IMPACT OF LAND USES ON WATER QUALITY IN BILASPUR DISTRICT OF HIMACHAL PRADESH

Thesis

by

DEEKSHA SHARMA
(F-2018-12-M)

submitted to

1985

Dr. YASHWANT SINGH PARMAR UNIVERSITY
OF HORTICULTURE AND FORESTRY
SOLAN (NAUNI) HP – 173 230 INDIA

in

partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE
(FORESTRY)
ENVIRONMENTAL MANAGEMENT
DEPARTMENT OF ENVIRONMENTAL SCIENCE
COLLEGE OF FORESTRY

2020

Dr MK Brahmi
(Associate Professor)

Department of Environmental Science
College of Forestry
Dr Yashwant Singh Parmar University of Horticulture and Forestry (Nauni) Solan
(HP) – 173230 India

CERTIFICATE-I

This is to certify that the thesis entitled, **“Impact of Land Uses on Water Quality in Bilaspur District of Himachal Pradesh”** submitted in partial fulfillment of the requirements for the award of degree of **Master of Science** (**Forestry**) **Environmental Management** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP)-173230 is a record of bonafide research work carried out by **Ms Deeksha Sharma (F-2018-12-M)** daughter of Shri Ram Lal Sharma under my guidance and supervision and that no part of this thesis has been submitted for any other degree or diploma.

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

Place: Nauni-Solan
Dated:

(Dr MK Brahmi)
Chairman
Advisory Committee

CERTIFICATE-II

This is to certify that the thesis entitled, **"Impact of Land Uses on Water Quality in Bilaspur District of Himachal Pradesh"** submitted by **Ms. Deeksha Sharma (F-2018-12- M)** D/o Shri Ram Lal Sharma to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-173 230, Solan (HP), India in partial fulfillment of the requirements for the award of degree of MSc (Forestry) Environmental Management in the department of Environmental Science has been approved by the Advisory Committee after an oral examination of the student in collaboration with the internal examiner.

27.11.2020
(MK Brahmi)
Chairman

27.11.20
(MS Jangra)
Internal Examiner

27.11.2020
(Anita Kumari)
Dean's Nominee

Member of the Advisory Committee

1. SK Bhardwaj
   Professor & Head
   Department of Environmental Science
   27.11.2020
2. Uday Sharma
   Principal Scientist
   Directorate of Extension Education
   27/11/20

Professor & Head
Department of Environmental Science

Dean
College of Forestry
Dr. YS Parmar University of Horticulture & Forestry
Nauni-173 230, Distt. Solan (H.P.)

ACKNOWLEDGEMENTS

First and foremost, praises and thanks to the supreme power of the universe "God", the almighty, for giving me strength, knowledge, ability and opportunity to undertake this task and to persevere and complete it satisfactorily. Without his showers of blessings, this achievement would not have been possible.

I wish to express my sincere appreciation and regards to chairman of my Advisory committee, Dr MK Brahmi, who convincingly guided and encouraged me to be professional and do the right thing even when the road got tough, without his persistent help, the goal of this research would not have been realized.

I pay my deepest sense of gratitude to the members of my Advisory committee, Dr SK Bhardwaj, Professor and Head, Department of Environmental Science and Dr Uday Sharma, Principal Scientist, Directorate of Extension Education, whose assistance was a milestone in the completion of this work.

I am highly thankful to Head, Department of Environmental Science for providing all necessary facilities to conduct research work. I would like to thank Dr JK Sharma, Mrs Balbir Kaur, Mrs Anita, Mr Amrit Lal and other staff members of the department for providing scrupulous support during my research work.

My special regards to all my teachers because of their teaching at different stages of education has made me able to reach a stage where I could write this manuscript.

I am privileged to have the company of my friends Lalita, Kanchan, Apurva, Munisha, Amita, Niyati, Shivani, Neha and seniors Bindu Thakur and Kavita Rana. I would like to express my sincere thanks to them for their constant encouragement and motivation for stepping ahead.

Satyanand stokes library will always remain a luscious remembrance for furnishing my studies with endless and invaluable information.

Lastly, I am extremely grateful and indebted to my parents Sh. Ram Lal Sharma and Smt. Kiran Bala for their love, prayers, caring and sacrifices for educating and preparing my future. Thanks are also due to my brother Mr Ashutosh Sharma and all other family members for their continuous love and moral support bestowed upon me during the entire study period. I dedicated the thesis to my beloved parents.

Being a social animal no one is perfect, so all errors and omissions are mine.

Place: Nauni, Solan (HP) **(Deeksha Sharma)**

Date:

CONTENTS

ABBREVIATIONS USED

µS cm^{-1}	:	micro Siemen per centimeter
°C	:	degree Celsius
ANOVA	:	Analysis of Variance
APHA	:	American Public Health Association
BIS	:	Bureau of Indian Standards
BOD	:	Biological oxygen demand
C.D.	:	Critical difference
cm	:	Centimetre
COD	:	Chemical oxygen demand
CPCB	:	Central Pollution Control Board
EC	:	Electrical Conductivity
et al.	:	Co-worker
FAO	:	Food and Agriculture Organization of the United States
HP	:	Himachal Pradesh
ICMR	:	Indian Council of Medical Research
Km^2	:	Square kilometre
mg l^{-1}	:	milligram per litre
mg	:	Milligram
ml	:	Millilitre
mm	:	Millimetre
TDS	:	Total Dissolved Solids
NTU	:	Nephelometric Turbidity Unit
pH	:	Hydrogen Ion Activity
RBD	:	Randomized Block Design
USPH	:	United States Public Health
Viz.	:	videlicet (which is)
WHO	:	World Health Organization
WQI	:	Water Quality Index

LIST OF TABLES

LIST OF FIGURES

Chapter-1

INTRODUCTION

Land is a primary, non-renewable and limited natural resource for every human settlement and the nation as a whole. Almost all the activities are associated with this resource in one way or the other. Land use is the use of terrestrial space for residential, economic, conservation and recreational purposes. The human and livestock population determine the land use to a great extent apart from the other factors like stage and pattern of development, type of land, physical features and climatic conditions. The existing land use systems due to their strong influence on how land would be used in future has become a crucial factor in deciding how land development, planning and management activities should be undertaken. Land use pattern of any area has a direct or indirect impact on the water regime and its quality. As we know that water is essential for all forms of life and become a basic source for all the economic activities from agricultural to industrial uses. Water quality plays a crucial role in all aspects of living organisms on earth. It measures use of water for different purposes such as drinking, industrial, agricultural and recreational by considering various parameters *viz.* physical, chemical and biological. Quality of Water changes with respect to sources of pollution, location, time and weather (Giri and Qiu, 2016).

About 71 percent of earth's surface is covered with water but only 3 percent is fresh water and a smaller portion is available for human consumption. In India, availability of surface and ground water is about 1869 cubic km out of which only 60 percent can be used. Due to topographical and hydrological constraints, about 690 cubic km of available surface water can be used for Agriculture (89 per cent), domestic (9 per cent) and industrial (2 per cent). The total utilizable ground water resources are about 432 cubic km out of which 92 percent is used for Agriculture, 3 percent for domestic and 5 percent for Industrial use (NCERT, 2015).

Conversion of land for agriculture and urban development impacts water ecosystem by changing hydrological regimes and increasing pollution and sediment load (Zhang *et al.,* 2010). Any change in the local topography and drainage system directly impaired both quality and quantity of water (Vasanthavigar *et al.*, 2010). Land use impacts water quality of surface and ground water sources through non-point pollution sources, which are difficult to regulate. Due to the human activities and the changes in the land cover pattern, water quality of rivers may degrade (Ngoye and Machiwa, 2004, Sliva and Williams, 2001). Changes in the land cover and land management practices are regarded as the influencing factors for the alteration of hydrological system that leads to the change in runoff and the water quality (Yong and Chen, 2002). Increase in the consumption of water resources for agricultural, urban and industrial needs, has remarkably degraded water sources (Carpenter *et al.,* 1998). The deterioration of ground and surface water quality leads to scarcity of drinking water (Sharda and Sharma, 2013).

It is important to understand the relationship between land use and water quality for judicious water management. Any change in land use causes alteration in water quality and is deteriorated due to rapid urbanization, with intense land use and land cover change and explosive population growth (Arnold and Gibbons, 1996, Chen *et al.,* 2016, Huang *et al.,* 2013). Land use practices are the most important factors which determine the water quality as all the land uses have more or less impact on water quality. Due to poor land use practices water quality is declining day by day. In agriculture, when chemicals like herbicides, insecticides and fertilizers are applied in more quantity than required, these chemicals may runoff into waterways or seep into ground water (Viman *et al.,* 2010). In urban areas, discharge from sewage, domestic waste and industrial effluents results in change in the hydrology and water quality (Mahadev and Gholami, 2010). Forests have strong influence on hydrology and water quality. The characteristics of forest soil aids in filtration of water, contaminant removal and nutrient recycling. Forests, yields higher water quality than agriculture and urban land uses (Foley *et al.,* 2005).

Himachal Pradesh falls in the lap of Himalayas and is situated between 30°22'40" to 33°12'40" N latitude and 75°47'55" to 79°04'22" E longitude with geographical area of 55,673 Km^2. Altitudinally, the state varied from 350 to 7000 meter above mean sea level. The annual average rainfall ranged from 332 to 2606 mm (Balokhra, 2017). Average temperature in summer and winter months varies from 22 to 37°C and 0 to 15°C respectively. The state includes 13 percent agricultural land use, 67 percent legally defined forests, 6 percent non-agricultural land use and 12 percent water bodies. The urban population is continuously increasing and degrading the environment (Project Report, 2009).

Bilaspur is one among the 12 districts of the state. It lies between 31°12'30" to 31°35'45" N latitude and 76°23'45" to 76°55'40" E longitude with an altitude of 560 to 1879 meter above mean sea level covering an area of 1167 Km^2 (Balokhra, 2017). Out of total geographical area of the district, 37 per cent is under legally defined forest, 33 per cent agricultural land use, 11 per cent non-agricultural land use and 8 percent water bodies (Project Report, 2009). More than 70 percent of population is directly or indirectly depends upon agriculture. About 88 per cent of the cultivable land is under dry cultivation. Major sources of irrigation are kuhals, wells and tube wells etc. and more area is being brought under irrigation by exploiting water resource from rivers, khads and nullahs. The important crops grown are maize, wheat, paddy, ginger, sugarcane, barley, gram, kulth etc. Due to mountainous and undulating topography most of the precipitation goes waste as runoff which has resulted in decreasing recharge of ground water (Year Book, 2018).

The land use change has noticed locally, regionally and worldwide over the last few decades and will carry on in the future, as increment in population, urbanization and industrialization has continued. More of land use associated with human activities and economic development in a region are mostly related with high concentration of water pollutants whereas uninfluenced areas like natural forests are associated with good water quality. Assessment of water quality will become important due to the progressive increase in human population, conversion of natural lands to agriculture, urbanization and industrialization which directly or indirectly affected the natural resources resulted in water scarcity and health hazards. Information regarding water quality parameters and its seasonal variation is very important for knowing the suitability of water for various purposes so that various preventive and remedial measures may be undertaken accordingly. Therefore, attention on effective land use planning and water contamination and its quality management are necessary due to its adverse impact on human health. Keeping in view the importance of water quality in relation to land uses the present study “Impact of Land Uses on Water Quality in Bilaspur District of Himachal Pradesh” was undertaken. The data generated on water quality parameters will be useful for efficient management of water resource through land use planning. In addition to this, the data will also be helpful for the Irrigation and public health (IPH) department, Health and family welfare department and other line departments of the state for framing future policy and planning measures to reduce health hazard risks. The objective of the study was as under:

- To assess seasonal variation in quality of surface and ground water sources under dominant land uses.

Chapter-2

REVIEW OF LITERATURE

Burgeoning population and urbanization directly impacted the existing land use pattern of any region. The indiscriminate use of natural sources, heavy inputs and unscientific practices leads to the deterioration of the land use systems. In order to have a clear and in-depth understanding of present investigation entitled "Impact of Land Uses on Water quality in Bilaspur District of Himachal Pradesh", the relevant work done by the various researchers has been reviewed under the following heads:

2.1 IMPACT OF LAND USES ON QUALITY PARAMETERS OF SURFACE AND GROUND WATER SOURCES

- **2.1.1 Urban/peri-urban land use**
- **2.1.2 Agriculture land use**
- **2.1.3 Forest land use**

2.2 IMPACT OF SEASONS ON QUALITY OF SURFACE AND GROUND WATER SOURCES

2.3 ESTIMATION OF WATER QUALITY INDEX (WQI)

2.1 IMPACT OF LAND USES ON QUALITY PARAMETERS OF SURFACE AND GROUND WATER SOURCES

Ding *et al.* (2015) studied the impact of land uses *viz.* Forest, agriculture and urban on water quality of Dongjiang river for dry and rainy season. Water quality parameters showed significant variations between urban and forest dominated sites. The findings indicated that urban land was strongly positively associated with the total nitrogen and ammonia nitrogen, whereas the forested land was positively associated with dissolved oxygen but negatively associated with temperature, electrical conductivity, permanganate index, total phosphorus, total nitrogen, ammonia nitrogen, nitrate nitrogen and chlorophyll-ᶐ. The agriculture land use did not reflect any significant impact on water quality. They concluded that urban land use was the key factor for changing water quality. Pullanikkalil *et al.* (2015) studied impact of land uses on water quality in Linkagala catchment and reported that overall water quality index (WQI) in both wet and dry season from urban and industrial sites was found medium and bad which indicated that water was unsuitable for human consumption without treatment.

Impact of land uses and seasons on surface water quality was studied by Chauhan and Verma (2016) in Solan district, Himachal Pradesh. They reported that pH, EC, Ca, Temperature, BOD and COD was maximum under urban land use and Mg, Cl^- and NO_3 were maximum under agricultural land use. Other parameters like pH, temperature, BOD, COD, Ca, Mg and Cl^- were maximum during summer season and EC and NO_3^- were maximum during Rainy season. According to Land use and season, water quality index (WQI) ranged from 1.0772 to 1.0919 and 1.0757 to 1.0956 respectively which indicated excellent water quality. Rana *et al.* (2016) assessed heavy metals in surface and ground water sources under urban, agriculture and forest land use in mid hills of Himachal Pradesh during summer, winter and rainy season. They found that in surface water As, Cd, Fe and Pb were noticed maximum under urban land use and Zn under forest land use wherein As, Fe, Pb and Zn was recorded maximum during rainy season and Cd during summer season. In ground water metals like As, Fe and Zn was found maximum under Forest land use, Cd in urban land use and Pb in agriculture land use system. The toxic metals such as As, Zn and Pb were recorded maximum during rainy season while Cd was recorded maximum during summer season and Fe during winter season which indicated that land uses do not adversely influence surface and ground water quality.

Chauhan and Bhardwaj (2017) examined the effects of different land use on quality of water in Solan, block of Himachal Pradesh. They reported that parameters such as EC, COD, Ca^{2+}, Cl^- and pH were recorded maximum under institutional land use, whereas BOD and Mg^{2+} was maximum under industrial land use wherein EC, Ca^{2+}, Cl^- were minimum under rural/agricultural land use. In urban/Semi-Urban land use pH and Mg^{2+} was noticed minimum. Shah and Joshi (2017) evaluated water quality index for Sabarmati River in Gujrat (India) by taking six water quality parameters (BOD, EC, pH, dissolved oxygen, nitrate-nitrogen and total coliform). They observed WQI values as 42.71-56.43, 80.75-86.34 and 85.67-95.08 at 1st, 2nd and 3rd station respectively which showed that highly urban area had worst water quality followed by the moderately urban area and lastly moderately rural area. It was concluded that water quality get deteriorated as river flowed from rural to urban area. The relationship between water quality and land use change was studied in Babos-Nautla River (Mexico) by Rodriguez-Romero *et al.* (2018). They found that the upper portion of river with high cover of natural vegetation exhibited best water quality, middle course with excessive agricultural use showed higher concentration of nitrogen and phosphorus and lower course with highest percentage of urbanization and human settlements indicated higher levels of faecal coliform and ammonia nitrogen. Dudley *et al.* (2020) studied the impacts of urban and agricultural land cover on water quality in New Zealand. They reported that the concentration of nitrate, ammonium, total and dissolved reactive phosphorous, water column chlorophyll-a, was greater in estuaries with higher urban cover while the concentration of total phosphorus and turbidity was greater in estuaries with higher agricultural land cover.

2.1.1. Urban/peri-urban land use

Yogendra and Puttaiah (2008) determined water quality index (WQI) of urban water body, Shimoga town, Karnataka and found poor quality of water. The results revealed that low dissolved oxygen, high bio-chemical oxygen demand and high concentration of nitrate indicated the eutrophication of water body and high concentration of chlorides and sulphates indicated the unsuitability of water for domestic use. Pandey *et al.* (2010) assessed heavy metal contamination in Ganga River at Varanasi. A highest concentration of Cd, Cr, Cu, Ni and Pb was recorded during winter season and Zn during summer season. Overall concentration trend of heavy metals was observed as Zn>Ni>Cr>Pb>Cu>Cd. The concentrations of metals were below the permissible limits of Indian standards but Cd and Ni levels were above the admissible limits as per WHO, that may lead to the potential health hazards. Physico-chemical quality of industrial waste effluent of industrial area in Bhiwandi city, Maharashtra, India was studied by Singare *et al.* (2010) and concluded that pollution level was high in city because most of the studied parameter exhibited higher values than the prescribed limit as per USPH Standard.

Quality of surface water sources in Zaria, Nigeria was assessed by Chigor *et al.* (2011). They reported that water quality parameters were higher in stream and river than dam. Hence, these water bodies became hazardous to public health, therefore, proper monitoring and treatment was needed. Jindal and Sharma (2011) examined water quality of Satluj River around Ludhiana at three stations and calculated water quality index (WQI). They noticed that water at station 2 and 3 was unsafe for human consumption. Lokhande *et al.* (2011) investigated pollution in Kasardi River along Taloja industrial area, Mumbai (India). They found that most of heavy metals were higher than prescribed standard limits which had created threat to aquatic ecosystem and may enter through biomagnification into the food chain. Khwakaram *et al.* (2012) studied water quality of Qalyasan stream at Sulaimani City, Kurdistan Region of Iraq. They reported good water quality (50-100) at 1st , 2nd, 3rd and 4th site and unsuitable (>300) at 5th, 6th, 7th, 8th, 9th, and 10th site which indicated heavy pollution load due to rapid urbanization and industrialization of the city.

