4 Biological oxygen demand (BOD)

The data presented in table 4.5 revealed that the BOD of tap water ranged from 0.69 to 2.26 mg l^{-1}, whereas, seasons wise BOD was found to vary from 1.39 to 1.49 mg l^{-1}, which was within the permissible limits as prescribed by BIS. It was observed that the maximum (2.26 mg l^{-1}) BOD was found in Government Middle School Anhech followed by Government Senior Secondary School Dharampur (2.22 mg l^{-1}), DAV School Kumarhatti (1.85 mg l^{-1}), Government Senior Secondary School Kandaghat (1.47 mg l^{-1}), Government

Primary School Waknaghat (1.35 mg l^{-1}), Government Senior Secondary School Salogra (1.25 mg l^{-1}), Government Senior Secondary School Shamror (0.95 mg l^{-1}), Government Senior Secondary School (Girls) Solan (0.92 mg l^{-1}) and minimum BOD was found in Government Senior Secondary School Oachghat (0.69 mg l^{-1}). The mean BOD was higher (1.49 mg l^{-1}) in summer while lower (1.39 mg l^{-1}) in winters. The interaction effect of school and season was also found to exert non-significant influence on the tap water.The results are inconformity with the findings of Trivedi and Goel (1986) and Mathur *et al*. (2007) who have indicated enrichment of water sources with organic matter as a reason for high BOD.

Table 4.5: Seasonal variation of BOD (mg l^{-1}) of tap water in selected Educational Institutes

Blocks	**Schools**	**Seasons**		**Mean**
		Winter	**Summer**	
Solan	Government Senior SecondarySchool (Girls) Solan	0.66	1.19	**0.92**
	Government Senior Secondary School Oachghat	0.51	0.87	**0.69**
	Government Senior Secondary School Shamror	0.88	1.01	**0.95**
Kandaghat	Government Senior Secondary School Salogra	1.21	1.34	**1.27**
	Government Senior Secondary School Kandaghat	1.36	1.58	**1.47**
	Government Primary School Waknaghat	1.62	1.09	**1.35**
Dharampur	Government Middle School Anhech	2.26	2.26	**2.26**
	DAV School Kumarhatti	1.81	1.90	**1.85**
	Government Senior Secondary School Dharampur	2.21	2.22	**2.22**
	Mean	**1.39**	**1.49**	

$CD_{0.05}$

School	=	0.29
Season	=	N/S
Schools × Season	=	N/S

4.2.5 Chemical oxygen demand (COD)

The data presented in table 4.6 revealed that the COD of tap water ranged from 56.50 to 119.75 mg l^{-1}, whereas, seasons wise COD was found to vary from 82.50 to 98.16 mg l^{-1}, which was within the permissible limits as prescribed by BIS. It was observed that the maximum (119.75 mg l^{-1}) COD was found in Government Senior Secondary School Salogra which was statistically at par with Government Primary School Waknaghat (113.25 mg l^{-1}) followed by Government Senior Secondary School Oachghat (106.75 mg l^{-1}), Government Senior Secondary School Dharampur (99.25 mg l^{-1}), Government Senior Secondary School

Shamror (95.75 mg l^{-1}), Government Middle School Anhech (81.25 mg l^{-1}), Government Senior Secondary School (Girls) Solan (74.50 mg l^{-1}), and minimum (56.50 mg l^{-1}) COD was found in DAV School Kumarhatti which was statistically at par with Government Senior Secondary School Kandaghat (66.00 mg l^{-1}). The mean COD was higher (98.16 mg l^{-1}) in summer while lower (82.50 mg l^{-1}).in winters. The interaction effect of school and season was also found to exert significant influence on the tap water. The results are in conformity with the findings of Joseph and Jacob (2010) and Chattopadhyay *et al.* (2005) who also reported similar results where they found maximum COD in summer season.

Table 4.6: Seasonal variation of COD (mg l^{-1}) of tap water in selected Educational Institutes

Blocks	Schools	Seasons		Mean
		Winter	Summer	
Solan	Government Senior Secondary School (Girls) Solan	66.00	83.00	**74.50**
	Government Senior Secondary School Oachghat	103.00	110.50	**106.75**
	Government Senior Secondary School Shamror	90.00	101.50	**95.75**
Kandaghat	Government Senior Secondary School Salogra	107.50	132.00	**119.75**
	Government Senior Secondary School Kandaghat	43.50	88.50	**66.00**
	Government Primary School Waknaghat	105.00	121.50	**113.25**
Dharampur	Government Middle School Anhech	80.00	82.50	**81.25**
	DAV School Kumarhatti	52.00	61.00	**56.50**
	Government Senior Secondary School Dharampur	95.50	103.00	**99.25**
	Mean	**82.50**	**98.16**	

$CD_{0.05}$

School = 10.11

Season = 4.76

Schools × Season = 14.30

4.2.6 Heavy metals

4.2.6.1. Concentration of Arsenic (As)

The As content of tap water in Solan district was not influenced by schools, seasons and their interaction (Appendix III). The data in appendix III further revealed that As content was zero in selected schools.

4.2.6.2. Concentration of Cadmium (Cd)

The data presented in table 4.7 revealed that the Cd of tap water ranged from 0.000 to 0.001 mg l^{-1}, whereas, seasons wise Cd was found to vary from 0.000 to 0.001 mg l^{-1}, which was within the permissible limits as prescribed by BIS. The interaction effect of school and season was also found to exert non-significant influence on the tap water. The results are in conformity with the findings of Lokeshwari and Chandrappa (2006) who reported Cd in the sampled water much below the permissible levels.