Water Quality Index of different zones in Chandrapur city, India was studied by Ansari and Hemke (2013). The study revealed that ground water quality of most of zones was not suitable for drinking purpose**.** Gangwar *et al.* (2013) conducted a pollution study in Ramganga at Bareilly, Uttar Pradesh (India). They reported that water was unsuitable for drinking purpose due to the discharge of domestic and industrial effluents, anthropogenic activities and lack of proper sanitation. Water quality of Swan River in Himachal Pradesh was evaluated by Sharda and Sharma (2013) and found that parameter, bio-chemical oxygen demand (BOD) and dissolved oxygen (DO) exceeded the prescribed permissible limits, thereby depicting the deterioration of water quality. This was due to lack of proper sanitation, discharge of untreated waste water and municipal solid waste into river. Kanakiya *et al.* (2014) determined water quality Index for Urban Dal Lake, Kashmir, India. They found WQI >100 which indicated that water is unsuitable for drinking purpose. Ohwo and Abotutu (2014) assessed the quality and quantity of potable water supply in Yenagoa and found that the quantity as well as quality of water supply was inadequate. Values for pH were higher than permissible limits (<6.5). Madhsudhan and Inayathulla (2015) assessed groundwater quality of Bidadi Industrial area, Bangalore, Karnataka (India). Water quality index was recorded 113.9 which indicated poor quality of water.

Nayak and Patil (2016) assessed water quality of Godavari in Nasik, India. They reported water quality as good, bad and very bad at three stretches and concluded that sewage was the main reason of pollution as the sewage treatment facilities were inadequate in the region. Aladimy *et al.* (2017) investigated groundwater quality of Aurangabad city, Maharashtra, India. The study revealed that water samples registered higher values of EC, sodium, dissolved oxygen, total hardness, total alkalinity which exceeded the standards limits given by BIS, WHO, ICMR. This indicated water pollution which was due to municipal sewage, man-made activities and lacking to protect groundwater sources. Mathuram *et al.* (2017) studied physico-chemical characteristics of Vaigai River near Madurai city, Tamil Nadu, India. The results indicated good water quality in upper and middle part of watershed and critical at the downstream of the city because of the impact of discharge of urban wastewater into the river. Dutta and Sarma (2018) assessed correlation and regression of groundwater quality in Nagaon Town, Assam (India). They studied physical, biological and chemical parameters such as iron, fluoride, nitrate, manganese, pH, alkalinity, turbidity, total hardness, chloride, magnesium hardness, calcium hardness and bacteria test. The study revealed relationship between variables that one variable actually caused change in other variable. The results were compared with BIS standards which revealed that most of the water samples were safe for drinking. Water quality trend of Mega city Jakarta, Indonesia was studied by Luo *et al.* (2019). They concluded that the concentration of BOD and TSS was decreased while the concentration of DO increased over time which was due to the rapid urbanization, population growth and lack of sewerage facilities. Olasoji *et al.* (2019) evaluated water quality of water sources and treatment plants of Peri-Urban town in Southwest region of Nigeria. The results reflected that most of physico-chemical parameters were within the permissible limits as per WHO and 86 per cent samples had excellent water quality. All the samples found positive for the presence of faecal coliform and *E. coli* which showed that only 7 per cent samples had excellent water quality and was unsafe for consumption without treatment. Cerqueria *et al.* (2020) studied the impact of urbanization on water quality in Cachoeira River, northeastern Brazil. They reported that NO_3^-, NO_2^-, NH_4^+ and PO_3^{3-} had higher concentrations at the site having highest population density and highest percent of urban area. They concluded that urbanization had negative impact on water quality because it altered the concentration of dissolved inorganic nutrients in the river. Toscano *et al.* (2020) assessed groundwater quality in the urban area of Zamora, Egypt. They reported excellent water quality at 7 locations and good at 3 locations which showed that water was suitable for drinking purpose according to the Mexican and international regulations.

2.1.2. Agriculture land use

Kolpin *et al.* (1999) studied nitrate in groundwater in Midwestern Unites States. They found that nitrate concentration was directly related to the amount of irrigated land. Bishnoi and Arora (2007) studied potable ground water quality in rural areas of Rohtak (Haryana), India. They revealed that fluoride concentration varied from 0.034-2.09 mg l^{-1} which was above the WHO Standard and water was unfit for drinking purpose. Burkholder *et al.* (2007) studied the impact of waste from agricultural livestock operations on water quality. They reported that the growth of concentrated animal feeding operations (CAFOs) had greater risk to water quality and emphasized to promote the best practices that minimize the input of toxicants and nutrients in the freshwater and marine ecosystems. Hoorman *et al.* (2008) studied the impacts of agriculture and concentrated livestock operations on lake and stream water quality in Grant Lake, St. Marys (Western Ohio). The results revealed that NH_4^+ and P concentration was recorded maximum whereas NO_3^- and DO minimum during summer season. The strong linear relationship ($r^2=0.81$; $p<0.01$) between UV absorption and P concentration showed major contribution of P concentration to the degradation of water quality which was mainly attributed to the land disposal manures from the feeding operation and direct deposition by the grazing animals. Nikolaidis *et al.* (2008) studied the impact of intensive agricultural practices on drinking water in Evros region, northern Greece. The study revealed high values of $NO3^-$, SO_4^{2-} and PO_4^{-3} than the permissible values and lower values of NO_2^- and NH_4^+ which were within permitted range. They concluded that drinking water found polluted which was attributed to the excessive use of the fertilizers from the agricultural sources. Water quality index of groundwater in Tumkur Taluk in Karnataka, India was assessed by Ramakrishanaiah *et al.* (2009). They found that WQI ranged from 89.21-660.56 due to higher concentration of iron, total dissolved solids, manganese, bicarbonate, fluoride, nitrate and hardness thereby recommended treatment of groundwater before its consumption and protection from any type of contamination.

Ghosh *et al.* (2013) assessed water quality of pond and ground water at Sirsakala village, Bhilai-3, Chhattisgarh, India. They reported high concentration of pollutants in some of the samples as prescribed by ICMR and BIS. These water samples were not suitable for drinking, bathing and domestic purpose and sources were needed to be protected from contamination and water treatment must be done before consumption. Tareen *et al.* (2014) evaluated heavy metals in drinking water of Pishin District, Balochistan (Pakistan) and revealed that lead and arsenic concentration was found within the permissible limits wherein pH, conductivity, antimony and aluminium was recorded higher than the standards values. This was happen due to the use of chemical fertilizers, insect repellents and population burden. Paul *et al.* (2015) studied water quality index of groundwater in kothamangalam Taluk, Kerala, India and reported the value of WQI ranged from 26 to 315. There was presence of higher amount of iron which made water unsuitable for drinking purpose. Agnieszka *et al.* (2016) studied the impact of agriculture on nitrogen contamination in surface and ground water in central-west Poland. High concentration of nitrogen was found in the areas with high level of nitrogen application. Severe shortage of phosphorous and potassium in applied fertilizers caused the leaching of nitrogen due to the limited consumption by plants. Khatri *et al.* (2016) assessed drinking water quality in rural areas of Harij Taluk, Patan (Gujrat). The samples were analysed for parameters such as TDS, fluoride, dissolved oxygen, magnesium, hardness and chloride and found higher values in some of the sample but falls within the tolerance limit hence water quality was good for the human use. Ramesh and Pavithra (2016) studied water quality of Rasipuram Taluk in Namakkal, Tamil Nadu. They reported that WQI was ranged from 37.34 to 650, which was found in the category of poor to very poor quality. The value of SAR, Na per cent, and RSC indicated that water was suitable for irrigation purposes and suggested that government should initiate the remedial measure for proper water management. Impact of polluted water on agriculture land in Aurangabad was studied by Shinde *et al.* (2016) and found that sodium, calcium, magnesium, nitrate and chloride registered higher concentration which indicated the influence of domestic and industrial effluent on groundwater and river in the village. Bharathi *et al.* (2017) assessed groundwater quality of samples collected from 18 villages in kariapatti, Virudhunagar, Tamil Nadu. The result showed that most of the parameters were exceeding the permissible limits as suggested by BIS. WQI found to be fall in poor to very poor category which showed that water was unsafe for drinking purpose and needed attention for the purification of water. Kamboj *et al.* (2017) studied WQI of rural areas of Haridwar (India). The physico-chemical analysis showed that all the parameters were found below the permissible limit as defined by WHO and BIS except for Ca^{2+} and Mn^{2+}. Water quality index of all sites were found within excellent category ($WQI<50$) indicated that water is suitable for drinking and irrigation purposes. Mendivil-Garcia *et al.* (2020) studied the impact of intensive agriculture on Culiacan river (Mexico). The results showed that TN values were low and TP values were high in the river basin and they suggested that intensive agricultural practices accelerated the loss of soil consolidation which then transported to the water bodies. The soils were in contact with fertilizers and pesticides which had transported by underground flow and runoff.

2.1.3. Forest land use

According to Foster and Chilton (1993) forest cover influenced groundwater table, water levels in wells and springs and also safeguarding water quality. Hamilton *et al.* (2005) reported that forest was the best land cover for maximizing the water yield, regulating seasonal flow and ensuring high water quality. Islam *et al.* (2014) studied physico-chemical properties of Deepor Beel (Ramsar site) a natural permanent wetland. They found high turbidity (12.6 NTU), low DO (1.4 mg/l) and high range of TDS (150 -725 mg/l) and some parameters were within permissible limits which indicated that water was unsuitable for drinking purpose. Some sites of wetland were contaminated and required quick action to improve the health of the wetland. Akbarimehr *et al.* (2016) studied the changes in chemistry of stream water *w.r.t.* logging practices of Darabkola forest, Iran. The study revealed that PO_4^{3-} and NO_3^- concentrations from logging treatment showed significantly higher concentrations ($p<0.05$) and NO_3^- concentration was significantly correlated with the stocking volume ($R=0.738$). They concluded that logging resulted in impairing water quality with decreasing tree uptake and increased litter deposition and suggested that longer time was needed to monitor the recovery of stream water quality from felling. Kandler *et al.* (2016) studied land use impact on water quality in Upper Nisa Catchment in Czech Republic and Germany. They revealed that portions of arable land and settlement area affected the water quality whereas forest area (>70%) showed less concentration of all parameters. Low water quality was noticed in densely populated areas even with high proportion of forest. Jana *et al.* (2017) studied the impact of forest and sacred groove on quality and quantity of water in Garhwal Himalaya, India. They reported that the values of different parameters in samples were found within the permissible limits as prescribed by WHO. The water discharge from oak forest (*Quercus leucotrichophora*) showed more consistency than deodar forest (*Cedrus deodara*). The pH of most samples was alkaline but the samples from coniferous forest dominated by deodar were acidic due to the presence of needles which add rich organic matter. Jana and Todaria (2017) investigated status of water quality in sacred grooves of Garhwal Himalaya (India). They reported that all the parameters *viz.* pH, hardness, alkalinity, nitrate, chloride was within the defined standards of WHO, thereby water was safe for various domestic purposes.

Water quality in Loktak Lake, Ramsar Site in Indo-Burma biodiversity hotspot was studied by Kangabam and Govindaraju (2017). They reported that WQI in lake varied from 64 to 77 whereas in river from 53 to 95 which indicated poor water quality. WQI of river water was higher than lake which showed that river was a major source of pollution in the lake. They suggested that long-term monitoring of Lake Ecosystem and identification of pollution for its proper management is needed. Zongo *et al.* (2017) studied water quality in protected forest areas and surrounding villages of Burkina Forest, Western Africa. They observed that water surface area, depth, nutrient content and algae biomass was significantly higher in the outside reserves than the inside reserves while macrophyte cover and water transparency was found higher inside the reserves. They reported that forests and land cover had prevented the negative human impacts on ponds. Zhu *et al.* (2018) compared water quality of Hun river (Northeast China) for different forests types i.e. secondary forests (SF) and *Pinus koraiensis* plantations (KP). They observed that physical properties declined after flowing through the catchments and the pH of the runoff was also decreased. The concentration of Cl^-, NO_3 and NH_4 in the runoff was found similar in both the catchments whereas total phosphorus concentration in runoff from SF catchment was higher than the KP catchment, which attributed to the presence of litter and more phosphorus in soil of the SF catchment. According to Ouyang *et al.* (2019) forest land slightly increased the water recharge from the land surface into the ground water while studying the forest of lower Mississippi river, USA. Neto *et al.* (2020) assessed water quality in the tropical forest. They found that Al^{3+}, Fe, N, NO_3^-, NO_2^-, P, PO_4^{3-} and pH was found to be 0.01-4.20, 0.01-4.50, 0.00-5.20, 0.00-15.50, 0.01-2.50, 0.00-2.22, 0.00-6.80 and 4.30-6.80 mgl^{-1} respectively which revealed that water quality was directly related to the state of conservation of forest. Rosli *et al.* (2020) studied water quality under different canopy cover of Tropical River in Malaysia. They reported that physico-chemical properties varied in disturbed to undisturbed forest ($p<0.05$) which was higher in the disturbed forest. The sensitivity of water quality toward the changes like extensive land management and natural ecosystem disturbance was noticed.

2.2. IMPACT OF SEASONS ON QUALITY OF SURFACE AND GROUND WATER SOURCES

Seasonal variation in quality of cross river, Nigeria was studied by Akpan and Offem (1993) and seasonal variations was found to be significant for temperature, salinity, dissolved oxygen, biological oxygen demand, ammonium, nitrate, phosphate and silicate and non-significant for transparency and pH. Water temperature during wet and dry season was found to be 21 and 31°C respectively. Khaiwal *et al.* (2003) studied seasonal variations in physico-chemical characteristics of Yamuna River in Haryana. They reported high levels of chloride and low levels of DO in river water and stated that water was unsuitable for domestic use. Seasonal variation of ground water in Guntur, Andhra Pradesh was studied by Rao (2006) and found that samples were unfit for drinking as well as irrigation during post-monsoon as compared to pre-monsoon season. Alam *et al.* (2007) analyzed quality of rivers in Surma Basin, Bangladesh during dry and monsoon periods. They found turbidity of river was high in monsoon season while BOD and fecal coliform was higher in dry season. Water quality index of river Ganga in Haridwar, Uttarakhand was studied by Joshi *et al.* (2009) by analyzing physico-chemical properties of water for summer, rainy and winter season. They concluded that pH, EC, TDS, TSS, turbidity and Na were found above the prescribed limits. The water quality index indicated that water was not suitable for drinking purpose. Pereira *et al.* (2009) studied seasonal variation of water quality in coastal lagoon, Portugal. The study revealed that nutrients were inversely correlated to salinity during autumn/winter which showed that freshwater was enriched with nitrogen and phosphorous wherein concentration of dissolved oxygen was less during night in warmer period. Reza and Singh (2010) assessed water quality index of ground water in Orissa and reported that WQI was ranged from 14 to 57 and

19 to 67 during summer and post-monsoon season respectively which showed the quality of water excellent to poor. Trivedi *et al.* (2010) studied seasonal variation in physico-chemical characteristics of water in Kanpur, India. They revealed that different parameters of water were recorded in higher limits in all the seasons except for pH during summer, total alkalinity and Fe during spring, winter and autumn and total dissolved solids during winter. The results showed that that Ganga water was better in monsoon than winter while ground water was better in winter than summer season. Rajankar *et al.* (2011) computed water quality index at Bhandara District, Maharashtra, India. The index was found to be 68 to 83 and 56 to 76 during pre-monsoon and post-monsoon season respectively. The study revealed that only 19 per cent locations were suitable for drinking purpose and other locations need proper treatment before use. Water quality of Malav Lake was evaluated by Solanki *et al.* (2011) in 2008-09. They found maximum EC during monsoon as water was free from aquatic vegetation and cover thereby the ions were accumulated in water whereas low oxygen level during summer, which was due to the removal of free oxygen through respiration by bacteria and other animals and oxygen demand for the decomposition of the organic matter. Tareq *et al.* (2013) studied seasonal variations in Ganga and Brahmaputra River, Bangladesh. The results showed good water quality in pre-monsoon. The seasonal pollution was recorded in the order as: monsoon>post-monsoon>pre-monsoon. The critical water quality in monsoon season was due to the terrestrial runoff and waste water in densely populated catchments. Machender *et al.* (2014) investigated hydro-geochemical characteristics of water in Chinnaeru River basin, Andhra Pradesh, India. They reported that ground water samples registered higher values of pH (7.36-8.33) in monsoon than post-monsoon season (7.15-8-1). Seasonal variation and WQI of water treatment plants in Delhi was studied by Saxena *et al.* (2014). The results indicated that most of the parameters exceeded during winter season as compared to the other seasons. Excellent water quality was noticed in monsoon and very poor in winter season. They emphasized that water treatments such as boiling, filtration and reverse osmosis should be applied before use for drinking.

Singh and Kamal (2014) assessed water quality of Surface water in Goa and reported that WQI ranged from 34 to 107. The highest value was recorded during monsoon season and lowest during post-monsoon season. Most of the samples were found in the category of good to moderate. Batabyal and Chakraborty (2015) assessed hydro-geochemistry of groundwater in Kanksa-Panagarh area, Bardhaman, West Bengal. They noticed good water in pre-monsoon and poor in post-monsoon season and major ions were found in the fashion as:

HCO_3>Ca>Na>Mg>Cl>SO_4 and HCO_3>Ca>Mg >Na>Cl>SO_4 during pre-monsoon and post-monsoon respectively. Pathak *et al*. (2015) calculated the Water quality index of Bhagirathi River for three seasons namely winter, summer and rainy season. They reported good water quality in winter and summer whereas poor in rainy season. Qureshimatva *et al.* (2015) studied WQI of Chandola Lake, Ahmedabad, Gujrat, India. They revealed that index values 120.8704, 93.0917 and 121.9263 were recorded during monsoon, winter and summer season and concluded that water during summer and monsoon season was unfit for drinking purpose. Sharma *et al.* (2015) conducted a study to investigate the seasonal variation in physico-chemical parameters in water of Tawi River, Rajouri, Jammu and Kashmir, India. They reported that temperature, transparency, phosphate, FCO_2, bicarbonate were noticed maximum during summer whereas sulphate during monsoon, DO during winter. Minimum values were recorded for DO, Cl^- during summer, transparency during monsoon and temperature, sulphate and phosphate during winter. To protect and restore the ecology of river, proper management and regulation of anthropogenic activities were suggested. Aladimy *et al.* (2016) studied water quality of Salim Ali Lake in Aurangabad, Maharashtra, India during winter season. They studied different physico-chemical parameters namely temperature, pH, BOD, COD, DO, Total hardness, Sodium ions (Na^+), Calcium ions (Ca^{2+}), TDS, TSS etc. and recorded values were compared with the prescribed standard limits. They summarized that water quality was degraded due to the domestic sewage which made it unfit for human consumption. Hydrochemistry of fresh water in Hospet city, Karnataka, India was studied by Mallanagoud *et al.* (2016). They reported WQI values ranged between 34.80 - 36.26, 38.52-48.67 and 55.05-84.94 during monsoon, winter and summer season, respectively which indicated medium water quality during summer and winter season except monsoon season.

Maurya (2016) analyzed physico-chemical parameters of Suraila Taal during winter season. It was observed that pH, total dissolved solids, magnesium, calcium, alkalinity, dissolved oxygen and total hardness values exceeded the limits as recommended by BIS and EC, nitrate, chloride and BOD were found within the permissible limits. The WQI indicated poor water quality which was due to high level of pollutants hence made it unfit for human consumption. Maurya and Singh (2016) studied physico-chemical parameters of Suralia Taal during summer season. They reported that pH, total dissolved solids, total hardness, alkalinity, calcium, magnesium and dissolved oxygen exceeded the limits as recommended by Indian standards and EC, chloride, nitrate and BOD were less than the limits and WQI indicated the poor water quality and recommended unsafe for use. Pawar *et al.* (2016) determined water quality index of Khokad Talav at Chandwad, Maharashtra. They reported WQI values 197.4, 160.9 and 90.09 during rainy whereas 128.4, 99.73 and 80.85 during winter season. The index indicated poor quality of water and unfit for consumption. Pollution load was noticed more in rainy season than in winter season. Taskeena *et al.* (2017) assessed seasonal variation in physico-chemical parameters of water in Yamuna River, India. They found alkalinity, BOD, COD, temperature, EC and TDS were maximum during summer, pH and DO during winter whereas COD and BOD was minimum during rainy season, pH and DO during summer season and temperature, EC, TDS and alkalinity during winter season. Most of the parameters exceeded the permissible limits for drinking purpose and within permissible limits for irrigation use, as recommended by WHO and ISI. Tiwari *et al.* (2017) analyzed physico-chemical quality of hydrosphere water of Deosar block, Singrauli, Madhya Pradesh. They reported WQI was maximum during post-monsoon and minimum during monsoon period whereas it was found overall high. Index value indicated poor water quality. Paul *et al.* (2018) evaluated the water quality index of Kuroorthodu River in Kerala (India). WQI was found to be ranged from 8.6 to 190.9 and 15.3 to 103.8 during monsoon and post-monsoon season respectively. Rout and Setia (2018) studied suitability of ground water for industrial use at Nalagarah and Baddi. Samples collected during post-monsoon and pre-monsoon season and found corrosivity ratio ranged between 0.201-1.587 and 0.263.1.543 at Nalagarh and Baddi indicated suitability for industrial use. Saini and Dube (2018) investigated quality of Narmada River in Jabalpur, MP, India and found that BOD was maximum during summer season and low during rainy season similarly COD was maximum in summer season which was due to human activities, discharge of effluents into the river. Chen *et al.* (2019) studied the concentration and health risk of heavy metals of Taizihe River in China. The results of the investigation showed that average concentration of different elements was found in the order of Pb>Cr>Cu>Zn>Cd and the concentration of Zn and Cu was significantly higher in wet season than dry season while the average concentration of Pb, Cr and Cd was similar in both the seasons.

Sudarshan *et al.* (2019) assessed water quality of Hebbal Lake, Bangalore, India. The results revealed that samples at station S1 recorded higher water quality index (>100) thereby fall under unsuitable category for all seasons. At station S2 index was found as very poor (75<WQI<100) in monsoon and unsuitable in post-monsoon and summer season. WQI at station S3 was obtained under very poor category in post-monsoon and summer and poor category (50<WQI<75) during monsoon season. Station S4 represented poor category in summer and very poor in monsoon and post-monsoon season. The highest value for WQI was recorded at station S1 in post-monsoon season and lowest at station S4 in summer season whereas overall water quality was found very poor. Xu *et al.* (2019) studied seasonal changes in Dan River basin, China and reported that nitrate- nitrogen (NO_3-N) concentration was lower during summer and total phosphorus during spring season. The contribution of land use to water quality was increased from spring to winter. They suggested that seasonal variations of water quality must be taken into consideration for the effective water management. Seasonal variation of drinking water in Hancheng City (China) was studied by Ji *et al.* (2020). They assessed pH, total Hardness, TDS, Cl^-, SO_4^{2-}, F^-, NH_4-N, NO_3-N, Cr^{6+}, As, Hg and Mn. The results showed that the order of average non-carcinogenic risk values of chlorinated and terminal tap water was observed as: $F^- > As > NO_3\text{-}N > Cr^{6+}$ and $F^- > NO_3\text{-}N > Cr^{6+} > As$ during dry and wet season, respectively.

2.3 ESTIMATION OF WATER QUALITY INDEX (WQI)

Kumar and Dua (2009) assessed water quality of Ravi river at Madhopur, Punjab, India through WQI technique. They used eight most important parameters viz. pH, TDS, Total Hardness, Ca, Mg, total alkalinity, Dissolved oxygen, EC for the calculation of water quality index. They found WQI value ranged from 54.8-97.88. They found that the parameter which required the least amount contributed to high statistical value of index and concluded that indices were most efficient method to give information on water quality trends to the public or policy makers and water quality management.

Al-hadithi (2012) used water quality index for the assessment of suitability of groundwater quality for drinking purpose in Ratmao-Pathri Rao watershed of Haridwar district, India. He used nine parameters for the computation of WQI as total hardness, pH, magnesium, calcium, chloride, bicarbonate, nitrate, chloride, sulphate and total dissolved solids. WQI was found high which was due to the higher values of TDS, Ca^{+2}, K^+, Cl^-, HCO_3^-, NO_3^{2-} and SO_4^{2-} and high correlation coefficient was noticed between them. Boah *et al.* (2015) computed water quality index of Vea Dam in Ghana. They used weighted arithmetic mean method on the basis of ten physico-chemical parameters *viz.* EC, pH, Total dissolved solid, Total Hardness, Chlorides, Nitrates, Calcium, Dissolved Oxygen and BOD for index calculation. The WQI was found 54.21 which indicated poor water quality. Elshemy (2016) studied water quality of Manzala Lake, Egypt. He used two water quality indices i.e. L-WQI and NSF-WQI on the basis of water quality data. He concluded that according to L-WQI indices, water quality exhibited critical and bad situation at southern and eastern zones. Both the indices showed worst status of water quality in August, 2011. It was reported that L-WQI was a representative tool for the assessment of water quality for lagoons but NSF-WQI was a general tool and could not be used for lagoons as it could lead to false evaluation. Oni and Fasakin (2016) used water quality index (WQI) method for the determination of portability of surface and groundwater in Nigeria. They compared recorded values of physico-chemical and biological parameters with standard values. The analysis through WQI method showed poor water quality due to high content of lead. They concluded that WQI method was effective tool for the determination of water quality and could be communicated to stakeholders in water industry. Abdel-Satar *et al.* (2017) studied indices of water quality in Nile River (Egypt). They computed heavy metal pollution Index (HPI), Contamination Index (C_d) and Water Quality Index (WQI). The results showed that aquatic WQI was found to be poor to marginal and drinking WQI from marginal to good as per WHO and Egyptian drinking water quality standards (EWQS). Anthropogenic sites showed high HPI and C_d, which indicated that water was not suitable for aquatic life.

Al-Mansori (2017) developed water quality index of Shatt-Al-Hilla River. He used seven parameters namely EC, pH, total hardness, total dissolved solids, Calcium, Chloride and sulphate. He used Visual Basic application program for the evaluation of WQI and was considered as the fast and good tool. The results showed that WQI ranged from 45.789 to 37.234 and graded as good. Bola *et al.* (2017) evaluated WQI of Gostami Velpur stream, a tributary of Godavari River on the basis of 11 parameters *viz.* EC, pH, dissolved solids, alkalinity, hardness, calcium, magnesium, chlorides, nitrate, dissolved oxygen and BOD. They used Brown WQI method for the evaluation of overall WQI. The results showed that physico-chemical parameters were higher than the permissible limit correspondingly WQI was higher means water was unsuitable for drinking. They recommended constant monitoring to maintain water quality. Water quality index by weighted arithmetic water quality index model was studied by Chandra *et al.* (2017) in Vijayawada and Krishna district of Andhra Pradesh in pre and post monsoon period during 2014. Water quality index was estimated with the help of various physico-chemical parameters viz. total dissolved solids, pH, Cl, SO_4, Na, K, Mg, Ca and total hardness. They concluded that pollution in post-monsoon was more than pre-monsoon in the study area. Sarma *et al.* (2017) analysed water quality index of Kolong River, Assam (India). They used various water quality parameters (Turbidity, pH, Hardness, Fluoride, Chloride, Nitrate, Manganese, iron and bacteria) for the calculation of WQI by arithmetic index method. The results showed that WQI ranged from 134.64 to 565.58 which fall in the category of unsuitable for drinking, therefore, water body needed proper treatment. Bansal and Dwivedi (2018) assessed ground water quality with the help of water quality index method. They used ten physico-chemical parameters namely, EC, pH, TDS, total hardness, COD, turbidity, total alkalinity, Chloride and sulphate. They used Canadian water quality index (CWQI) method that was predicted on three attributes of water quality which relate to water quality objectives (Scope, Frequency and Amplitude). The results showed that water quality parameters were slightly higher in the wet season than in summer season and suggested periodical evaluation of water quality parameters. Kumar *et al.* (2018) studied WQI of Yamuna River on the basis of secondary data. They categorized WQI into four categories and the results showed that 25, 42, 32 and 1 per cent samples were found in very bad, bad, medium and good categories, respectively. Shirodhkar (2019) determined water quality index of Kali River, Karnataka on the basis of various physical, chemical and biological parameters. The observed values were compared with the standards of WHO and BIS. The results showed that WQI of samples was ranged between 19.3 to 104.14 per cent. WQI of 66.67 per cent samples was found excellent, 16.67 per cent good and 16.66 per cent in very poor category.

Water quality index of groundwater in Aundha Nagnath Town (Maharashtra) was computed by Wagh *et al.* (2019) on the basis of standards values as per BIS. The WQI result showed that 42.86 and 28.57 % of samples were found under poor category during post and pre-monsoon season and 7.14 and 14.29 % of samples were found under excellent category during post and pre-monsoon season which depicted poor to excellent water quality during both the seasons. Nihalani and Meeruty (2020) computed water quality index of major rivers in Gujrat. They used weighted arithmetic water quality index method by using pH, EC, DO, BOD, nitrate nitrogen and total coliform parameters for its computation. The results indicated that WQI value was found to be 30-50, 42-65, 28-52 and 35-70 for Mahi, Sabarmati, Narmada and Tapi rivers respectively which were found under the category of good to poor quality. The poor water quality was attributed to the discharge of sewage, industrial effluent and urban runoff.

Chapter-3

MATERIALS AND METHODS

The present study entitled “Impact of Land Uses on Water Quality in Bilaspur District of Himachal Pradesh” was conducted during the period 2019-2020 and the analysis work was performed in the laboratory of Department of Environmental Science, College of Forestry, Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP). The description of materials and methods adopted during study has been discussed in this chapter.

3.1 DESCRIPTION OF THE STUDY AREA

3.1.1 Location

The study was conducted in Bilaspur district of Himachal Pradesh. The study area lies between 31°12'30" to 31°35'45" N latitude and 76°23'45" to 76°55'40" E longitude in the inner shiwalik and outer hills of Himalaya with an altitude of 560 to 1879 meter above mean sea level covering an area of 1167 Km^2. The district is divided into four development blocks namely Bilaspur Sadar, Ghumarwin, Jhandutta and Shri Naina Devi ji. Satluj is the main river flowing through the district and formed Govindsagar Lake due to Bhakhra - Nangal dam. The major natural resources of this district are forests, minerals (gold pyrites, sand stone, lime stone, quartzite etc.) and water sources both surface and ground. The surface water sources include stream, river, pond, khad, nalla etc. and ground water sources include natural spring (chasma), bowrie, hand pump, dug well etc..

3.1.2 Climate and Soil

Bilaspur district falls in the Humid Sub-Tropical Zone and experiences four seasons namely the summer (March to June), the southwest monsoon (June to September), the post-monsoon (October and November) and the winter (December to February). Summers are hot and humid and winters are cold. The average temperature usually ranges from 22 to 38°C in summer season and 5 to 22°C in winter season. About 81.5 percent rainfall is received during monsoon season and the average rainfall is about 1373 mm. The soils of this district are sandy, non-calcic brown soils and the texture is sandy to loam and it also contains calcium carbonates.

3.2 SITE SELECTION

A preliminary survey of the district Bilaspur was conducted, then the sites representing particular dominant land use *viz.* Urban/Peri-Urban, Agriculture and Forest were selected randomly for the study.

Urban: Urban land is comprised of areas of intensive use with land covered by structures. This category includes cities, towns, industrial and commercial complexes (James *et al.,* 1976).

Peri-urban: Peri-urban area is a transition zone where urban and rural activities are connected and landscape features are subject to rapid modifications, including by human activities (Douglas, 2006).

Agriculture: Ecosystem modified or created by man for the production and consumption of biological products. This includes cropland, pasture, vineyards, nurseries, ornamental horticultural areas etc. (James *et al.,* 1976).

Forest: Forests land have tree-crown with aeral density of 10 percent or more, are stocked with the trees capable to produce timber and other wood products and exert an influence on climate and water regime (James *et al.,* 1976).

The details of selected sites are given in Table 3.1.

Table 3.1: List of selected sites under dominant land uses

Land Use	Selected Sites	Latitude (N)	Longitude (E)	Altitude (m)
Urban/ Peri- Urban	Bilaspur Sadar	31°20'23"N	76°45'50"E	619 m
	Ghumarwin	31°27'1"N	76°42'9"E	667 m
	Jhandutta	31°22'15"N	76°38'35"E	712 m
Agriculture	Dabla	31°28'32"N	76°42'12"E	662 m
	Jabloo	31°20'12"N	76°39'52"E	561 m
	Luhnu	31°32'30"N	76°43'24"E	699 m
Forest	Jangal Baner	31°13'59"N	76°45'16"E	703 m
	Reserved Forest Ghumarwin	31°25'27"N	76°41'23"E	609 m
	Jangal Tiun Khas	31°28'59"N	76°44'10"E	895 m

3.3 TREATMENT DETAILS:

Dominant land use = 3

1. Urban/Peri-Urban
2. Agriculture
3. Forest

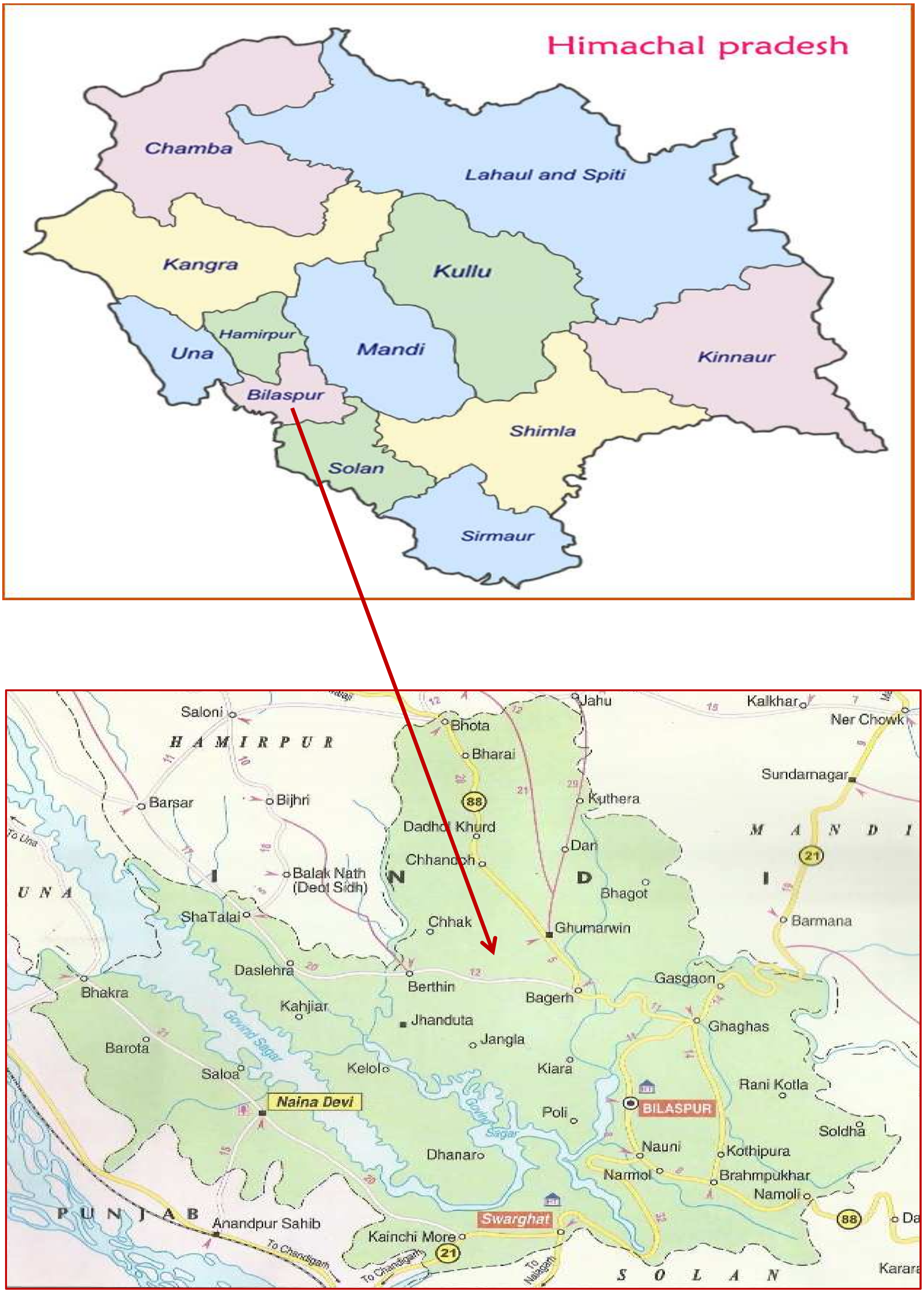

Fig. 3.1: Map showing Study Area

Water Sources = 2

1. Surface Water
2. Ground Water

Seasons = 2

1. Winter season
2. Monsoon season

Treatment combinations: 3 (Land use) × 2 (Water Sources) × 2 (Seasons) = **12**

Replications - 3

Design - Randomized Block Design (RBD) Factorial

3.4 WATER SAMPLE COLLECTION AND PREPARATION

The surface and ground water samples from dominant land use i.e. Urban/Peri-Urban, Agriculture and Forest were collected in two seasons namely winter and monsoon season with three replications during 2019-2020. Surface water were collected from rivers, khads, nallas or other tributaries and ground water samples were collected from hand pumps, natural springs, bowries and dug wells. The colour, odour and temperature were determined at the sampling site. All the collected samples were labelled properly and then taken to Environmental Science laboratory for further analysis.