Table 4.7: Seasonal variation of Cd (mg l^{-1}) of tap water in selected Educational Institutes.

Blocks	Schools	Seasons		Mean
		Winter	Summer	
Solan	Government Senior Secondary School (Girls) Solan	0.001	0.002	**0.001**
	Government Senior Secondary School Oachghat	0.000	0.001	**0.000**
	Government Senior Secondary School Shamror	0.001	0.002	**0.001**
Kandaghat	Government Senior Secondary School Salogra	0.000	0.001	**0.001**
	Government Senior Secondary School Kandaghat	0.001	0.001	**0.001**
	Government Primary School Waknaghat	0.001	0.001	**0.001**
Dharampur	Government Middle School Anhech	0.000	0.001	**0.001**
	DAV School Kumarhatti	0.001	0.001	**0.001**
	Government Senior Secondary School Dharampur	0.000	0001	**0.001**
	Mean	**0.000**	**0.001**	

$CD_{0.05}$

School	=	N/S
Season	=	0.000
Schools × Season	=	N/S

4.2.6.3.Concentration of Zinc (Zn)

The data presented in table 4.8 revealed that the Zn of tap water ranged from 0.001 to 0.003 mg l^{-1}, whereas, seasons wise Zn was found to vary from 0.001 to 0.002 mg l^{-1}, which was within the permissible limits as prescribed by BIS. It was observed that the maximum (0.003 mg l^{-1}) Zn was found in Government Senior Secondary School Salogra followed by Government Senior Secondary School Oachghat, Government Primary School Waknaghat and DAV School Kumarhatti (0.002 mg l^{-1}), and minimum (0.001 mg l^{-1}) Zn was found in Government Senior Secondary School (Girls) Solan, Government Senior Secondary School

Shamror, Government Senior Secondary School Kandaghat, Government Middle School Anhech and Government Senior Secondary School Dharampur. The mean Zn was higher (0.002 mg l^{-1}) in summer while lower (0.001 mg l^{-1}) in winter. The interaction effect of school and season was also found to exert non significant influence on the tap water. The results are in conformity with the findings of Shanbehzadeh *et al*. (2014) that the concentration of Zn was within the standard range for drinking water.

Table 4.8. Seasonal variation of Zn (mg l^{-1}) of tap water in selected Educational Institutes.

Blocks	**Schools**	**Seasons**		**Mean**
		Winter	**Summer**	
Solan	Government Senior Secondary School (Girls) Solan	0.001	0.002	**0.001**
	Government Senior Secondary School Oachghat	0.001	0.002	**0.002**
	Government Senior Secondary School Shamror	0.001	0.002	**0.001**
Kandaghat	Government Senior Secondary School Salogra	0.002	0.003	**0.003**
	Government Senior Secondary School Kandaghat	0.001	0.001	**0.001**
	Government Primary School Waknaghat	0.001	0.002	**0.002**
Dharampur	Government Middle School Anhech	0.001	0.001	**0.001**
	DAV School Kumarhatti	0.001	0.002	**0.002**
	Government Senior Secondary School Dharampur	0.000	0.001	**0.001**
	Mean	**0.001**	**0.002**	

$CD_{0.05}$

School = 0.001

Season = 0.000

Schools × Season = N/S

4.2.6.4. Concentration of Lead (Pb)

The data presented in table 4.9 revealed that the Pb of tap water ranged from 0.00 to 0.01 mg l^{-1}, whereas, seasons wise Pb was found to vary from 0.00 to 0.01 mg l^{-1}, which was within the permissible limits as prescribed by BIS. The mean Pb was same (0.00 mg l^{-1}) in winter and summer. The interaction effect of school and season was also found to exert non significant influence on the tap water. The results are in conformity with the findings of Wogu and Okaka (2011) where Pb had the least mean concentration of 0.01 mg l^{-1}.

Table 4.9: Seasonal variation of Pb (mg l^{-1}) of tap water in selected Educational Institutes.

Blocks	Schools	Seasons		Mean
		Winter	Summer	
Solan	Government Senior Secondary School (Girls) Solan	0.00	0.00	**0.00**
	Government Senior Secondary School Oachghat	0.00	0.01	**0.01**
	Government Senior Secondary School Shamror	0.00	0.00	**0.00**
Kandaghat	Government Senior Secondary School Salogra	0.00	0.01	**0.01**
	Government Senior Secondary School Kandaghat	0.00	0.01	**0.01**
	Government Primary School Waknaghat	0.00	0.00	**0.00**
Dharampur	Government Middle School Anhech	0.01	0.00	**0.00**
	DAV School Kumarhatti	0.00	0.01	**0.00**
	Government Senior Secondary School Dharampur	0.00	0.01	**0.00**
	Mean	**0.00**	**0.01**	

$CD_{0.05}$

School	=	N/S
Season	=	0.00
Schools × Season	=	N/S

4.2.6.5. Concentration of Copper (Cu)

The data presented in table 4.10 revealed that the Cu of tap water ranged from 0.00 to 0.02 mg l^{-1}, whereas, seasons wise Cu was found to vary from 0.00 to 0.01 mg l^{-1}, which was within the permissible limits as prescribed by BIS. It was observed that the maximum (0.02 mg l^{-1}) Cu was found in Government Senior Secondary School Salogra and Government Primary School Waknaghat which was statistically at par with Government Senior Secondary School Oachghat, Government Senior Secondary School Shamror, Government Middle School Anhech, DAV School Kumarhatti (0.01 mg l^{-1}) and lower (0.00 mg l^{-1}) Cu was found in Government Senior SecondarySchool (Girls) Solan and Government Senior Secondary School Kandaghat. The Mean Cu was higher (0.01 mg l^{-1}) in summer while lower (0.00 mg l^{-1}) in winters. The interaction effect of school and season was also found to exert significant influence on the tap water. The results are in conformity with the findings of Shanbehzadeh *et al.* (2014) who reported that the mean concentration of Cu was within the standard range for drinking water.