3.5 WATER QUALITY ANALYSIS

The collected water samples were analyzed for physical and chemical parameters by adopting the following procedures:

1.5.1 PHYSICAL PARAMETERS

1. Temperature

Temperature was recorded at the sampling site with the help of laboratory thermometer and expressed in degree Celsius (°C).

2. Colour

The colour of samples was noted visually at the sampling site and expressed as per the CPCB classification (Table 3.2).

Table 3.2: Central Pollution Control Board classification for colour of water

Sr. No.	Colour code
1.	Light Brown
2.	Brown
3.	Dark Brown
4.	Light Green
5.	Green
6.	Dark Green
7.	Clear
8.	Other

(CPCB, 2008)

3. Odour

The odour of water samples was assessed at the sampling location by smelling and expressed as per CPCB classification (Table 3.3).

Table 3.3: Central Pollution Control Board classification for odour of water

Sr. No.	Odour Code
1.	Odour Free
2.	Rotten Eggs
3.	Burnt Sugar
4.	Soapy
5.	Fishy
6.	Septic
7.	Aromatic
8.	Chlorinus
9.	Alcoholic
10.	Unpleasant

(CPCB, 2008)

4. Turbidity

Turbidity refers to the cloudiness of a solution. It represents the presence of dispersed and suspended solids like silt, clay, organic matter, algae and other micro-organisms. It was measured with the help of digital Turbidity meter (Model 331) and is expressed in NTU.

1.5.2 CHEMICAL PARAMETERS

1. pH

pH is a measure of acidic or basic nature of a solution. It is the concentration of hydrogen ion (H^+) activity in a solution. The pH of water sample was measured by Microprocessor based pH System (Model 510 of EIA Make).

2. Electrical Conductivity (EC)

Electrical Conductivity is the measure of ability of water to conduct electric current that depends on the number of ions or charged particles present in water. EC was measured with the help of Microprocessor based Conductivity/ TDS Meter (Model 1601 of EIA make) and expressed in $\mu S\ cm^{-1}$.

3. Total Dissolved Solids (TDS)

TDS is the measure of concentration of ionic substances in water. TDS was measured by using Microprocessor based Conductivity/ TDS Meter (Model 1601 of EIA make) and expressed in $mg\ l^{-1}$.

4. Biological oxygen demand (BOD)

BOD is the amount of oxygen required by bacteria for stabilizing decomposable organic matter in water under aerobic conditions. It is a measure of biochemically organic matter in the sample. BOD was determined by employing 5 day BOD test as per 5210B methods (APHA, 2005). The pH of water samples were adjusted in the range of 6.5 to 7.5. Water sample measuring 157 ml was taken in a BOD bottle and 5-6 drops of nitrification inhibitor was added and stirred. Gasket was placed on BOD bottle and 3-4 drops of KOH solution was poured. Sensors were attached to the BOD bottle by using BOD system oxi-direct (Aqualytic Make). The BOD bottles were placed in the system in incubator for 5 days at 20°C. The readings were noted after 5 days and expressed as $mg\ l^{-1}$.

5. Chemical oxygen demand (COD)

COD represents the amount of oxygen required to oxidize all the organic pollutants present in water sample. The COD was determined by oxidizing water sample with hot H_2SO_4 solution of potassium chromate with catalyst as silver sulphate by employing closed reflux method as per 5220 D method (APHA, 2005). The samples were digested at 148°C in pre-heated thermo-reactor (Model TR 320 of Merk Make) for 120 minutes. Chloride was masked with mercury sulphate in the system and the concentration of Cr^{3+} was measured photo-metrically with the help of Spectroquant Pharo 300 (Merk Make) instrument and expressed as $mg\ l^{-1}$.

6. Cations and Anions (Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-)

The concentration of Ca^{2+}, Mg^{2+}, Cl^- and NO_3^- were determined by applying standard methods (APHA, 2005) photo-metrically with Spectroquant Pharo 300 (Merk Make) instrument by using kits and expressed as mg l^{-1}.

7. Heavy Metals (Cd, Fe, Pb, Zn, Ni)

The concentration of Cd, Fe, Zn and Ni were determined by applying standard methods (APHA, 2005) photo-metrically with Spectroquant Pharo 300 (Merk Make) instrument by using kits and expressed as mg l^{-1}.

3.6 PERMISSIBLE LIMIT

The physical and chemical parameters of water samples were studied by comparing with ICMR and BIS standards (Table 3.4).

Table 3.4: Limits for domestic and drinking water quality parameters

Sr. No.	Parameters	Standard permissible Limit	Recommending Agency
1.	EC (µS cm^{-1})	300	ICMR, 1975
2.	TDS (mg l^{-1})	500	BIS, 2012
3.	pH	8.5	BIS, 2012
4.	Turbidity (NTU)	5	BIS, 2012
5.	BOD (mg l^{-1})	5	ICMR, 1975
6.	COD (mg l^{-1})	250	BIS, 2012
7.	Ca^{2+} (mg l^{-1})	75	BIS, 2012
8.	Mg^{2+} (mg l^{-1})	30	BIS, 2012
9.	Cl^- (mg l^{-1})	250	BIS, 2012
10.	NO_3^- (mg l^{-1})	45	BIS, 2012
11.	Ni (mg l^{-1})	0.087	BIS, 2003
12.	Cd (mg l^{-1})	0.03	BIS, 2012
13.	Fe (mg l^{-1})	0.3	BIS, 2012
14.	Pb (mg l^{-1})	0.05	BIS, 2012
15.	Zn (mg l^{-1})	5	BIS,2012

Table 3.5: Limits for irrigation water quality parameters

Sr. No.	Parameters	Permissible limit	Recommending Agency
1.	EC (µS cm^{-1})	1000	FAO, 1985
2.	pH	6.5-8.5	FAO, 1985
3.	TDS (mg l^{-1})	1000	Arshad and Shakoor, 2017
4.	Cl^- (mg l^{-1})	1065	FAO, 1985
5.	Ca^{2+} (mg l^{-1})	400	FAO, 1985
6.	Mg^{2+} (mg l^{-1})	60	FAO, 1985
7.	Cd (mg l^{-1})	0.05	Rowe and Abdel-Mgid, 1995
8.	Fe (mg l^{-1})	5	Rowe and Abdel-Mgid, 1995
9.	Pb (mg l^{-1})	5	Rowe and Abdel-Mgid, 1995
10.	Ni (mg l^{-1})	0.2	Rowe and Abdel-Mgid, 1995
11.	Zn (mg l^{-1})	2	Rowe and Abdel-Mgid, 1995

3.7 WATER QUALITY INDEX (WQI)

Water quality index indicate quality with index number that represents overall quality of water for any designated use. It is defined as a rating that reflects the composite influence of different water quality parameters on the overall quality of water. It was calculated by using the standards recommended by BIS and ICMR (Table 3.4) and computed by using weighted arithmetic water quality index method developed by Brown *et al.* (1972) and Inayathulla *et al.* (2013). The details of the methods are as below:

$$WQI = \sum qiwi / \sum wi$$

Where,

qi – (Water Quality Rating) = $100\times[(V_a - V_i)/(V_s - V_i)]$

V_a – Actual Value present in the Sample

V_i – Ideal Value (0 For all parameters except pH which is 7.0)

V_s – Standard Value

wi – (Unit Weight) = K/S_n

K – Proportionality Constant is given as (Kalavathy *et al.* 2011)

$$K = 1/[1/V_{s1}+1/V_{s2}\text{-------}+1/V_{sn}]$$

S_n – Standard Value

The water quality status based on WQI values are given in Table 3.6

Table 3.6: Water Quality Status

Sr. No.	WQI Value	Water Quality Status	Grading
1.	Less than 25	Excellent water quality	A
2.	26-50	Good water quality	B
3.	51-75	Poor water quality	C
4.	76-100	Very poor water quality	D
5.	More than 100	Unsuitable for human consumption	E

(Mishra and Patel, 2001)

3.8 STATISTICAL ANALYSIS

The observations and data recorded on water parameters from the above experiments were subjected to statistical analysis through RBD Factorial Design and the significance of each treatment was calculated by following the standard procedure suggested by Gomez and Gomez (1984).

Table 3.7: Analysis of Variance (ANOVA) for Randomized Block Design (RBD) Factorial

Source of Variation	Degree of Freedom	Sum of squares	Mean sum of squares	F_{cal}
Treatments	(t-1)	S_t	$M_t = S_t / (t-1)$	M_t / M_e
Replications	(r-1)	S_r	$M_r = S_r / (r-1)$	M_r / M_e
Error	(r-1) × (t-1)	S_e	$M_e = S_e / (r-1) \times (t-1)$	
Total	(r) × (t) – 1	S_T		

Where,

t = Number of treatments

r = Number of replications

S_t = Sum of squares due to treatments

S_r = Sum of squares due to replications

S_e = Sum of square due to error

S_T = Total sum of square

M_t = Mean sum of square due to treatment

M_r = Mean sum of square due to replication

M_e = Mean sum of square due to error

The replication and treatment mean sum of square is tested against mean sum of square due to error by 'F' test at (r-1), (r-1) × (t-1) and (t-1) × (r-1) degree of freedom for RBD factorial at 5% level of significance.

The calculated F- values are compared with tabulated F-value. When F-test is found to be significant, critical difference is calculated to find the superiority of one treatment over others.

Critical difference (CD) for RBD Factorial is calculated as

CD$_{0.05}$ = SE(d) × t$_{(0.05)}$(r-1)(t-1) df

SE(d)± = $\sqrt{2Me}/r$

SE(m)± = $\sqrt{Me}/r$

Where,

SE (d)± = Standard error of difference of mean

SE (m)± = Standard error of mean

CD$_{0.05}$ = Critical difference at 5% level of significance

Chapter-4

RESULTS AND DISCUSSION

The present investigation entitled **"Impact of Land Uses on Water Quality in Bilaspur District of Himachal Pradesh"** was undertaken in the Department of Environmental Science, College of Forestry, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, HP during 2019-2020. The observations recorded during analysis have been presented in this chapter and analysis of variance is given in appendix. The results have been described under the following heads:

4.1 Physical Parameters
4.2 Chemical Parameters
4.3 Cations and Anions
4.4 Heavy Metals
4.5 Water Quality Index (WQI)

4.1 PHYSICAL PARAMETERS

4.1.1 Temperature

The perusal of data in the Table 4.1 revealed significant variations in temperature recorded in respect of different land uses water sources and seasons. Temperature was found highest (21.67°C) under urban/peri-urban land use followed by agriculture (19.67°C) and lowest in forest (17.17°C). Temperature was found more during monsoon season (24.25°C) than winter (14.75°C). Whereas it was found higher in ground water (20.36°C) than the surface water (18.64°C).

The combined effect of land use and water sources was found to be significant. In surface water sources higher temperature was recorded at urban/peri-urban land use (20.75°C) succeeded by agriculture (19.08°C) and lower in forest land use (16.08°C). Similar pattern was followed in ground water sources. Land uses and seasons significantly influenced the temperature of water sources. During winter season urban/peri-urban (16.67°C) land use recorded higher temperature followed by agriculture (15.25°C) and forest (12.33°C) and similar pattern was observed in monsoon season. The effect of interaction of water sources and season was found to be significant. Ground water sources recorded higher temperature

(15.89°C) than surface water (13.61°C) during winter. Similar trend was followed during monsoon. The interactional effect of land uses, water sources and seasons was found to be non-significant.

The variation in temperature might be due to different timing of water samples collection and seasons. Temperature is influenced by the seasons and prevailing atmospheric conditions on the region. The results are in congruous with the findings of Trivedi *et al.* (2010) and any fluctuation in temperature of water body depends upon the geographic location of sampling site and the temperature of effluents entering into the water body (Ahipathi and Puttaiah, 2006). The temperature recorded in winter attributed to shorter day length, physiographic features or aspects and depth of the ground water sources. Sharma *et al.* (2015) also reported lowest temperature during winter season which was attributed to shorter photoperiod and shorter day length.

Table 4.1: Seasonal Variation of Temperature (°C) in ground and surface water sources under dominant land uses

Water Sources / **Land Uses**	**Ground Water**	**Surface Water**	**Mean**	**Ground Water**	**Surface Water**	**Mean**	**Land use and Water Sources Interaction**		
	Winter			**Monsoon**			**Ground Water**	**Surface Water**	**Mean of Land Use**
Urban/ Peri Urban	17.83	15.50	**16.67**	27.33	26.00	**26.67**	22.58	20.75	**21.67**
Agriculture	16.00	14.50	**15.25**	24.50	23.67	**24.08**	20.25	19.08	**19.67**
Forest	13.83	10.83	**12.33**	22.67	21.33	**22.00**	18.25	16.08	**17.17**
Mean	**15.89**	**13.61**		**24.83**	**23.67**		**20.36**	**18.64**	
Mean of Season			**14.75**			**24.25**			**19.50**

C.D. $_{0.05}$

Land Uses = 0.23
Land Uses x Water Sources = 0.325
Land Uses x Water sources x Seasons = NS
Water Sources = 0.188
Land Uses x Seasons = 0.325
Seasons = 0.188
Water Sources x Seasons = 0.266

4.1.2 Colour

Data presented in Table 4.2 showed surface water exhibited clear colour of water in winter season under all land use systems whereas ground water under urban/peri-urban land use showed light brown to clear colour of water and clear under agriculture and forest land use. During monsoon season, both water sources in all the 3 dominant land use systems represented light brown to clear colour of water.

Light brown colour of ground water under urban/peri-urban land use during winter and monsoon might be due to the presence of ferric iron. The light brown colour of water sources during monsoon season might be due to high rainfall and runoff during rainy days and the runoff mixed with organic substances may have resulted in light brown colour of water sources. The results are in line with the findings of Joseph and Jacob (2010) who also noticed such changes in colour which was ascribed to the organic materials, algal growth and erosion.

Table 4.2: Seasonal variation of Colour in ground and surface water sources under dominant land uses

Water Sources Land Uses	Ground Water	Surface Water	Ground Water	Surface Water
	Winter		Monsoon	
Urban/Peri Urban	Light Brown-Clear	Clear	Light Brown-Clear	Light Brown – Clear
Agriculture	Clear	Clear	Light Brown-Clear	Light Brown-Clear
Forest	Clear	Clear	Light Brown-Clear	Light Brown – Clear

4.1.3 Odour

The perusal of data in Table 4.3 revealed that water samples from all sources i.e. ground and surface found odour free under all land use system during winter and monsoon seasons. This indicated that the water sources are free from any type of physical contamination.

Table 4.3: Seasonal variation of Odour in ground and surface water sources under dominant land uses

Water Sources Land Uses	Ground Water	Surface Water	Ground Water	Surface Water
	Winter		Monsoon	
Urban/Peri Urban	Odour Free	Odour Free	Odour Free	Odour Free
Agriculture	Odour Free	Odour Free	Odour Free	Odour Free
Forest	Odour Free	Odour Free	Odour Free	Odour Free

4.1.4 Turbidity

The resume of the data presented in Table 4.4 indicated significant variations in turbidity with respect to different land uses and seasons whereas it was found to be non-significant in respect of water sources. Turbidity was recorded highest (3.83 NTU) under urban/peri-urban land use followed by agriculture (2.75 NTU) and lowest in forest (1.50 NTU), whereas seasonally it was found higher in monsoon (2.94 NTU) than winter (2.44 NTU). Similarly, the turbidity was found more in surface water (2.89 NTU) than the ground water (2.50 NTU). All the interactional effects with respect to land uses and water sources, land uses and seasons, water sources and seasons and land uses, water sources and seasons was recorded to be non-significant. Turbidity was found within the permissible limits (5 NTU) as per BIS, 2012.

Higher turbidity under urban land use might be due to high concentration of suspended solid in water runoff from urban area and due to increased anthropogenic activities. The results are in confrontation with the findings of Alam *et al.* (2007) and Mathur *et al.* (2008). Higher turbidity in monsoon was attributed to discharge of surface runoff having organic matter load and effluents of high suspended matter content into the water sources. Similar results were reported by Utang and Akpan (2012) who recorded higher turbidity in monsoon season.