Table 4.10: Seasonal variation of Cu (mg l^{-1}) of tap water in selected Educational Institutes.

Blocks	Schools	Seasons		Mean
		Winter	Summer	
Solan	Government Senior Secondary School (Girls) Solan	0.00	0.01	**0.00**
	Government Senior Secondary School Oachghat	0.01	0.02	**0.01**
	Government Senior Secondary School Shamror	0.01	0.02	**0.01**
Kandaghat	Government Senior Secondary School Salogra	0.02	0.02	**0.02**
	Government Senior Secondary School Kandaghat	0.00	0.01	**0.00**
	Government Primary School Waknaghat	0.01	0.03	**0.02**
Dharampur	Government Middle School Anhech	0.00	0.02	**0.01**
	DAV School Kumarhatti	0.01	0.01	**0.01**
	Government Senior Secondary School Dharampur	0.00	0.00	**0.00**
	Mean	**0.00**	**0.01**	

$CD_{0.05}$

School = 0.00

Season = 0.00

Schools × Season = 0.00

4.2.6.6. Concentration of Iron (Fe)

The data presented in table 4.11 revealed that the Fe of tap water ranged from 0.63 to 0.95mg l^{-1}, whereas, seasons wise Fe was found to vary from 0.75 to 0.88 mg l^{-1}, which was above the permissible limits as prescribed by BIS. It was observed that the maximum (0.95 mg l^{-1}) Fe was found in Government Senior Secondary School Salogra which was statistically at par with DAV School Kumarhatti (0.94 mg l^{-1}) followed by Government Middle School Anhech (0.92 mg l^{-1}), Government Senior Secondary School Kandaghat (0.87 mg l^{-1}), Government Primary School Waknaghat (0.84 mg l^{-1}), Government Senior Secondary School Shamror (0.84 mg l^{-1}) and the minimum (0.63 mg l^{-1}) Fe was found in Government Senior Secondary School (Girls) Solan which was statistically at par with Government Senior Secondary School Oachghat and Government Senior Secondary School Dharampur (0.67 mg l^{-1}). The mean Fe was higher (0.88 mg l^{-1}) in summer while lower (0.75 mg l^{-1}) in winter. The interaction effect of school and season was also found to exert significant influence on the tap water. The results are in conformity with the findings of Puri (2011) who have also indicated increase in Fe concentration during summer.

Table 4.11: Seasonal variation of Fe (mg l^{-1}) of tap water in selected Educational Institutes

Blocks	Schools	Seasons		Mean
		Winter	Summer	
Solan	Government Senior Secondary School (Girls) Solan	0.60	0.66	**0.63**
	Government Senior Secondary School Oachghat	0.62	0.71	**0.67**
	Government Senior Secondary School Shamror	0.82	0.87	**0.84**
Kandaghat	Government Senior Secondary School Salogra	0.94	0.96	**0.95**
	Government Senior Secondary School Kandaghat	0.85	0.89	**0.87**
	Government Primary School Waknaghat	0.66	1.01	**0.84**
Dharampur	Government Middle School Anhech	0.85	0.98	**0.92**
	DAV School Kumarhatti	0.90	0.98	**0.94**
	Government Senior Secondary School Dharampur	0.51	0.83	**0.67**
	Mean	**0.75**	**0.88**	

$CD_{0.05}$

School = 0.03

Season = 0.01

Schools × Season = 0.04

4.2.6.7. Concentration of Manganese (Mn)

The data presented in table 4.12 revealed that the Mn of tap water ranged from 0.03 to 0.06 mg l^{-1}, whereas, seasons wise Mn was found to vary from 0.04 to 0.05 mg l^{-1}, which was within the permissible limits as prescribed by BIS. It was observed that the maximum (0.06 mg l^{-1}) Mn was found in Government Senior Secondary School (Girls) Solan and Government Senior Secondary School Shamror (0.06 mg l^{-1}) followed by Government Senior Secondary School Oachghat and Government Senior Secondary School Salogra (0.05 mg l^{-1}), Government Senior Secondary School Kandaghat, Government Senior Secondary School Dharampur (0.04 mgl^{-1}), DAV School Kumarhatti, Government Middle School Anhech, Government Primary School Waknaghat (0.03 mg l^{-1}). The mean Mn was higher (0.05 mg l^{-1}) in summer while lower (0.04 mg l^{-1}) in winter. The interaction effect of school and season was also found to exert non significant influence on the tap water. The results are in conformity with the findings of Dwivedi and Tiwary (1997) who found that the manganese content in water samples was below the permissible limit.

Table 4.12: Seasonal variation of Mn (mg l^{-1}) of tap water in selected Educational Institutes

Blocks	Schools	Seasons		Mean
		Winter	Summer	
Solan	Government Senior Secondary School (Girls) Solan	0.06	0.07	**0.06**
	Government Senior Secondary School Oachghat	0.04	0.06	**0.05**
	Government Senior Secondary School Shamror	0.05	0.07	**0.06**
Kandaghat	Government Senior Secondary School Salogra	0.04	0.06	**0.05**
	Government Senior Secondary School Kandaghat	0.03	0.05	**0.04**
	Government Primary School Waknaghat	0.03	0.04	**0.03**
Dharampur	Government Middle School Anhech	0.03	0.04	**0.03**
	DAV School Kumarhatti	0.04	0.05	**0.03**
	Government Senior Secondary School Dharampur	0.03	0.04	**0.04**
	Mean	**0.04**	**0.05**	

$CD_{0.05}$

School	=	0.00
Season	=	0.00
Schools × Season	=	0.00

4.2.6.8. Concentration of Nickel (Ni)

The data presented in table 4.13 revealed that the Ni of tap water ranged from 0.00 to 0.02 mg l^{-1} whereas, seasons wise Ni was found to vary from 0.00to 0.02 mg l^{-1}, which was within the permissible limits as prescribed by BIS. It was observed that the maximum (0.02 mg l^{-1}) Ni was found in DAV School Kumarhatti and minimum Ni was found in Government Senior Secondary School Oachghat and Government Senior Secondary School Salogra (0.00 mg l^{-1}). The mean Ni was higher in summer (0.02 mg l^{-1}) while lower in winter (0.00 mg l^{-1}). The interaction effect of school and season was also found to exert non significant influence on the tap water. The results are in conformity with the findings of Lokeshwari and Chandrappa (2006) where it was found that all the samples from various sources contain Ni much below thelimits prescribed.

Table 4.13: Seasonal variation of Ni (mg l^{-1}) of tap water in selected Educational Institutes

Blocks	Schools	Seasons		Mean
		Winter	Summer	
Solan	Government Senior Secondary School (Girls) Solan	0.00	0.02	**0.01**
	Government Senior Secondary School Oachghat	0.00	0.01	**0.00**
	Government Senior Secondary School Shamror	0.01	0.02	**0.01**
Kandaghat	Government Senior Secondary School Salogra	0.00	0.00	**0.00**
	Government Senior Secondary School Kandaghat	0.01	0.02	**0.01**
	Government Primary School Waknaghat	0.00	0.02	**0.01**
Dharampur	Government Middle School Anhech	0.01	0.02	**0.01**
	DAV School Kumarhatti	0.00	0.04	**0.02**
	Government Senior Secondary School Dharampur	0.01	0.02	**0.01**
	Mean	**0.00**	**0.02**	

$CD_{0.05}$

School = N/S

Season = 0.00

Schools × Season = N/S

4.3 BIOLOGICAL PARAMETERS

4.3.1. Coliform

The data presented in table 4.14 revealed that the total coliform of tap water ranged from 20.00 to 54.00 MPN ml^{-1}, whereas, season wise total coliform was found to vary from 34.11 to 41.53 MPN ml^{-1}, which was within the permissible limits as prescribed by BIS. It was observed that the maximum (54.00 MPN ml^{-1}) total coliform was found in Government Senior Secondary School Dharampur followed by Government Primary School Oachghat (48.50 MPN ml^{-1}), Government Primary School Waknaghat (46.00 MPN ml^{-1}), Government Senior Secondary School Shamror (43.00 MPN ml^{-1}), DAV School Kumarhatti (43.25MPN ml^{-1}), Government Senior Secondary School Salogra (35.25 MPN ml^{-1}), Government Senior SecondarySchool (Girls) Solan (29.00MPN ml^{-1}), Government Middle School Anhech (23.50 MPN ml^{-1}) and Government Senior Secondary School Kandaghat (20.00 MPN ml^{-1}). The mean total coliform was higher (41.53 MPN ml^{-1}) in summer while lower (34.11 MPN ml^{-1}) in winter. The interaction effect of school and season was also found to exert significant influence on the tap water.The results are in conformity with the findings of Shaikh and Mandre (2009) who also observed maximum concentration of total coliform in summer and minimum in winter.

Table 4.14: Seasonal variation total coliform (MPN ml^{-1}) of tap water in selected Educational Institutes

Blocks	Schools	Seasons		Mean
		Winter	Summer	
Solan	Government Senior Secondary School (Girls) Solan	25.00	33.00	**29.00**
	Government Senior Secondary School Oachghat	39.00	58.00	**48.50**
	Government Senior Secondary School Shamror	52.00	34.00	**43.00**
Kandaghat	Government Senior Secondary School Salogra	34.00	36.00	**35.25**
	Government Senior Secondary School Kandaghat	19.00	21.00	**20.00**
	Government Primary School Waknaghat	35.00	57.00	**46.00**
Dharampur	Government Middle School Anhech	21.00	26.00	**23.50**
	DAV School Kumarhatti	34.00	52.00	**43.25**
	Government Senior Secondary School Dharampur	52.00	56.00	**54.00**
	Mean	**34.11**	**41.53**	

$CD_{0.05}$

School = 2.72
Season = 1.28
Schools × Season = 3.84

4.4 Correlation analysis of Parameters

The table 4.15 revealed that during winter the pH has highly significant negative correlation with chemical oxygen demand (r = -0.86, p<0.01), significant with copper (r =-0.68, p<0.05). Akoto *et al*. (2008) have reported similar results (r = -0.69, p<0.05). The electrical conductivity has negative correlation with total dissolved solids (r = -0.436) and positive correlation with chemical oxygen demand (r = 0.32) and biological oxygen demand (r = 0.417). The temperature has highly significant positively correlation with nickel (r = 0.87, p<0.01). The biological oxygen demand has significant negative correlation with manganese (r=-0.717, p<0.05) and positive with arsenic (r = 0.021), lead (r = 0.510), iron (r = 0.107) and nickel (r = 0.426). The Arsenic has highly significant and positively correlation with copper (r = 0.66, p<0.05). Zinc has highly significant and positively correlation with copper (r = 0.70, p<0.05) and iron (r = 0.70, p<0.05). Kar *et al*. (2008) have also reported similar results. Lead correlatednegatively with copper (r = -0.354), manganese (r = -0.316) and positively with iron (r = 0.244) and nickel (r = 0.395). Copper has negative correlation with nickel (r = -0.559) and positive with iron (r = 0.438) manganese (r = 0.112). Iron has negative correlation with manganese (r = -0.077) and positive with nickel (r = 0.046). Manganese was negatively correlated with nickel (r = -0.350).