Table 4.4: Seasonal Variation of Turbidity (NTU) in ground and surface water sources under dominant land uses

Water Sources	**Ground Water**	**Surface Water**	**Mean**	**Ground Water**	**Surface Water**	**Mean**	**Land use and Water Sources Interaction**		
Land Uses	**Winter**			**Monsoon**			**Ground Water**	**Surface Water**	**Mean of Land Use**
Urban/ Peri Urban	3.33	3.67	**3.50**	4.33	4.00	**4.17**	3.83	3.83	**3.83**
Agriculture	2.33	2.67	**2.50**	2.67	3.33	**3.00**	2.50	3.00	**2.75**
Forest	1.00	1.67	**1.33**	1.33	2.00	**1.67**	1.17	1.83	**1.50**
Mean	**2.22**	**2.67**		**2.78**	**3.11**		**2.50**	**2.89**	
Mean of Season			**2.44**			**2.94**			**2.69**

C.D. $_{0.05}$

Land Uses = 0.487 Land Uses x Water Sources = NS Land Uses x Water sources x Seasons = NS
Water Sources = NS Land Uses x Seasons = NS
Seasons = 0.398 Water Sources x Seasons = NS

4.2 CHEMICAL PARAMERTERS

4.2.1 pH

The data in Table 4.5 evinced that pH ranged from 6.96-8.59. Significant variation in pH was recorded with respect to different land uses, water sources and seasons. Higher pH (8.16) was recorded under urban/peri-urban land use succeeded by agriculture (7.75) and lower (7.38) in forest land use. Seasonally, pH was found more in monsoon (7.92) followed by winter (7.61). Surface water exhibited higher pH (7.92) than the ground water (7.61). The effect of land use on water sources was also found significant. In surface water higher pH (8.34) was recorded under urban/peri-urban land use followed by agriculture (7.82) and lower (7.60) under forest. Similar pattern was recorded in ground water sources. The combined effect of land use and season was found to be significant. During winter season urban/peri-urban land use recorded higher pH (7.93) followed by agriculture (7.65) and forest (7.26). Similar trend was obtained for monsoon season. The interactional effect of water sources and season was found to be non-significant.

The combined effect of land uses, water sources and seasons was found to be significant. Higher pH of ground water (8.18) was registered under unban /peri-urban land use during monsoon season and lower under forest (6.96) land use in winter and similar pattern was observed for surface water. The recorded pH in all the aspect was found within permissible limits as prescribed BIS, 2012. The recorded higher pH under urban/peri-urban land use might be ascribed to dumping of waste and sewage which led to increase in the concentration of ions. The lower pH i.e. acidic under forest land use might be attributed to dominance of *Pinus roxburghii* trees and their leaf litter (needles) decomposition may have resulted in acidification (Rana, 2012). The results are in congruous with the findings of Calmels *et al.* (2006) and Chauhan and Verma (2016). Seasonally, the results are in line with the findings of Qureshimatva *et al.* (2015), Pawar *et al.* (2016) and Srivastava *et al.* (2016) as they reported more pH during monsoon which might be attributed to increased rate of pollutants from the surrounding areas with the rain water (Singh *et al.*, 2013).

Table 4.5: Seasonal Variation of pH in ground and surface water sources under dominant land uses

Water Sources **Land Uses**	**Ground Water**	**Surface Water**	**Mean**	**Ground Water**	**Surface Water**	**Mean**	**Land use and Water Sources Interaction**		
	Winter			**Monsoon**			**Ground Water**	**Surface Water**	**Mean of Land Use**
Urban/ Peri Urban	7.77	8.09	**7.93**	8.18	8.59	**8.39**	7.98	8.34	**8.16**
Agriculture	7.61	7.68	**7.65**	7.77	7.95	**7.86**	7.69	7.82	**7.75**
Forest	6.96	7.55	**7.26**	7.36	7.64	**7.50**	7.16	7.60	**7.38**
Mean	**7.45**	**7.77**		**7.77**	**8.06**		**7.61**	**7.92**	**7.76**
Mean of Season			**7.61**			**7.92**			

C.D. $_{0.05}$

Land Uses = 0.059 Land Uses x Water Sources = 0.084 Land Uses x Water sources x Seasons = 0.119
Water Sources = 0.048 Land Uses x Seasons = 0.084
Seasons = 0.048 Water Sources x Seasons = NS

4.2.2 Electrical Conductivity (EC)

The data presented in Table 4.6 showed significant variation in EC according to different land uses, water sources and seasons. Highest EC (655.83 µS cm^{-1}) was recorded under urban/peri-urban land use followed by agriculture (478.92 µS cm^{-1}) and lowest in forest (219.33 µS cm^{-1}). Higher EC (489.00 µS cm^{-1}) was noticed in ground water as compared to surface water (413.72 µS cm^{-1}) whereas monsoon season recorded more EC (466.67 µS cm^{-1}) than winter season (436.06 µS cm^{-1}). All the interactional effects in relation to land uses, water sources and seasons were found to be non-significant. The EC values were found above the permissible limits (300 µS cm^{-1}) as given by ICMR, 1975. High EC under urban/peri-urban land use might be ascribed to inorganic pollutants from the dumping of waste which have resulted increase in the ions concentration. EC above the permissible limits under agriculture land use might be attributed to application of excessive fertilizers and insecticides and/or pesticides. The results are in agreement with the study of Grasby *et al.* (1997) and Nkwocha *et al.* (2011). Seasonally, higher EC in monsoon season might be contributed to runoff from non-point sources and accumulation of the salts therein. Similar results were reported by Mullane (1997), Panabokkle *et al.* (2002), Solanki *et al.* (2011) and Chauhan and Verma (2016).

Table 4.6: Seasonal Variation of Electrical Conductivity (EC µS cm^{-1}) in ground and surface water sources under dominant land uses

Water Sources	**Ground Water**	**Surface Water**	**Mean**	**Ground Water**	**Surface Water**	**Mean**	**Land use and Water Sources Interaction**		
Land Uses	**Winter**			**Monsoon**			**Ground Water**	**Surface Water**	**Mean of Land Use**
Urban/ Peri Urban	680.33	603.67	**642.00**	723.67	615.67	**669.67**	702.00	609.67	**655.83**
Agriculture	500.33	416.67	**458.50**	538.67	460.00	**499.33**	519.50	438.33	**478.92**
Forest	235.33	180.00	**207.67**	255.67	206.33	**231.00**	245.50	193.17	**219.33**
Mean	**472.00**	**400.11**		**506.00**	**427.33**		**489.00**	**413.72**	
Mean of Season			**436.06**			**466.67**			**451.36**

C.D. $_{0.05}$

Land Uses = 27.903
Water Sources = 22.783
Seasons = 22.783
Land Uses x Water Sources = NS
Land Uses x Seasons = NS
Water Sources x Seasons = NS
Land Uses x Water sources x Seasons = NS

4.2.3 Total Dissolved Solids (TDS)

The data in Table 4.7 depicted that TDS varied from 101.23 – 480.67 mg l^{-1}. Significant variations was observed with different land uses and water sources whereas seasons did not show any significant variation in TDS values however, monsoon season exhibited higher TDS values. Higher TDS (416.83 mg l^{-1}) was noticed under urban/peri-urban land use preceded by agriculture (291.25 mg l^{-1}) and lower (129.95 mg l^{-1}) in forest land use system. Ground water recorded more TDS (308.08 mg l^{-1}) than surface water (250.61 mg l-1) and monsoon season exhibited more TDS (286.92 mg l^{-1}) than winter season (271.77 mg l^{-1}). The combined effect of land use and water sources was found significant. Ground water recorded higher TDS (455.67 mg l^{-1}) under urban land use followed by agriculture (326.50 mg l^{-1}) and forest (142.08 mg l^{-1}). Similar trend was observed in surface water sources. All the interactional effects with respect to land use and seasons, water sources and seasons and land uses, water sources and seasons was found to be non-significant. All the TDS values were found below the permissible limits (500 mg l^{-1}) as prescribed by BIS, 2012. Higher TDS under urban/peri-urban land use attributed to increased anthropogenic activities such as dumping of waste material and adding of other domestic wastewater effluents. Low TDS under forest land use might be due to clean environment and low anthropogenic activities. The findings are in harmony with the study of Khaund *et al.* (2012). Season wise variation in the TDS are in agreement with the findings of Shaik and Mandre (2009) and Utang and Akpan (2012) who reported more TDS during monsoon which was attributed to increased runoff and discharge in monsoon season.

Table 4.7: Seasonal Variation of Total Dissolved Solids (TDS mg l^{-1}) in ground and surface water sources under dominant land uses

Water Sources Land Uses	Ground Water	Surface Water	Mean	Ground Water	Surface Water	Mean	Land use and Water Sources Interaction		
	Winter			Monsoon			Ground Water	Surface Water	Mean of Land Use
Urban/ Peri Urban	430.67	380.33	**405.50**	480.67	375.67	**428.17**	455.67	378.00	**416.83**
Agriculture	323.33	262.33	**292.83**	329.67	249.67	**289.67**	326.50	256.00	**291.25**
Forest	132.70	101.23	**116.97**	151.47	134.40	**142.93**	142.08	117.82	**129.95**
Mean	**295.57**	**247.97**		**320.60**	**253.24**		**308.08**	**250.61**	
Mean of Season			**271.77**			**286.92**			**279.34**

C.D. $_{0.05}$

Land Uses = 19.839 Land Uses x Water Sources = 28.057 Land Uses x Water sources x Seasons = NS
Water Sources =16.199 Land Uses x Seasons = NS
Seasons = NS Water Sources x Seasons = NS

4.2.4 Biological oxygen demand (BOD)

The perusal of data in Table 4.8 revealed that land uses, water sources and seasons showed significant impact on BOD. Urban/peri-urban land use exhibited higher BOD (2.88

mg l^{-1}) succeeded by agriculture (2.28 mg l^{-1}) and lower (1.04 mg l^{-1}) in forest land use. Surface water recorded more BOD (2.22 mg l^{-1}) than ground water (1.92 mg l^{-1}). Higher BOD (2.60 mg l^{-1}) was recorded in monsoon as compared to winter season (1.54 mg l^{-1}). All the interactional effect *viz.* land use and water source, land use and seasons, water sources and season and land uses, water sources and seasons was found to be non-significant. All the recorded BOD values fall within the permissible limits (5 mg l^{-1}) as given by ICMR, 1975. Highest BOD in urban/peri-urban land system might be due to the addition of domestic, animal and sewage waste. Similar results were reported by Raveen *et al.* (2008) and Chauhan and Verma (2016). More BOD in monsoon season attributed to addition of more effluent in water sources whereas low in winter ascribed to less accumulation of organic materials under low rainfall conditions. Similar findings were reported by Phiri *et al.* (2005).

Table 4.8: Seasonal Variation of Biological Oxygen Demand (BOD mg l^{-1}) in ground and surface water sources under dominant land uses.

Water Sources Land Uses	Ground Water	Surface Water	Mean	Ground Water	Surface Water	Mean	Land use and Water Sources Interaction		
	Winter			Monsoon			Ground Water	Surface Water	Mean of Land Use
Urban/ Peri Urban	2.32	2.42	**2.37**	3.13	3.65	**3.39**	2.73	3.04	**2.88**
Agriculture	1.47	1.90	**1.68**	2.70	3.07	**2.88**	2.08	2.48	**2.28**
Forest	0.53	0.60	**0.57**	1.37	1.67	**1.52**	0.95	1.13	**1.04**
Mean	**1.44**	**1.64**		**2.40**	**2.80**		**1.92**	**2.22**	
Mean of Season			**1.54**			**2.60**			**2.07**

C.D. $_{0.05}$

Land Uses = 0.263

Water Sources = 0.215

Seasons = 0.215

Land Uses x Water Sources = NS

Land Uses x Seasons = NS

Water Sources x Seasons = NS

Land Uses x Water sources x Seasons = NS

4.2.5 Chemical oxygen demand (COD)

The data in Table 4.9 evinced that COD value varied from 39.00 – 215.67 mg l^{-1}. Significant variation in COD was recorded in relation to different land use system, water sources and seasons. Under different land use types, urban/peri-urban recorded higher COD (156.00 mg l^{-1}) followed by agriculture (76.67 mg l^{-1}) and lower in forest (50.08 mg l^{-1}). Surface water recorded higher COD (114.78 mg l^{-1}) as compared to ground water (73.72 mg l^{-1}). Seasonally, monsoon season recorded more COD (107.33 mg l^{-1}) than winter season (81.17 mg l^{-1}). The combined effect of land use and water sources was found to be significant. Ground water sources recorded higher COD (110.00 mg l^{-1}) under urban/peri-urban land use followed by agriculture (65.67 mg l^{-1}) and lower (45.50 mg l^{-1}) in forest. Surface water sources also behaved in similar fashion. All the interactional effect like land uses and seasons, water sources and seasons and land uses, water sources and seasons was found to be non-significant. The COD values were lying below the permissible limits (250 mg l^{-1}) as prescribed by BIS, 2012.

Higher COD under urban/peri-urban land use might be due to dumping of solid waste and runoff of effluents. The results are in confirmity with the findings of Srivastava *et al.* (1996), Boyd (1981) and Chauhan and Verma (2016). Higher COD in monsoon was attributed to waste water from dumping and surface runoff. Similar findings were reported by Fokmare and Musaddiq (2002).

Table 4.9: Seasonal Variation of Chemical Oxygen Demand (COD mg l^{-1}) in ground and surface water sources under dominant land uses

Water Sources	**Ground Water**	**Surface Water**	**Mean**	**Ground Water**	**Surface Water**	**Mean**	**Land use and Water Sources Interaction**		
Land Uses	**Winter**			**Monsoon**			**Ground Water**	**Surface Water**	**Mean of Land Use**
Urban/ Peri Urban	92.33	188.33	**140.33**	127.67	215.67	**171.67**	110.00	202.00	**156.00**
Agriculture	54.33	69.00	**61.67**	77.00	106.33	**91.67**	65.67	87.67	**76.67**
Forest	39.00	44.00	**41.50**	52.00	65.33	**58.67**	45.50	54.67	**50.08**
Mean	**61.89**	**100.44**		**85.56**	**129.11**		**73.72**	**114.78**	
Mean of Season			**81.17**			**107.33**			**94.25**

C.D. $_{0.05}$
Land Uses = 21.759 Land Uses x Water Sources = 30.773 Land Uses x Water sources x Seasons = NS
Water Sources = 17.767 Land Uses x Seasons = NS
Seasons = 17.767 Water Sources x Seasons = NS

4.3 CATIONS AND ANIONS

4.3.1 Calcium (Ca^{2+})

The perusal of data in Table 4.10 depicted that Ca^{2+} concentration was ranged between 35.33 – 129.67 mg l^{-1}. Significant variations in Ca^{2+} content was recorded with respect to different land uses, water sources and seasons. Highest Ca^{2+} content (112.67 mg l^{-1}) was observed under agriculture land use followed by urban/peri-urban (76.75 mg l^{-1}) and lowest in forest (51.17 mg l^{-1}). In water sources, surface water registered higher (88.28 mg l^{-1}) concentration of Ca^{2+} than ground water (72.11 mg l^{-1}). Higher Ca^{2+} (85.44 mg l^{-1}) content was noticed in winter season as compared to monsoon season (74.94 mg l^{-1}). The conjoint effect of land use and water sources was found to be significant. Surface water recorded Higher Ca^{2+}content (123.83 mg l^{-1}) under agriculture land use succeeded by urban/peri-urban (79.33 mg l^{-1}) and lower in forest (61.67 mg l^{-1}). Similar trend was also observed in ground water sources whereas all other interactional effects with respect to land use, water sources and seasons was found to be non-significant.

The calcium concentration values were found within the permissible limit (200 mg l^{-1}) but exceed the desirable limits except forest land use, as per BIS, 2012. Higher concentration of Ca^{2+} under agriculture land use may be attributed to rich geological formation of the region and excessive use of calcium rich fertilizers. The results are in line with the findings of Pallisamy and Geetha (2007) and Rana (2012) who had reported that 98% of water sources are dominated by calcium and bicarbonate due to weathering of limestone. Potasznik and Szymczyk (2015), Shinde *et al.* (2016) and Kamboj *et al.* (2017) recorded high Ca^{2+} content in canals drained by agriculture catchments. Lower calcium content in rainy season was ascribed to dilution by rain water. Pande and Sharma (1998) also reported similar findings.

Table 4.10: Seasonal Variation of Calcium (Ca^{2+} mg l^{-1}) in ground and surface water sources under dominant land uses

Water Sources	Ground Water	Surface Water	Mean	Ground Water	Surface Water	Mean	Land use and Water Sources Interaction		
Land Uses	Winter			Monsoon			Ground Water	Surface Water	Mean of Land Use
Urban/ Peri Urban	78.33	85.67	**82.00**	70.00	73.00	**71.50**	74.17	79.33	**76.75**
Agriculture	108.00	129.67	**118.83**	95.00	118.00	**106.50**	101.50	123.83	**112.67**
Forest	46.00	65.00	**55.50**	35.33	58.33	**46.83**	40.67	61.67	**51.17**
Mean	**77.44**	**93.44**		**66.78**	**83.11**		**72.11**	**88.28**	
Mean of Season			**85.44**			**74.94**			**80.19**

C.D. $_{0.05}$
Land Uses = 4.824 Land Uses x Water Sources = 6.823 Land Uses x Water sources x Seasons = NS
Water Sources = 3.939 Land Uses x Seasons = NS
Seasons = 3.939 Water Sources x Seasons = NS

4.3.2 Magnesium (Mg^{2+})

The data presented in Table 4.11 revealed that different land uses, water sources and seasons showed significant variations in Mg^{2+} content. Agriculture land use recorded highest value (48.73 mg l^{-1}) of Mg^{2+} followed by urban/peri-urban (45.88 mg l^{-1}) and lowest in forest (22.26 mg l^{-1}). More Mg^{2+} content (43.29 mg l^{-1}) was recorded in winter than monsoon season (34.62 mg l^{-1}). Surface water sources registered more Mg^{2+}content (41.60 mg l^{-1}) as compared to ground water sources (36.31 mg l^{-1}). All the interactional effects in relation to land uses, water sources and seasons were found to be non-significant.