The table 4.16 revealed that during summer the pH showed significant positively correlation with electrical conductivity (r = 0.725, $p<0.05$) and chemical oxygen demand (r = 0.686, $p<0.05$). Tripathi *et al*. (2014) have reported have similar findings. Electrical conductivity has negative correlation with arsenic (r = -0.052), cadmium (r = -0.382), zinc (r = -0.165) and nickel (r = -0.023) and positive with temperature (r = 0.012), biological oxygen demand (r = 0.270) and chemical oxygen demand (r = 0.427). The temperature has negative correlation with biological oxygen demand (r = -0.564), arsenic(r = -0.451), lead (r = -0.482) and iron (r = -0.010) and positive with chemical oxygen demand (r = 0.169), cadmium (r = 0.514), zinc (r = 0.367), copper (r = 0.534) and nickel (r = 0.052). The biological oxygen demand showed significant and negative correlation with manganese (r = -0.672, $p<0.05$) and positively with lead (r = 0.196), iron (r = 0.375) and nickel (r = 0.396). The chemical oxygen demand showed highly significant negative correlation with nickel (r = -0.83, $p<0.01$) and positive with zinc (r =0.466), copper (r = 0.490), iron (r = 0.061), total coliform (r = 0.240) and manganese (r = 0.047). The arsenic showed significant negative correlation with iron (r = -0.79, $p<0.05$) and positive with cadmium (r = 0.060) and lead (r = 0.350). Similar finding have been reported by Akoto *et al*. (2008). The cadmium showed significant positive correlation with manganese (r = 0.77, $p<0.05$). The zinc has negative correlation with nickel (r = -0.395) and positive with (r = 0.040), copper (r = 0.449), iron (r = 0.020) and manganese (r = 0.561). The lead has negative correlation with copper (r = -0.478), iron (r = -0.025), manganese (r = -0.129) and nickel (r = -0.100). The iron has negative correlation with manganese (r = -0.592) and total coliform (r = -0.050) and positive with nickel (r = 0.197). The manganese was negatively correlated with nickel (r = -0.258).

Table 4.15 Correlation among the water quality parameters during winter in selected Educational Institutes

	pH	EC	TDS	TEMP	BOD	COD	As	Cd	Zn	Pb	Cu	Fe	Mn	Ni	TC
pH	1.000														
EC	-0.133	1.000													
TDS	0.090	-0.436	1.000												
TEMP	0.211	0.131	0.148	1.000											
BOD	0.294	0.417	0.294	0.279	1.000										
COD	**-0.860****	0.232	0.211	-0.157	-0.101	1.000									
As	-0.332	0.238	0.223	-0.430	0.021	0.567	1.000								
Cd	0.470	-0.212	0.022	0.003	-0.232	-0.560	-0.060	1.000							
Zn	-0.182	-0.147	-0.102	-0.218	-0.392	0.126	0.567	0.000	1.000						
Pb	0.190	-0.229	0.599	0.563	0.510	-0.039	-0.189	-0.395	0.000	1.000					
Cu	-0.686*	0.168	-0.284	-0.367	-0.306	0.521	0.668*	-0.112	0.707*	-0.354	1.000				
Fe	0.164	0.074	-0.224	0.272	0.107	-0.301	0.185	0.124	0.700*	0.244	0.438	1.000			
Mn	-0.168	-0.242	-0.225	-0.191	-0.717*	-0.097	-0.209	0.350	0.237	-0.316	0.112	-0.077	1.000		
Ni	0.350	0.399	-0.033	**0.879****	0.426	-0.210	-0.478	-0.100	-0.474	0.395	-0.559	0.046	-0.350	1.000	
TC	-0.698*	0.530	-0.320	0.049	-0.047	0.554	-0.003	-0.154	-0.376	-0.425	0.305	-0.357	0.095	0.114	1.000

Table 4.16 Correlation among the water quality parameters during summer in selected Educational Institutes.

	pH	EC	TDS	TEMP	BOD	COD	As	Cd	Zn	Pb	Cu	Fe	Mn	Ni	TC
pH	1.000														
EC	0.725*	1.000													
TDS	0.065	0.018	1.000												
TEMP	0.058	0.012	-0.100	1.000											
BOD	0.111	0.270	0.106	-0.564	1.000										
COD	0.686*	0.427	0.061	0.169	-0.478	1.000									
As	0.011	-0.052	-0.173	-0.451	-0.055	-0.083	1.000								
Cd	0.067	-0.382	-0.312	0.514	-0.429	-0.153	0.060	1.000							
Zn	-0.242	-0.165	-0.501	0.367	-0.620	0.466	-0.395	0.189	1.000						
Pb	0.114	0.140	-0.342	-0.482	0.196	0.045	0.350	-0.598	0.040	1.000					
Cu	-0.111	-0.092	0.447	0.534	-0.552	0.490	-0.598	-0.036	0.449	-0.478	1.000				
Fe	-0.078	0.278	0.479	-0.010	0.375	0.061	-0.796*	-0.510	0.020	-0.025	0.373	1.000			
Mn	0.230	-0.598	-0.539	0.435	-0.672*	0.047	0.129	0.772*	0.561	-0.129	0.039	-0.592	1.000		
Ni	0.374	-0.023	0.021	0.052	0.396	**-0.837****	-0.125	0.060	-0.395	-0.100	-0.329	0.197	-0.258	1.000	
TC	-0.422	0.647	-0.346	0.237	-0.139	0.240	0.037	-0.313	0.207	0.260	0.047	-0.050	-0.251	0.127	1.000

4.5 Water quality index (WQI)

The data presented in table 4.17 revealed that the water quality index (WQI) of tap water ranged from 25.80 to 36.38. The maximum WQI (36.38) was found in Government Middle School Anhech followed by Government Senior Secondary School Salogra (35.75), DAV School Kumarhatti (33.31), Government Primary School Waknaghat (32.72), Government Senior Secondary School Kandaghat (32.03), Government Senior Secondary School Shamror (31.38), Government Senior Secondary School Dharampur (30.91), Government Senior Secondary School Oachghat (28.16) and minimum(25.80) WQI was found in Government Senior Secondary School (Girls) Solan. The WQI for all the selected educational institutes in Solan district was categorized as excellent.

Table 4.17: Water quality index in selected Educational Institutes

	Schools	WQI
1	Government Senior SecondarySchool (Girls) Solan	25.80
2	Government Senior Secondary School Oachghat	28.16
3	Government Senior Secondary School Shamror	31.38
4	Government Senior Secondary School Salogra	35.75
5	Government Senior Secondary School Kandaghat	32.03
6	Government Primary School Waknaghat	32.72
7	Government Middle School Anhech	36.38
8	DAV School Kumarhatti	33.31
9	Government Senior Secondary School Dharampur	30.91

Chapter-5

SUMMARY AND CONCLUSION

The present investigation entitled **"Assessment of Water Quality in Educational Institutes in Solan District of Himachal Pradesh"** was conducted during the years 2018-2019 in three blocks of Solan district (Solan, Dharampur and Kandaghat) and analysis was carried out in the department of Environmental Science, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (Nauni) HP. The quality parameters of tap water analyzed were pH, EC, colour, odour, temperature, TDS, BOD, COD and heavy metals (As, Cd, Zn, Pb, Cu, Fe, Mn, Ni) and total coliform. To communicate water quality effectively the water quality index (WQI) was also calculated.

5.1. Water quality parameters

The pH of tap water ranged from 6.95 to 7.13 in all the selected locations. Among the seasons, the mean pH was found higher (7.07) in summer and lower (6.99) in winter season. The pH of tap water in the study area was within the permissible limits as given by BIS.

The EC of tap water was in the range of 0.24 and 0.51 dS m^{-1} in all the selected schools. Among the seasons, the mean EC was found higher (0.35 dS m^{-1}) in summer and lower (0.32 dS m^{-1}) was in winter season. The EC of tap water in the study area was within the permissible limits as given by WHO.

The colour of tap water in selected educational institutes was colourless in all the selected locations.

The odour of tap water in selected educational institutes was odourless in all the selected locations.

The TDS of tap water was in the range of 107.90 and 194.02 mg l^{-1}in selected institutes. Among the seasons, the mean TDS was found higher (143.77 mg l^{-1}) in summer and lower (133.83 mg l^{-1}) in winter season. The TDS of tap water in the study area was within the permissible limits as given by BIS.

The temperature of tap water ranged from 18.31 to 21.21^{o}C in selected educational institutes. Among the seasons, the mean temperature was found higher (24.87^{o}C) in summer and lower (13.22^{o}C) in winter season. The temperature of tap water in the study area was within the permissible limits as given by BIS.

The BOD of tap water was found to be between 0.69 and 2.26 mg l^{-1} in all the selected educational institutes. Among the seasons, the mean BOD was found higher (1.49 mg l^{-1}) in summer and lower (1.39 mg l^{-1}) in winter season. The BOD of tap water in the study area was within the permissible limits as given by BIS.

The COD of tap water ranged between 56.50 and 119.75 mg l^{-1} in selected educational institutes. Among the seasons, the mean COD was found higher (98.16 mg l^{-1}) in summer and lower (82.50 mg l^{-1}) in winter season. The COD of tap water in the study area was within the permissible limits as given by BIS.

The concentration of As of tap water was found to be 0 mg l^{-1} in selected educational institutes and within the permissible limits as given by BIS.

The concentration of Cd of tap water ranged from 0.000 to 0.001 mg l^{-1} in selected educational institutes. Among the seasons, the mean Cd was found higher (0.001 mg l^{-1}) in summer and lower (0.000 mg l^{-1}) in winter season. The Cd of tap water in the study area was within the permissible limits as given by BIS.

The concentration of Zn of tap water ranged from 0.001 to 0.003 mg l^{-1}in selected educational institutes. Among the seasons, the mean Zn was found higher (0.002 mg l^{-1}) in summer and lower (0.001 mg l^{-1}) in winter season. The Zn of tap water in the study area was within the permissible limits as given by BIS.

The Pb concentration of tap water was in the range of 0.00 to 0.01 mg l^{-1} in selected educational institutes. Among the seasons, the mean Pb was found higher (0.01 mg l^{-1}) in summer and lower (0.00 mg l^{-1}) in winter season. The Pb of tap water in the study area was within the permissible limits as given by BIS.