The recorded values were exceeding the desirable limits (30 mg l^{-1}) but remained within the permissible limits as given by BIS, 2012. Higher concentration in agriculture might be due to use of fertilizers, manures and pesticides in the agricultural fields. The results are congruous with the findings of Shaik and Mandre (2009) and Balamurgan and Dheenadayalan (2012) who have reported higher values of magnesium under urban and agriculture land use system. Lower concentration of mg in monsoon season was ascribed to dilution effect of rainwater. Similar findings were reported by Pande and Sharma (1998) who also reported low Mg^{2+} content in monsoon season.

Table 4.11: Seasonal Variation of Magnesium (Mg^{2+} mg l^{-1}) in ground and surface water sources under dominant land uses

Water Sources **Land Uses**	**Ground Water**	**Surface Water**	**Mean**	**Ground Water**	**Surface Water**	**Mean**	**Land use and Water Sources Interaction**		
	Winter			**Monsoon**			**Ground Water**	**Surface Water**	**Mean of Land Use**
Urban/ Peri Urban	47.00	54.50	**50.75**	38.33	43.67	**41.00**	42.67	49.08	**45.88**
Agriculture	49.57	55.33	**52.45**	43.20	46.80	**45.00**	46.38	51.07	**48.73**
Forest	25.33	28.00	**26.67**	14.40	21.30	**17.85**	19.87	24.65	**22.26**
Mean	**40.63**	**45.94**		**31.98**	**37.26**		**36.31**	**41.60**	
Mean of Season			**43.29**			**34.62**			**38.95**

C.D. $_{0.05}$
Land Uses = 2.525 Land Uses x Water Sources = NS Land Uses x Water sources x Seasons = NS
Water Sources = 2.061 Land Uses x Seasons = NS
Seasons = 2.061 Water Sources x Seasons = NS

4.3.3 Chloride (Cl^-)

Different land uses, water sources and seasons indicated significant variations in Cl^- content (Table 4.12). The concentration of chloride was varied from 25 to 137.67 mg l^{-1}. Urban/peri-urban land use registered Higher Cl^- content (99.17 mg l^{-1}) followed by agriculture (50.67 mg l^{-1}) and lower (35.67 mg l^{-1}) in forest land use system. In water sources, surface water sources recorded higher concentration of Cl^- (74.78 mg l^{-1}) in comparison to ground water sources (48.89 mg l^{-1}). Season wise, higher content of Cl^- was noticed in monsoon (68.61 mg l^{-1}) in relation to winter season (55.06 mg l^{-1}). The combined effect of land uses and water sources on chloride content was found significant. Surface water sources recorded higher Cl^- content (128.17 mg l^{-1}) under urban/peri-urban land use followed by agriculture (55.83 mg l^{-1}) and lower in forest land use (40.33 mg l^{-1}). Similar trend was observed for ground water sources. The interactional effect of seasons with land uses and water sources was found to be non-significant. All the recorded values were found within permissible limits (250 mg l^{-1}) as per BIS, 2012.

Higher chloride content under urban/peri-urban land use may be ascribed to sewage and domestic waste that contain high quantity of chloride. The results are in corresponding with the findings of Dwivedi and Odi (2003) and Sanap *et al.* (2006) who also reported Higher Cl$^-$ under urban/peri-urban land use.

The lower chloride concentration in both the water sources under forest was attributed to non-addition of fertilizers, chemicals and lower anthropogenic activities in forest ecosystem. Higher chloride content was recorded in monsoon season which might be resulted due to more surface runoff containing sewage, animal and other organic waste. The findings are in line with the study of Pathak *et al.* (2015) and Pawar *et al.* (2016) who had reported more chloride content during monsoon season.

Table 4.12: Seasonal Variation of Chloride (Cl$^-$ mg l^{-1}) in ground and surface water sources under dominant land uses

Water Sources **Land Uses**	**Ground Water**	**Surface Water**	**Mean**	**Ground Water**	**Surface Water**	**Mean**	**Land use and Water Sources Interaction**		
	Winter			**Monsoon**			**Ground Water**	**Surface Water**	**Mean of Land Use**
Urban/ Peri Urban	63.67	118.67	**91.17**	76.67	137.67	**107.17**	70.17	128.17	**99.17**
Agriculture	38.67	48.00	**43.33**	52.33	63.67	**58.00**	45.50	55.83	**50.67**
Forest	25.00	36.33	**30.67**	37.00	44.33	**40.67**	31.00	40.33	**35.67**
Mean	**42.44**	**67.67**		**55.33**	**81.89**		**48.89**	**74.78**	
Mean of Season			**55.06**			**68.61**			**61.83**

C.D. $_{0.05}$
Land Uses = 12.13 Land Uses x Water Sources = 17.155 Land Uses x Water sources x Seasons = NS
Water Sources = 9.904 Land Uses x Seasons = NS
Seasons = 9.904 Water Sources x Seasons = NS

4.3.4 Nitrate (NO$_3^-$)

The nitrate concentration in surface and ground water sources varied from 3.67 to 27.73 mg l^{-1} (Table 4.13). Significant variations in NO$_3^-$ content was observed in relation to different land uses, water sources and seasons. Higher NO$_3^-$ content (19.18 mg l^{-1}) was recorded under agriculture land use succeeded by urban/peri-urban (7.65 mg l^{-1}) and lower in forest land use (4.68 mg l^{-1}). Surface water sources contained more NO$_3^-$ content (12.21 mg l^{-}

^{1}) than ground water sources (8.79 mg l^{-1}). However, more NO_3^- concentration was found in monsoon season (11.89 mg l^{-1}) as compared to winter season (9.11 mg l^{-1}). Land uses showed significant variation in nitrate content with respect to seasons and water sources. Surface water sources registered higher NO_3^- content (23.65 mg l^{-1}) under agriculture land use preceded by urban/peri-urban (7.85 mg l^{-1}) and lower in forest land use (5.12 mg l^{-1}). Ground water sources behaved in the similar mode. According to seasons, Higher NO_3^- (22.12 mg l^{-1}) content was recorded under agriculture land use succeeded by urban/peri-urban (8.33 mg l^{-1}) and lower in forest (5.23 mg l^{-1}). Winter season showed the similar trend. Other interactional effects such as water sources and season and land use, water source and season were found to be non-significant. All the values fall within the permissible limits (45 mg l^{-1}) as given by BIS, 2012.

Table 4.13: Seasonal Variation of Nitrate (NO_3^- mg l^{-1}) in ground and surface water sources under dominant land uses

Water Sources	Ground Water	Surface Water	Mean	Ground Water	Surface Water	Mean	Land use and Water Sources Interaction		
Land Uses	**Winter**			**Monsoon**			**Ground Water**	**Surface Water**	**Mean of Land Use**
Urban/ Peri Urban	6.67	7.27	**6.97**	8.23	8.43	**8.33**	7.45	7.85	**7.65**
Agriculture	12.90	19.57	**16.23**	16.50	27.73	**22.12**	14.70	23.65	**19.18**
Forest	3.67	4.57	**4.12**	4.80	5.67	**5.23**	4.23	5.12	**4.68**
Mean	**7.74**	**10.47**		**9.84**	**13.94**		**8.79**	**12.21**	
Mean of Season			**9.11**			**11.89**			**10.50**

C.D. $_{0.05}$

Land Uses = 1.921
Water Sources = 1.568
Seasons = 1.568
Land Uses x Water Sources = 2.716
Land Uses x Seasons = 2.716
Water Sources x Seasons = NS
Land Uses x Water sources x Seasons = NS

Higher nitrate content under agriculture land use may be attributed to intensive farming practices viz. application of agrochemicals, chemical fertilizers and manures by the farmers at higher rates. The results are in conformity with the findings of Jeyaruba and Thushyanthy (2009) and Chauhan and Verma (2016) as they had reported that overuse of inorganic fertilizers resulted in higher content in surface water and their percolation into the ground water increases the concentration of this element. Whereas lower concentration in forest land use might be due to non-application of chemicals and fertilizers. High concentration of nitrate in monsoon season was attributed to runoff of nutrients by rain and the results are in line with the findings of Irene (1991) and Gupta *et al.* (2010) who had recorded higher concentration of nitrate during monsoon season.

4.4 HEAVY METALS

4.4.1 Cadmium (Cd)

The perusal of data in Table 4.14 showed that concentration of Cd ranged between 0 - 0.024 mg l^{-1}. Significant variation in Cd content was recorded with respect to different land use, water sources and seasons. Urban/peri-urban land use registered Higher Cd content (0.019 mg l^{-1}) preceded by agriculture (0.005 mg l^{-1}) and lower in forest land use (0.001 mg l^{-1}). Ground water sources exhibited higher Cd content (0.011 mg l^{-1}) than the surface water (0.006 mg l^{-1}). Seasonally, the concentration of Cd was obtained Higher in winter (0.009 mg l^{-1}) as compared to monsoon season (0.007 mg l^{-1}). The interaction of land uses with season and water sources showed significant variation in Cd concentration. Ground water sources acquired Higher Cd content (0.023 mg l^{-1}) under urban/peri-urban land use preceded by agriculture (0.007 mg l^{-1}) and lower in forest land use (0.002 mg l^{-1}). Similar trend was observed for surface water sources. According to seasons, higher Cd content (0.020) was recorded in winter under urban/peri-urban land use preceded by agriculture (0.006 mg l^{-1}) and lower in forest land use (0.002 mg l^{-1}). Similar pattern was obtained for monsoon season. Non-significant results were obtained for the interaction of water sources and seasons. The interactional effect of land use, water source and season was found to be significant. Ground water sources showed higher content of Cd (0.024 mg l^{-1}) under urban/peri-urban land use in winter season whereas lowest content (0.001 mg l^{-1}) was recorded under forest land use during monsoon season. The surface water sources also behaved in similar pattern. The values of Cd content was found within the permissible limit (0.03 mg l^{-1}) as described by BIS, 2012.

Higher Cd concentration in urban/peri-urban land use might be attributed to dumping of domestic waste and release of waste effluents. The results are in consonant with the findings of Sankar *et al.* (2010) who reported higher Cd content under urban/Peri-urban land uses. Seasonally, higher content in winter probably due to the more percolation of water in rainy season and accumulated into the ground water with passage of time. The results are in agreement with the findings of Kar *et al.* (2008) who also reported Higher Cd content during winter.

Table 4.14: Seasonal Variation of Cadmium (Cd mg l^{-1}) in ground and surface water sources under dominant land use

Water Sources	Ground Water	Surface Water	Mean	Ground Water	Surface Water	Mean	Land use and Water Sources Interaction		
Land Uses	**Winter**			**Monsoon**			**Ground Water**	**Surface Water**	**Mean of Land Use**
Urban/ Peri Urban	0.024	0.016	**0.020**	0.022	0.012	**0.017**	0.023	0.014	**0.019**
Agriculture	0.009	0.004	**0.006**	0.005	0.003	**0.004**	0.007	0.003	**0.005**
Forest	0.002	0.001	**0.002**	0.001	0.000	**0.001**	0.002	0.001	**0.001**
Mean	**0.012**	**0.007**		**0.009**	**0.005**		**0.011**	**0.006**	
Mean of Season			**0.009**			**0.007**			**0.008**

C.D. $_{0.05}$
Land Uses = 0.001 Land Uses x Water Sources = 0.001 Land Uses x Water sources x Seasons = 0.002
Water Sources = 0.001 Land Uses x Seasons = 0.001
Seasons = 0.001 Water Sources x Seasons = NS

4.4.2 Iron (Fe)

The data in Table 4.15 evinced that iron content varied from 0.01 to 0.29 mg l^{-1}. Different land uses, water sources and seasons significantly impacted the iron content. Higher Fe content (0.27 mg l^{-1}) was noticed under urban/peri-urban land use followed by agriculture (0.20 mg l^{-1}) and lower in forest land use (0.04 mg l^{-1}). Ground water sources exhibited higher iron content (0.19 mg l^{-1}) than surface water sources (0.15 mg l^{-1}). Higher iron content was recorded in monsoon season (0.18 mg l^{-1}) as compared to winter season (0.16 mg l^{-1}). Land use and water sources interaction was found to be significant. Under urban/peri-urban land use ground water sources registered Higher Fe content (0.27 mg l^{-1}) preceded by agriculture (0.23 mg l^{-1}) and lower in forest land use (0.07 mg l^{-1}). Non-significant variation in Fe content with respect to the interaction of land use and season, water sources and seasons and land uses, water sources and seasons was observed. However, the values of iron content were found within permissible limit (0.3 mg l^{-1}) as per BIS, 2012.

Higher content of iron under urban/peri-urban land use might be due to vehicle washing, weathering of minerals and soils and atmospheric deposition. The results are in confirmation with the findings of Puri (2011). High Fe concentration in monsoon season may be attributed to the addition of Fe from point and non-point sources through higher rate of runoff during monsoon season. The results are in agreement with the findings of Rana *et al.* (2016) who also reported more Fe content in monsoon.

Table 4.15: Seasonal Variation of Iron (Fe mg l^{-1}) in ground and surface water sources under dominant land uses

Water Sources Land Uses	Ground Water	Surface Water	Mean	Ground Water	Surface Water	Mean	Land use and Water Sources Interaction		
	Winter			Monsoon			Ground Water	Surface Water	Mean of Land Use
Urban/ Peri Urban	0.26	0.27	**0.26**	0.29	0.28	**0.29**	0.27	0.27	**0.27**
Agriculture	0.22	0.15	**0.18**	0.24	0.17	**0.21**	0.23	0.16	**0.20**
Forest	0.05	0.01	**0.03**	0.08	0.02	**0.05**	0.07	0.01	**0.04**
Mean	**0.17**	**0.14**		**0.21**	**0.16**		**0.19**	**0.15**	
Mean of Season			**0.16**			**0.18**			**0.17**

C.D. $_{0.05}$
Land Uses = 0.02 Land Uses x Water Sources = 0.028 Land Uses x Water sources x Seasons = NS
Water Sources = 0.016 Land Uses x Seasons = NS
Seasons = 0.016 Water Sources x Seasons = NS

4.4.3 Lead (Pb)

Table 4.16 depicted that Pb content varied from 0-0.038 mg l^{-1}. Lead concentration was found to be influenced by different land uses, water sources and seasons. Higher Pb content (0.021 mg l^{-1}) was recorded under urban/peri-urban land use followed by agriculture (0.004 mg l^{-1}) and lower in forest land use (0.001 mg l^{-1}). In surface water sources, higher content of Pb (0.012 mg l^{-1}) was noticed in comparison to ground water sources (0.005 mg l^{-1}). Season wise, monsoon season registered higher content of Pb (0.010 mg l^{-1}) in relation to winter season (0.007 mg l^{-1}). All the interactional effects of land uses, water sources and seasons was found to be impacted. The combined effect of land use and water sources showed that surface water sources recorded Higher Pb (0.031 mg l^{-1}) under urban/peri-urban land use preceded by agriculture (0.004 mg l^{-1}) and lower in forest (0.001 mg l^{-1}) whereas similar pattern was also observed for ground water sources. Land use and season was found to be significantly affected the Pb concentration. Monsoon season recorded higher Pb concentration (0.025 mg l^{-1}) under urban/peri-urban land use preceded by agriculture (0.004 mg l^{-1}) and lower in forest (0.001 mg l^{-1}). Land use behaved in similar fashion during winter season. Water sources and seasons significantly influenced the Pb concentration. Ground water sources registered higher Pb content (0.005 mg l^{-1}) in monsoon season than winter season (0.004 mg l^{-1}). Similar trend was also recorded in surface water sources. The interactional effect of land uses, water sources and seasons was found to be significantly impacted the Pb concentration. Higher Pb content (0.038 mg l^{-1}) was found in surface water sources under urban/peri-urban land use during monsoon season and lower (0.000 mg l^{-1}) under forest land use during winter season. Similar pattern was observed for ground water sources, land uses and seasons interaction. However, the recorded values for Pb was found within the permissible limit (0.05 mg l^{-1}) as given by BIS, 2012.

Higher Pb content under urban/peri-urban land use might be ascribed to the disposal and dumping of waste, vehicular emissions, spent petroleum, pigments of paints and vehicle washing units etc. The results are in congruous with the findings of Kar *et al.* (2008) and Rao *et al.* (2010) who also reported Higher Pb under urban/peri-urban land use. Pb content in surface water during monsoon season was attributed to the mixing of lead containing waste water from dumping and other sources with rain water. Similar findings were reported by Oyeku and Elucoyin (2010) who also reported Higher Pb concentration during monsoon.

Table 4.16: Seasonal Variation of Lead (Pb mg l^{-1}) in ground and surface water sources under dominant land uses

Water Sources	**Ground Water**	**Surface Water**	**Mean**	**Ground Water**	**Surface Water**	**Mean**	**Land use and Water Sources Interaction**		
Land Uses	**Winter**			**Monsoon**			**Ground Water**	**Surface Water**	**Mean of Land Use**
Urban/ Peri Urban	0.009	0.023	**0.016**	0.012	0.038	**0.025**	0.011	0.031	**0.021**
Agriculture	0.004	0.003	**0.003**	0.002	0.006	**0.004**	0.003	0.004	**0.004**
Forest	0.000	0.001	**0.001**	0.000	0.001	**0.001**	0.000	0.001	**0.001**
Mean	**0.004**	**0.009**		**0.005**	**0.015**		**0.005**	**0.012**	
Mean of Season			**0.007**			**0.010**			**0.008**

C.D. $_{0.05}$

Land Uses = 0.002
Water Sources = 0.001
Seasons = 0.001
Land Uses x Water Sources = 0.002
Land Uses x Seasons = 0.002
Water Sources x Seasons = 0.002
Land Uses x Water sources x Seasons = 0.003

4.4.4 Zinc (Zn)

The data presented in Table 4.17 revealed that Zn content ranged from 0.006 to 0.120 mg l^{-1}. Significant variations in Zn content was recorded with respect to different land uses, water sources and seasons. Agriculture land use registered higher Zn content (0.083 mg l^{-1}) whereas forest land use was recorded lower (0.013 mg l^{-1}). Ground water sources (0.058 mg l^{-1}) exhibited higher Zn concentration as compared to surface water sources (0.037 mg l^{-1}). Seasonally, higher Zn was recorded in monsoon season (0.053 mg l^{-1}) in relation to winter season (0.041 mg l^{-1}). Land uses significantly influenced the Zn concentration according to water sources and seasons. Higher concentration (0.102 mg l^{-1}) was observed in ground water sources under agriculture land use followed by urban/peri-urban (0.053 mg l^{-1}) and lower in forest land use (0.018 mg l^{-1}). Surface water was found to be behaved in the similar pattern. Higher content of Zn (0.072 mg l^{-1}) was obtained during winter season under agriculture land use succeeded by urban/peri-urban (0.041 mg l^{-1}) and lower in forest land use (0.011 mg l^{-1}). Similar trend was observed during winter season. The interactional effect of water sources and season and land uses, water sources and seasons was found to be non-significant. The recorded values were fall within the permissible limits (5 mg l^{-1}) as per BIS, 2012. Higher zinc content under agriculture land use might be attributed to the more use of fertilizers and agrochemicals including micronutrients in commercial farming of vegetables in the area. The results are in consonance with the findings of Singh *et al.* (2010) who also reported the higher concentration of Zn in agriculture land use. Higher Zn content in monsoon season and ground water might be ascribed to high runoff rates that may have accumulated Zn content from point and non-point sources and percolate to the ground water with passage of time. Similar results were reported by Kar *et al.* (2008).