The concentration of Cu of tap water ranged from 0.00 to 0.02 mg l^{-1} in selected educational institutes. Among the seasons, the mean Cu was found higher (0.01 mg l^{-1}) in summer and lower (0.00 mg l^{-1}) in winter season. The Cu of tap water in the study area was within the permissible limits as given by BIS.

The Fe concentration of tap water ranged from 0.63 to 0.95 mg l^{-1} in selected educational institutes. Among the seasons, the mean Fe was found higher (0.88 mg l^{-1}) in summer and lower (0.75 mg l^{-1}) Fe in winter season. The Fe of tap water in the study area was above the permissible limits as given by BIS.

The Mn concentration of tap water ranged between 0.03 and 0.06 mg l^{-1} in selected educational institutes. Among the seasons, the mean Mn was found higher (0.05 mg l^{-1}) in summer and lower (0.04 mg l^{-1}) Mn in winter season. The Mn of tap water in the study area was within the permissible limits as given by BIS.

The Ni concentration of tap water ranged from 0.00 to 0.02 mg l^{-1}in selected educational institutes. Among the seasons, the mean Ni was found higher (0.02 mg l^{-1}) in summer and lower (0.00 mg l^{-1}) Ni in winter season. The Ni of tap water in the study area was within the permissible limits as given by BIS.

The total coliform of tap water ranged from 20.00 to 54.00 MPN ml^{-1} in selected educational institutes. Among the seasons, the mean total coliform was found higher (41.53 MPN ml^{-1}) in summer and lower (34.11 MPN ml^{-1}) total coliform in winter season. The total coliform of tap water in the study area was within the permissible limits as given by BIS.

The water quality parameters were correlated with each other significantly during winter. The pH was correlated negatively with chemical oxygen demand ($r = -0.86$, $p<0.01$) copper ($r = -0.68$, $p<0.05$) and total coliform ($r = -0.69$, $p<0.05$). The temperature has highly significant positive correlation with nickel ($r =0.87$, $p<0.01$). The biological oxygen demand has significant negative correlation with manganese (r = 0-0.71, $p<0.05$). The Arsenic has highly significant and positive correlation with copper ($r = 0.66$, $p<0.05$). Zinc has highly significant and positive correlation with copper ($r = 0.70$, $p<0.05$) and iron ($r = 0.70$, $p<0.05$).

The water quality parameters were correlated with each other significantly during summer. The pH showed significant positive correlation with electrical conductivity ($r = 0.725$, $p<0.05$) and chemical oxygen demand ($r = 0.686$, $p<0.05$). The biological oxygen demand showed significant and negative correlation with manganese ($r = -0.672$, $p<0.05$) The chemical oxygen demand showed highly significant negative correlation with nickel ($r = -0.83$, $p<0.01$). The arsenic showed significant and negativecorrelation with iron ($r = -0.79$, $p<0.05$). The cadmium showed significant and positive correlation with manganese ($r = 0.77$, $p<0.05$).

5.2 Water quality index (WQI)

The water quality index ranged from 25.80 to 36.38 in selected educational institutes. The WQI for all the selected educational institutes in Solan district categorized as excellent.

CONCLUSIONS

The study revealed that various water quality parameters of tap water in selected educational institutes were found to be within the permissible limits prescribed by BIS and WHO except iron (0.63 to 0.95 mg l^{-1}) which was above the permissible limit. The water quality index in selected schools was found to be excellent.

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APPENDIX- I

1. Seasonal variation of colour of tap water in selected Educational Institutes

Blocks	**Schools**	**Colour**
Solan	Government Senior Secondary School (Girls) Solan	Colourless
	Government Senior Secondary School Oachghat	Colourless
	Government Senior Secondary School Shamror	Colourless
Kandaghat	Government Senior Secondary School Salogra	Colourless
	Government Senior Secondary School Kandaghat	Colourless
	Government Primary School Waknaghat	Colourless
Dharampur	Government Middle School Anhech	Colourless
	DAV School Kumarhatti	Colourless
	Government Senior Secondary School Dharampur	Colourless

APPENDIX-II

2. Seasonal variation of odour of tap water in selected Educational Institutes

Blocks	**Schools**	**Odour**
Solan	Government Senior Secondary School (Girls) Solan	Odourless
	Government Senior Secondary School Oachghat	Odourless
	Government Senior Secondary School Shamror	Odourless
Kandaghat	Government Senior Secondary School Salogra	Odourless
	Government Senior Secondary School Kandaghat	Odourless
	Government Primary School Waknaghat	Odourless
Dharampur	Government Middle School Anhech	Odourless
	DAV School Kumarhatti	Odourless
	Government Senior Secondary School Dharampur	Odourless

APPENDIX-III

3. Seasonal variation of As (mg l^{-1}) of tap water in selected Educational Institutes

Blocks	Schools	Seasons		Mean
		Winter	Summer	
Solan	Government Senior Secondary School (Girls) Solan	0.00	0.01	0.00
	Government Senior Secondary School Oachghat	0.00	0.01	0.00
	Government Senior Secondary School Shamror	0.000.	0.00	0.00
Kandaghat	Government Senior Secondary School Salogra	0.01	0.00	0.00
	Government Senior Secondary School Kandaghat	0.00	0.01	0.00
	Government Primary School Waknaghat	0.01	0.00	0.00
Dharampur	Government Middle School Anhech	0.00	0.00	0.00
	DAV School Kumarhatti	0.00	0.00	0.00
	Government Senior Secondary School Dharampur	0.00	0.01	0.00
	Mean	0.00	0.00	0.00