Table 4.17: Seasonal Variation of Zinc (Zn mg l^{-1}) in ground and surface water sources under dominant land uses

Water Sources Land Uses	Ground Water	Surface Water	Mean	Ground Water	Surface Water	Mean	Land use and Water Sources Interaction		
	Winter			Monsoon			Ground Water	Surface Water	Mean of Land Use
Urban/ Peri Urban	0.047	0.034	**0.041**	0.058	0.041	**0.049**	0.053	0.037	**0.045**
Agriculture	0.084	0.061	**0.072**	0.120	0.068	**0.094**	0.102	0.065	**0.083**
Forest	0.016	0.006	**0.011**	0.020	0.010	**0.015**	0.018	0.008	**0.013**
Mean	**0.049**	**0.034**		**0.066**	**0.040**		**0.058**	**0.037**	
Mean of Season			**0.041**			**0.053**			**0.047**

C.D. $_{0.05}$

Land Uses = 0.007
Water Sources = 0.005
Seasons = 0.005
Land Uses x Water Sources = 0.009
Land Uses x Seasons = 0.009
Water Sources x Seasons = NS
Land Uses x Water sources x Seasons = NS

4.5.5 Nickel (Ni)

The perusal of data in Table 4.18 evinced that Ni content in surface and ground water sources varied from 0.030 to 0.360 mg l^{-1}. Land use and season was found to be significantly influenced the Ni content in water sources. Agriculture land use recorded Higher Ni content (0.243 mg l^{-1}) followed by urban/peri-urban (0.124 mg l^{-1}) and lower in forest land use (0.036

mg l^{-1}). Whereas, higher Ni content (0.185 mg l^{-1}) was noticed in monsoon season than winter season (0.083 mg l^{-1}). All the interactional effects of land use, water sources and seasons were found to be non-significant. The observed values for Ni content exceed the permissible limits as prescribed by BIS, 2012. Higher concentration of Ni under agriculture land use might be ascribed to excessive use of chemical fertilizers and pesticides in agriculture. In ground water sources might be leaching from metal pipes and fittings that are in contact with water and dissolution from the Ni ore bearing rocks or geological formations. Higher Ni content in monsoon attributed to runoff from the waste mainly containing nickel-cadmium batteries, welding products, pigments and electronic products, paints etc. Similar results were reported by (Kashyap and Verma, 2015 and Saleem *et al.*, 2015).

Table 4.18: Seasonal Variation of Nickel (Ni mg l^{-1}) in ground and surface water sources under dominant land uses

Water Sources **Land Uses**	**Ground Water**	**Surface Water**	**Mean**	**Ground Water**	**Surface Water**	**Mean**	**Land use and Water Sources Interaction**		
	Winter			**Monsoon**			**Ground Water**	**Surface Water**	**Mean of Land Use**
Urban/ Peri Urban	0.057	0.050	**0.053**	0.330	0.060	**0.195**	0.193	0.055	**0.124**
Agriculture	0.190	0.137	**0.163**	0.360	0.283	**0.322**	0.275	0.210	**0.243**
Forest	0.037	0.030	**0.033**	0.040	0.037	**0.038**	0.038	0.033	**0.036**
Mean	**0.094**	**0.072**		**0.243**	**0.127**		**0.169**	**0.099**	
Mean of Season			**0.083**			**0.185**			**0.134**

C.D. $_{0.05}$
Land Uses = 0.106
Water Sources = NS
Seasons = 0.087
Land Uses x Water Sources = NS
Land Uses x Seasons = NS
Water Sources x Seasons = NS
Land Uses x Water sources x Seasons = NS

4.5 WATER QUALITY INDEX (WQI)

4.5.1 Land use based WQI

It was observed from the data presented in Table 4.19 that urban/peri-urban land use system showed highest WQI (57.44) preceded by agriculture (45.06) and lowest (18.65) in forest land use for ground water sources. Surface water sources also acquired Higher WQI (61.65) under urban/peri-urban land use followed by agriculture (53.39) and lower in forest (27.29). Water quality of both surface and ground water sources was rated poor under urban/peri-urban land use and excellent and good under forest land. Agriculture land use exhibited good water quality for ground water sources and poor for surface water sources.

The results of the study are in confirmation with the findings of Oni and Fasakin (2016) and Shah and Joshi (2017) who also reported Higher WQI under urban/peri-urban land use.

Table 4.19: Water quality status of water sources under dominant land uses

Water Sources Land Uses	Ground Water		Surface Water	
	WQI	**Status**	**WQI**	**Status**
Urban/Peri-urban	57.44	Poor	61.65	Poor
Agriculture	45.06	Good	53.39	Poor
Forest	18.65	Excellent	27.29	Good

4.5.2 Seasonal WQI

The perusal of data presented in Table 4.20 revealed that monsoon season registered higher WQI (45.17) in comparison to winter (35.60) for ground water sources whereas similar trend was observed for surface water sources. Based on WQI the water quality of both the water sources i.e. surface and ground water was found good in winter season whereas during monsoon season good water quality was observed in ground water sources poor in surface water sources. The results are in confirmation with the findings of Reza and Singh (2010), Tareq *et al.* (2013) and Singh and Kamal (2014) who also reported Higher WQI during monsoon.

Table 4.20: Seasonal water quality status of water sources

Water Sources Seasons	Ground Water		Surface Water	
	WQI	**Status**	**WQI**	**Status**
Winter	35.60	Good	42.34	Good
Monsoon	45.17	Good	52.54	Poor

Chapter-5

SUMMARY AND CONCLUSIONS

The present investigation entitled **"Impact of Land Uses on Water Quality in Bilaspur District of Himachal Pradesh"** was conducted in Bilaspur district of Himachal Pradesh during 2019-2020 and analysis work was carried out in the department of Environmental Science, College of Forestry, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, HP. The study was conducted by selecting three dominant land uses *viz.* urban/peri-urban, agriculture and forest, two water sources i.e. surface and ground water and two seasons namely winter and monsoon season. The samples were analyzed to assess the different physico-chemical parameters such as temperature, colour, odour, turbidity, pH, EC, TDS, BOD, COD, cations and anions (Ca^{2+}, Mg^{2+}, Cl^-, and NO_3^-) and heavy metals. Water quality was assessed by developing water quality index through weighted arithmetic water quality index method based on analyzed physical and chemical parameters.

The important findings of the study have been summarized under the following heads:

5.1 PHYSICAL PARAMETERS

- Temperature of water samples recorded at the sampling site ranged from 10.83 to 17.83°C in winter season and 21.33 to 27.33°C in monsoon season. The temperature of ground water varied from 13.83 to 27.33°C whereas in surface water it ranged from 10.33 to 26.00°C.
- Under all the land uses, the colour of surface and ground water in winter was recorded clear whereas during monsoon season it was found from light brown to clear.
- The odour of both water sources under all the land uses during winter and monsoon season was found to be odour free.
- The turbidity of ground and surface water sources ranged from 1 NTU to 4.33 NTU and 1.67 NTU to 4.00 NTU respectively. Highest turbidity (4.33 NTU) was recorded in ground water under urban/peri-urban land use during monsoon season and lowest in forest land use.

5.2 CHEMICAL PARAMETERS

- pH of ground and surface water ranged from 6.96 to 8.18 and 7.55 to 8.59 respectively. Highest pH (8.59) was recorded in surface water under urban/peri-urban land use in monsoon season whereas lower (6.96) in forest land use in winter season.
- EC of surface and ground water varied from 180.00 to 615.67 µS $cm^{-1}$and 235.33 to 723.67 µS cm^{-1}. The highest value of EC (723.67 µS cm^{-1}) was recorded in ground water under urban/peri-urban land use during monsoon season. The concentration of salts exceeded the permissible limits as per the standards of ICMR for drinking water whereas within limits for irrigation water.
- TDS of ground water was found between 132.70 - 480.67 mg l^{-1} whereas in surface water it was ranged from 101.23 to 375.67 mg l^{-1}. Higher TDS (480.67 mg l^{-1}) was recorded in ground water under urban/peri-urban land use in monsoon season and lower in forest land use.
- BOD of ground and surface water sources ranged from 0.53 to 3.13 mg l^{-1} and 0.60 to 3.65 mg l^{-1}. Higher BOD value (3.65 mg l^{-1}) was recorded in surface water in monsoon season under urban/peri-urban land use and lower in forest.
- COD of ground and surface water sources was found between 39.00 - 127.67 mg l^{-1} and 44.00- 215.67 mg l^{-1}. Higher COD value (215.67 mg l^{-1}) was recorded in surface water under urban/peri-urban land use during monsoon season and lowest in forest land use.
- All the values for physio-chemical parameters were found within the permissible limits for irrigation water. Hence, the water from all the sources is suitable for irrigation purpose.

5.3 CATIONS AND ANIONS

- Calcium content in both water sources i.e. ground and surface water ranged from 35.33 to 108.00 mg l^{-1} and 58.33 to 129.67 mg l^{-1} respectively. Highest Ca^{2+} content (129.67 mg l^{-1}) was recorded in surface water under agriculture land use in winter season. The calcium concentration values were found within the permissible limit (200 mg l^{-1}) but exceed the desirable limits except forest land use, as per BIS, 2012.
- Magnesium content of surface and ground water sources ranged from 21.30 to 55.33 mg l^{-1} and 14.40 to 49.57 mg l^{-1}. Higher Mg^{2+} content (55.33 mg l^{-1}) was recorded in surface water under agriculture land use during winter season. The recorded values

were exceeding the desirable limits (30 mg l^{-1}) but remained within the permissible limits as given by BIS, 2012.

- Chloride concentration in ground and surface water sources was found between 25 - 76.67 mg l^{-1} and 36.33 - 137.67 mg l^{-1}. Higher chloride content (137.67 mg l^{-1}) was recorded in surface water under urban/per-urban land use in monsoon season.
- NO_3^- content in both the water sources i.e. surface and ground water was varied from 4.57 to 27.73 mg l^{-1} and 3.67 to 16.50 mg l^{-1}. Higher content (27.73 mg l^{-1}) was recorded in surface water under agriculture land use in monsoon season.

5.4 HEAVY METALS

- In surface and ground water sources cadmium content was found between 0.001- 0.024 mg l^{-1} and 0- 0.016 mg l^{-1}. Highest Cd content (0.024 mg l^{-1}) was recorded in ground water under urban/peri-urban land use in winter season.
- The iron content of ground and surface water sources ranged from 0.05 to 0.29 mg l^{-1} and 0.01 mg l^{-1} to 0.28 mg l^{-1}. Higher Fe content (0.29 mg l^{-1}) was observed in ground water under urban/peri-urban land use during monsoon season.
- Lead concentration in ground and surface water sources ranged from 0to 0.012 mg l^{-1} whereas in surface water it was ranged from 0.001 to 0.038 mg l^{-1}. The highest content (0.038 mg l^{-1}) was recorded in surface water under urban/peri-urban land use in monsoon season.
- Ground and surface water sources contained Zn content between 0.016- 0.120 mg l^{-1} and 0.006- 0.068 mg l^{-1} respectively. Ground water recorded higher content (0.120 mg l^{-1}) under agriculture land use in winter season.
- Ni content in ground and surface water sources ranged from 0.037 to 0.360 mg l^{-1} and 0.030 to 0.283 mg l^{-1}. Higher content (0.360 mg l^{-1}) was observed in ground water under agriculture land use in monsoon season.
- It was found that all the heavy metals under study fall within the permissible limits for drinking and irrigation except nickel.

5.5 Water Quality Index (WQI)

- Land use wise, ground and surface water quality index ranged from 18.65 to 57.44 and 27.29 to 61.65. Highest WQI (61.65) was recorded in surface water under urban/peri-urban land use which was rated as poor quality.

- Season wise, water quality index of ground and surface water sources ranged from 35.60 to 45.17 and 42.34 to 52.54 respectively. Highest WQI (52.54) was recorded in surface water during monsoon. The water quality was found poor in monsoon season whereas it was found good in winter season.

CONCLUSIONS

The study inferred that the land uses like urban/peri-urban and agriculture in Bilaspur district have started impacting the quality of surface and ground water sources. In the district, urbanization and agricultural practices have resulted poor surface water quality as compared to forest, wherein it was good. The urbanization has also impacted ground water quality in the region. The monsoon season has also influenced the surface water quality negatively. Therefore, there is urgent need to regulate urbanization and agricultural practices in the district by promoting environmental friendly development and practices for healthy ecosystem.

LITERATURE CITED

Abdel-Satar AM, Ali MH and Goher ME. 2017. Indices of Water quality and metal pollution of Nile River, Egypt. *Egyptian Journal of Aquatic Research* 43: 21-29.

Agnieszka EL, Janina ZBN, Krzysztof A, Artur G, Krzysztof K. 2016. Impact of agriculture and Land use on Nitrate contamination in groundwater and running water in central-west Poland. *Environmental Monitoring and Assessment* 188: 01-17.

Ahipathi MV and Puttaiah ET. 2006. Ecological Characteristics of Vrishabhavati river in Bangalore (India). *Ecology Geology* 49: 1217-22.

Akbarimehr M, Hosseini SA, Hodjati SM and Shariati F. 2016. Analysis of changes in stream water chemistry following logging practices in north of Iran (Darabkola Forest). *Journal of the Faculty of Forestry Istanbul University* 66: 539-47.

Akpan EK and Offem JO. 1993. Seasonal variation in water quality of the Cross River, Nigeria. *Revenue d’hydrobiologietropicale* 26: 95-103.

Aladimy STA, Ali SMS and Muke MB. 2016. Water quality study of Salim Ali lake from Aurangabad city of Maharashtra state (India) during winter season. *International Journal for Science and Advanced Research in Technology* 2: 93-100.

Aladimy STA, Jadhav PA and Mule MB. 2017. Assessment of groundwater quality of various areas of Aurangabad city, Maharashtra, India. *International Journal of Innovative Research in Science, Engineering and Technology* 6: 21698-701.

Alam JB, Islam MR, Muyen Z, Mamun M and Islam S. 2007. Water quality parameters along rivers. *International Journal of Environmental Science and Technology* 4: 159-67.

Al-Hadithi M. 2012. Application of Water Quality Index to assess suitability of groundwater for drinking purposes in Ratmao-Pathri Rao Watershed, Haridwar District, India. *American Journal of Scientific and Industrial Research* 3: 395-402.

Al-Mansori NJ. 2017. Develop and apply Water Quality Index to evaluate water Quality of Shatt-Al-Hilla- River. *Journal of Babylon University/Engineering Sciences* 25: 368-74.

Ansari K and Hemke NM. 2013. Water quality index for Assessment of Water samples of different Zones on Chandrapur City. *International Journal of Engineering Research and Applications* 3: 233-37.

APHA. 2005. Standard methods for water and waste water analysis. American Public health Association. USA.

Arnold CL and Gibbons CJ. 1996. Impervious surface coverage: The emergence of a key environmental indicator. *Journal of the American Planning Association* 62: 243-58.

Arshad MG and Shakoor A. 2017. Irrigation water quality. pp - 145-160.

Balamurugan C and Dheenadayalan M S. 2012. Ground water quality and its suitability for drinking and agricultural use in Vaigai river basin at Madurai, Tamil Nadu. India 2: 1073-78.

Balokhra JM. 2017. The Wonderland Himachal Pradesh: An Encyclopedia on a tiny state of Western Himalayas. HG Publications, New Delhi. 1632p.

Bansal J and Dwivedi AK. 2018. Assessment of Ground Water Quality by Using Water quality Index method and physico-chemical Parameters: Review Paper. *International Journal of Engineering Sciences and Research Technology* 7: 170-74.

Batabyal AK and Chakraborty S. 2015. Hydrochemistry and water quality index in the assessment of groundwater quality for drinking uses. *Water Environment Research* 87: 607-17.

Bharathi SV, Kumar PS, Rajasekar V, Saravanan N and Kannan. 2017. Hydro-chemical Assessment of Ground water in and Around Kariapatti Region. *International Research Journal of Engineering and Technology* 4: 2083-91.

BIS. 2003. Indian Standard Specification (IS: 10500: 1991, Edition 2.2) for drinking water, Bureau of Indian Standards, New Delhi.

BIS. 2012. Indian Standards (IS: 10500) Drinking Water Specification: Bureau of Indian Standards. New Delhi.

Bishnoi M and Arora S. 2007. Potable ground water quality in some villages of Haryana, India: Focus on fluoride. *Journal of Environmental Biology* 28: 291-94.

Boah DK, Twum SB, Peng-Ba KB. 2015. Mathematical Computation of water quality Index of Vea Dam in Upper East Region of Ghana. *Environmental Sciences* 3: 11-16.

Bola GS, Rao GVRS, Raju PARK, Raju MJ. 2017. Water Quality Index: A tool for evaluation of Surface water Quality. *International Journal of Civil Engineering and Technology* 8: 814-21.

Boyd CE. 1981. Water Quality in warm water fish ponds. Anburn University, Alabama. Craftmaster Printers, Inc. Opelika, Alabama. 354p.