$CD_{0.05}$

School = N/S
Season = N/S
Schools × Season = N/S

APPENDIX-IV

4. Seasonal variation of pH of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	0.127	0.016	299.670
Seasons	1	0.054	0.054	1,016.692
Schools × Seasons	8	0.068	0.009	161.299
Error	18	0.001	0.000	
Total	35	0.249		

5. Seasonal variation of EC of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	0.217	0.027	27.791
Seasons	1	0.011	0.011	11.307
Schools × Seasons	8	0.056	0.007	7.147
Error	18	0.018	0.001	
Total	35	0.301		

6. Seasonal variation of TDS of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	35,050.167	4,381.271	380.046
Seasons	1	890.299	890.299	77.227
Schools × Seasons	8	8,953.653	1,119.207	97.084
Error	18	207.509	11.528	
Total	35	45,101.628		

7. Seasonal variation of Temperature of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	26.284	3.286	13.951
Seasons	1	1,220.686	1,220.686	5,183.289
Schools × Seasons	8	15.192	1.899	8.064
Error	18	4.239	0.236	
Total	35	1,266.401		

8. Seasonal variation of BOD of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	10.219	1.277	32.679
Seasons	1	0.095	0.095	2.432
Schools × Seasons	8	0.691	0.056	2.211
Error	18	0.704	0.039	
Total	35	11.708		

9. Seasonal variation of COD of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	15,355.500	1,919.438	42.031
Seasons	1	2,209.000	2,209.000	48.372
Schools × Seasons	8	1,309.500	163.688	3.584
Error	18	822.000	45.667	
Total	35	19,696.000		

10. Seasonal variation of Cd of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	0.000	0.000	1.528
Seasons	1	0.000	0.000	13.444
Schools × Seasons	8	0.000	0.000	1.694
Error	18	0.000	0.000	
Total	35	0.000		

11. Seasonal variation of Zn of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	0.000	0.000	10.350
Seasons	1	0.000	0.000	45.000
Schools × Seasons	8	0.000	0.000	0.450
Error	18	0.000	0.000	
Total	35	0.000		

12. Seasonal variation of Pb of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	0.000	0.000	0.977
Seasons	1	0.000	0.000	11.000
Schools × Seasons	8	0.000	0.000	0.977
Error	18	0.001	0.000	
Total	35	0.001		

13. Seasonal variation of Fe of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	0.502	0.063	
Seasons	1	0.144	0.144	
Schools × Seasons	8	0.120	0.015	
Error	18	0.007	0.000	
Total	35	0.773		

14. Seasonal variation of Cu of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	0.001	0.000	17.833
Seasons	1	0.001	0.001	75.000
Schools × Seasons	8	0.000	0.000	6.000
Error	18	0.000	0.000	
Total	35	0.002		

15. Seasonal variation of Mn of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	0.004	0.000	86.627
Seasons	1	0.002	0.002	288.011
Schools × Seasons	8	0.000	0.000	5.624
Error	18	0.000	0.000	
Total	35	0.006		

16. Seasonal variation of Ni of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	0.001	0.000	2.382
Seasons	1	0.001	0.001	25.941
Schools × Seasons	8	0.001	0.000	2.382
Error	18	0.001	0.000	

17. Seasonal variation of Total coliform of tap water in selected Educational Institutes

Source of Variation	DF	Sum of squares	Mean squares	F-calculated
Schools	8	4,481.500	560.188	183.334
Seasons	1	498.778	498.778	163.236
Schools × Seasons	8	1,163.722	145.465	47.607
Error	18	55.000	3.056	
Total	35	6,199.000		

Dr. Y S PARMAR UNIVERSITY OF HORTICULTURE AND FORESTRY
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DEPARTMENT OF ENVIRONMENTAL SCIENCE

Title of thesis	**:**	**Assessment of Water Quality in Educational Institutes in Solan District of Himachal Pradesh**
Name of the student	**:**	Aarti Sharma
Admission Number	**:**	F-2017-12-M
Major Advisor	**:**	Dr. R. K Aggarwal
Major Field	**:**	Environmental Science
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ABSTRACT

The present study entitled **"Assessment of Water Quality in Educational Institutes in Solan District of Himachal Pradesh"** was conducted in the department of Environmental Science, Dr. Y S Parmar University of Horticulture and Forestry, Nauni-Solan. The aim of the study was to assess the water quality in selected educational institutes in Solan district. The study was conducted in Solan, Dharampur and Kandaghat blocks of Solan district Himachal Pradesh during winter and summer seasons. The collected water samples were analyzed for their physical, chemical and biological parameters. The study revealed that the different water quality parameters like pH, EC, colour, odour, TDS, temperature, BOD, COD, heavy metals (Ar, Cd, Zn, Pb, Cu, Mn, Ni) and total coliform ranged from 6.95 to 7.13, 0.24 to 0.51 dS m^{-1}, colourless, odourless, 107.90 to 194.02 mg l^{-1}, 18.31 to 21.21°C, 0.69 to 2.26 mg l^{-1}, 56.50 to 119.75 mg l^{-1}, 0 mg l^{-1}, 0.000 to 0.001 mg l^{-1}, 0.001 to 0.003 mg l^{-1}, 0.00 to 0.01 mg l^{-1}, 0.00 to 0.02 mg l^{-1}, 0.03 to 0.06 mg l^{-1}, 0.00 to 0.02 mg l^{-1} and 20.00 to 54.00 MPN ml^{-1}, which were within the permissible limits whereas, Fe ranged from 0.63 to 0.95 mg l^{-1} was above the permissible limits. The water quality index of tap water for all the selected educational institutes ranged from 25.80 to 36.38 and categorized as excellent.

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Signature of the student
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