Brown RM, Mc-Cleiland NJ, Deiniger RA and O’Connor MFA. 1972. “Water quality index – crossing the physical barrier”, (Jenkis, S.H. ed.) Proceedings in International Conference on water pollution Research Jerusalem 6: 787-97.

Burkholder J, Libra B, Weyer P, Heathcote S, Kolpin D, Thorne PS and Wichman M. 2007. Impacts of Waste from Concentrated Animal feeding operations on water quality. *Environmental Health Perspectives.* 115: 298-312.

Calmels D, Gaillardit J and Francois L. 2006. Modelling and impact of vegetation on carbonate weathering rates. *Geophysical Research Abstracts* 8: 09690.

Carpenter SR, Caraco NF, Correl DL, Howrath RW, Sharpley AN and Smith VH. 1998. Non-point pollution of Surface waters with phosphorus and nitrogen. *Ecological Applications* 8: 559- 68.

Cerqueria TC, Mendonca RL, Gomes RL, de-Jesus RM, and de-Silva DML. 2020. Effects of Urbanization on water quality in a watershed in northeastern Brazil. *Environmental Monitoring and Assessment* 192: 01-17.

Chandra DS, Asadi SS and Raju MVS. 2017. Estimation of water quality Index by Weighted Arithmetic Water quality Index Method: A model Study. *International Journal of Civil Engineering and Technology* 8: 1215-22.

Chauhan A and Verma SC. 2016. Impact of Land Uses and Seasons on Physico-chemical Characteristics of Surface water in Solan District of Himachal Pradesh. *Nature Environment and Pollution Technology* 15: 667-72.

Chauhan S and Bhardwaj SK. 2017. Effect of different land use on quality of water in Solan Block of Himachal Pradesh. *Indian Journal of Ecology* 44: 808-12.

Chen Q, Lu Z, Yan D, Wang Q and Xin S. 2019. Sources analysis and health risk of heavy metals in the different seasons from Taizihe River, China. *Acta Ecologica Sinica* 0: 64.-71.

Chen X, Zhou W, Pickett STA, Li W and Han L. 2016. Spatial-temporal variations of water quality and its relationship to land use and land cover in Beijing, China. *International Journal of Environmental Research and Public Health* 13:449.

Chigor VN, Umoh VJ, Okuofu CA, Ameh JB, Igbinosa EO and Okah AI. 2011. Water quality assessment: Surface water sources used for drinking and irrigation in Zaria, Nigeria are a public health hazard. *Environmental Monitoring and Assessment* 184: 3389-400.

CPCB. 2008. Guidelines for Water Quality Monitoring. Central Pollution Control Board, Delhi-32.

Ding J, Jiang Y, Fu L, Liu Q, Peng Q and Kang M. 2015. Impacts of Land Use on Surface Water Quality in a subtropical River Basin: A case study of the Dongjiang River basin, southeastern China. *Water* 7: 4427- 45.

Douglas I. 2006. Peri-urban ecosystems and societies transitional zones and contrasting values. D McGregor, D Simon and D Thompson (Eds.) In Peri-urban Interface: Approaches to Sustainable Natural and Human Resource Use, Earthscan Publication Ltd., London, UK. pp-18-29.

Dudley BD, Burge OR, Plew D and Zeldis J. 2020. Effects of agricultural and Urban Land Cover on New Zealand's estuarine water quality. *New Zealand Journal of Marine and Freshwater Research* 54: 372-92.

Dutta B and Sarma B. 2018. Correlation study and Regression Analysis of ground water quality assessment of Nagaon town of Assam, India. *International Journal of Engineering Research and Technology* 7: 320-31.

Dwivedi P and Odi P. 2003. Evaluation of potable water quality in streams and the Dickrong river in the district Papum Pore, Arunachal Pradesh. *Indian Journal of Ecology, Environment and Conservation* 9: 437-40.

Elshemy M. 2016. Water Quality Assessment of Lake Manzala Egypt: A comparative study. *International Journal of Scientific Research in Environmental Sciences* 4: 196-207.

FAO. 1985. Water Quality for Agri. Irrigation and Drainage paper No. 29 Rev. 1. Food and Agriculture Organization of the United Nations, Rome, Italy. 182p.

Fokmare AK and Musaddiq M. 2002. A study of physico-chemical characteristics of Kapsilake and Purna rivers in Akola district of Maharashtra (India). *Nature Environment and Pollution Technology* 1: 261-63.

Foley JA, Defries R, Asner GP,Barford C, Bonan G, Carpenter SR, Chapin FS, Coe MT, Daily GC, Gibbs HK, Helkowski JH, Holloway T, Howard EA, Kucharik CJ, Monfreda C, Patz JA, Prentice C, Ramankutty N and Snyder PK. 2005. Global Consequences of Land use. *Science* 309:570-74.

Foster SSO and Chilton PJ. 1993. Groundwater systems in the humid tropics. In: Bonell M, Hufschmidt MM and Glaclwell (eds.). Hydrology and Water management in the humid tropics. pp- 261-72.

Gangwar RK, Singh J, Singh AP and Singh DP. 2013. Assessment of Water Quality Index: A Case study of River Ramganga at Bareilly U.P. India. *International Journal of Scientific and Engineering Research* 4: 2325-329.

Ghosh MK, Ghosh S and Tiwari R. 2013. A Study of water Quality Index Assessment of Ground Water and Pond water in Sirsakala village of Bhilai-3, Chhatisgarh, India. *International Journal of Civil, structural, Environmental and Infrastructure Engineering Research and Development* 3: 63-74.

Giri S and Qiu Z. 2016. Understanding the relationship of land uses and water quality in twenty first century: A review. *Journal of Environmental Management* 173: 41- 48.

Gomez KA and Gomez AA. 1984. Statistical procedures for agricultural research (2nd ed.). John wiley and sons, New York. 680p.

Grasby SE, Hutcheon I and Krouse I. 1997. Application of the stable isotope composition of SO_4^{2-} to tracing anomalous TDS in Nose Creek, Southern Alberta, Canada. *Applied Geochemistry* 567: 567-75.

Gupta P, Agarwal S and Gupta I. 2010. Assessment of Physico-chemical parameters of various lakes of Jaipur, Rajasthan, India. *Indian Journal of Fundamental and Applied Life Sciences* 1: 246-48.

Hamilton LS, Gilmou DA and Cassells DS. 2005. Montane forests and forestry. In: Messerli B and Ives JD (eds.). Mountains of the world: a global priority. pp- 281-311.

Hoorman J, Hone T, Sudman Jr. T, Dirksen T, Iles J and Islam KR. 2008. Agricultural Impacts on Lake and stream water quality in Grant Lake St. Marys, Western Ohio. *Water, Air and Soil Pollution* 193: 309-22.

Huang J, Zhan J, Yan H, Wu F and Deng X. 2013. Evaluation of Impacts of land Use on Water Quality: A case study in the Chaou Lake Basin. *The scientific World journal* 2013: 1-7.

ICMR. 1975. ICMR Manual of Standards of quality for drinking water supplies. ICMR, New Delhi.

Inayathulla M, Paul JM. 2013. Water Quality Index Assessment of Ground Water in Jakkur Sub Watershed of Bangalore, Karnataka, India. *International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development* 3: 99-108.

Irene G. 1991. Saw mill river: The effect of urbanization on water quality of America. 2nd edition. Kendall/Hunt Company, Dubuque, Lowa. pp-45-48.

Islam M, Ahmed AM, Barman B, Dakua S and Debnath D. 2014. Studies on physico-chemical properties of water in some selected sites of Deepor Beel (Ramsar site), Assam, India. *The Clarion: international Multidisciplinary Journal* 3: 25-32.

James RA, Ernest EH, John TR and Richard EW. 1976. A Land use and land cover classification system for use with remote sensor data. Geological Survey Professional Paper 964. 28p.

Jana P and Todaria NP. 2017. Water quality status in sacred grooves of Garhwal Himalaya, India. *Forestry Ideas* 23: 11-23.

Jana P, Dasgupta S and Todaria. 2017. Impact and ecosystem service of forest and sacred grove as savior of water quantity and quality in Garhwal Himalaya, India. *Environmental Monitoring and Assessment* 189: 476-77.

Jeyaruba T and Thushyanthy M. 2009. The effect of agriculture on quality of ground water: A case study Jaffina, Sri Lanka. *Middle East Journal of Scientific Research* 4: 110-14.

Ji Y, Wu J, Wang Y, Elumalai V and Subramani T. 2020. Seasonal Variation of Drinking water Quality and Human Health Risk Assessment in Hancheng City of Guanzhong Plain, China. *Exposure and Health* 17p.

Jindal R and Sharma C. 2011. Studies on water quality of Sutlej river around Ludhiana with reference to Physiochemical parameters. *Environmental Monitoring and Assessment* 174: 417-25.

Joseph PV and Jacob C. 2010. Physicochemical characteristics of Pennar River: A freshwater wetland in Kerala, India. *E-Journal of Chemistry* 7: 1266-73.

Joshi DM, Kumar A and Aggarwal N. 2009. Studies on physico-chemical parameters to assess the water quality of River Ganga for drinking purpose in Haridwar district. *Rasayan Journal of Chemistry* 2: 195-203.

Kalavathy ST, Sharma R and Sureshkumar P. 2011. Water quality Index river Cauvery in Tiruchirappalli district, Tamilnadu. *Archives of Environmental Science* 5: 55-61.

Kamboj N, Matta G, Bharti M, Kumar A, Kamboj V and Gautam RK. 2017. Water quality categorization using WQI in rural areas of Haridwar, India. *ESSENCE – International Journal for Environmental Rehabilitation and Conservation* 8: 108-16.

Kanakiya RS, Singh SK and Sharma JN. 2014. Determining the Water Quality Index of and Urban water body Dal Lake, Kashmir, India. *Journal of Environmental Science, Toxicology and Food Technology* 8: 64-71.

Kandler M, Blechinger K, Seidler C, Pavlu V, Sanda M, Dostal T, Krasa J, Vitvar T and Stich M. 2016. Impact of land use on water quality in the upper Nisa catchment in the Czech Republic and in Germany. *Science of the Total environment* 586: 1316-25.

Kangabam RD and Govindaraju M. 2017. Anthropogenic activity-induced water quality degradation in the Loktak Lake, a Ramsar site in the Indo-Burma biodiversity hotspot. *Environmental Technology* 10p.

Kar D, Sur P, Mandal SK, Saha T and Kole RK. 2008. Assessment of heavy metal Pollution in Surface water. *International Journal of Environment Science and Technology* 5: 119-24.

Kashyap R and Verma KS. 2015. Seasonal Variation of certain heavy metals in Kuntbhyog Lake of Himachal Pradesh, India. *Journal of Environment, Ecology, Family and Urban Studies* 1: 15-26.

Khaiwal R, Ameena, Meenakshi, Monika, Rani and Kaushik A. 2003. Seasonal variations in physico-chemical characteristics of River Yamuna in Haryana and its ecological best-designated use. *Journal of Environmental Monitoring* 5: 419-26.

Khatri N, Tyagi S and Rawtani D. 2016. Assessment of Drinking Water quality and its health effects in Rural Areas of Harij Taluka, Paton District of Northern Gujrat. *Environmental Claims Journal* 0: 01-24.

Khaund NJ, Phukon P and Bhattacharya KG. 2012. Physico-chemical studies on surface water quality in the Jia-Bharoli river Basin, North Brahmputra Plain, India. *Archives of Applied Science Research* 4: 1169-74.

Khwakaram AI, Majid SN and Hama NY. 2012. Determination of Water quality index (WQI) for Qalyasan stream in Sulaimani city/ Kurdistan region of Iraq. *International Journal of Plant, Animal and Environmental Sciences* 2: 148-57.

Kolpin D, Burkart M and Goolsby D. 1999. Nitrate in groundwater of the Midwestern United States: a regional investigation on relations to land use and soil properties. Impact of Land uses change on Nutrient loads from Diffuse sources. In Proceedings of IUGG 99 Symposium HS3 (pp.-111-116) Birmingham.

Kumar A and Dua A. 2009. Water Quality Index for Assessment of Water Quality of River Ravi at Madhopur (India). *Global Journal of Environmental Sciences* 8: 49-57.

Kumar B, Singh UK and Ojha SN. 2018. Evaluation of geochemical data of Yamuna River using WQI and multivariate statistical analysis: A case study. *International Journal of River Basin System* 17:143-55.

Lokhande RS, Singare PU and Pimple DS. 2011. Pollution in Water of Kasardi River flowing along Taloja Industrial Area of Mumbai, India. *World Environment* 1: 6-13.

Luo P, Kang S, Apip, Zhou M, Lyu J, Aisyah S, Binaya M, Regmi RK and Nover D. 2019. Water Quality trend assessment in Jakarta: A rapidly growing Asian Megacity. *Plos One* 14: 1-17.

Machender G, Dhakate R, Reddy MN and Peddy IP. 2014. Hydrogeochemical characteristics of surface water (SW) and groundwater (GW) of the Chinnaeru River basin, northern part of Nalgonda District, Andhra Pradesh, India. *Environment and Earth Science* 71: 2885-910.

Madhsudhan R and Inayathulla M. 2015. Assessment of Groundwater quality in and around Bidadi Industrial Area, Ramanagar District, Karnataka. *International Journal of Applied Engineering Research and Development* 5: 3-12.

Mahadev J, Gholami S. 2010. Heavy metal analysis of Cauvery river water around Krs dam, Karnataka, India. *Journal of Advanced Laboratory Research in Biology* 1:10-14.

Mallanagoud G, Manjappa S and Suresh B. 2016. Hydrochemistry of Fresh surface water (tanks) in Hospet city (India) based on water quality index (WQI). *International Journal of Science Technology & Engineering* 3: 73-77.

Mathur P, Agarwal P and Nag M. 2008. Assessment of Physico-chemical characteristics and suggested restoration measures for Pushkar lake, Ajmer Rajasthan (India). Proceedings of Taal 2007: The 12th lake conference. pp-1518-29.

Mathuram T, Chandran M and Dinakaran K. 2017. Study on Physico-chemical parameters of surface water of Vaigai river near Madurai City, Tamil Nadu, India. *International Journal of Creative Research Thoughts* 5: 2368- 91.

Maurya PM and Singh VK. 2016. An analysis of Physico-chemical parameters and water quality index of Suraila taal in summer season. *Centum* 9: 300-06.

Maurya PM. 2016. An analysis of physico-chemical parameters and water quality index of suraila taal in winter season. *Renewable Research Journal* 4: 223-30.

Mendivil-Garcia K, Amabilis- Sosa LE, Rodriguez-Mata AE, Rangel-Peraza JG, Gonzalez-Huitron V and Cedillo-Herrera CIG. 2020. Assessment of intensive agriculture on water quality in the Culiacan River Basin, Sinaloa, Mexico. *Environmental Science and Pollution Research* 16p.

Mishra PC and Patel RK. 2001. Quality of drinking water in Rourkela, outside the steel township. *Journal of Environmental Pollution* 8: 165-169.

Mullane N. 1997. The Willamette River of Oragon: A River restored. In: A.Laenen and D. A. Dunnette, eds. River Quality Dynamics and Restoration. New York: Lewis Publishers, CRC Press. pp - 69.

Nayak JG, Patil LG. 2016. Assessment of water quality of Godavari river at Nashik, Maharashtra, India. *International Journal of Civil Engineering and Technology* 7: 83-92.

NCERT. 2015. India People and Economy. NCERT, New Delhi. 168p.

Neto R, Luz LD and Aguiar Jr. TR. 2020. Springs' Water Quality Assessment in Areas with different degrees of Forest Conservation: a study in Tropical Climate Basins. *Water, Air and Soil Pollution* 231: 227p.

Ngoye E and Machiwa JF. 2004. The influence of land-use patterns in the Ruvu river watershed on water quality in the river system. *Physics and chemistry of the earth* 29: 1161- 66.

Nihalani S and Meeruty A. 2020. Water Quality Index Evaluation for major rivers in Gujrat. *Environmental Science and Pollution Research* 1: 1-10.

Nikolaidis C, Mandalos P and Vantarakis A. 2008. Impact of Intensive agricultural Practices on Drinking water quality in EVROS Region (NE GREECE) by SIS analysis. *Environmental Monitoring and Assessment* 143: 43.50.

Nkwocha EE, Pat M, Bano EC and Nnnaji AO. 2011. Effect of solid waste dump on river water quality: A paradigm in a Nigerian Tropical environment. *International Journal of Science and Nature* 2: 501-07.

Ohwo O and Abotutu A. 2014. Access to potable water supply in Nigerian cities evidence from Yenagoa metropolis. *American Journal of Water Resources* 2: 31-36.

Olasoji SO, Oyewole NO, Abiola B and Edokpayi JN.2019. Water Quality Assessment of Surface and Ground Water sources using a Water Quality Index Method: A case Study of a Peri-Urban Town in Southwest Nigeria. *Environments* 6: 01-11.

Oni O and Fasakin O. 2016. The Use of Water Quality Index method to determine the Potability of Surface water and Ground water in the Vicinity of a Municipal Solid waste Dumpsite in Nigeria. *American Journal of Engineering Research* 5: 96-101.

Ouyang Y, Jin W, Grace JM, Obalum SE, Zipperer WC and Huang X. 2019. Estimating impact of forest land on groundwater recharge in a humid subtropical watershed of the lower Mississippi River Alluvial Valley. *Journal of Hydrology: Regional studies* 13p.

Oyeku OT and Eludogin AO. 2010. Heavy metal contamination of ground water resources in a Nigerian urban settlement. *African Journal of Environmental Sciences and Technology* 4: 201-14.

Pallisamy PN and Geetha A. 2007. Assessment of groundwater quality in and around Gobichettipalayam town Erode district, Tamil Nadu, India. *E-Journal of Chemistry* 4: 434-39.

Pande KS and Sharma SD. 1998. Studies of toxic pollutants in Ramganga river at Moradabad India. *Environment Geology* 1: 93-96.

Pandey J, Shubhashish K and Pandey R. 2010. Heavy Metal contamination of Ganga river at Varanasi in relation to atmospheric deposition. *Tropical Ecology* 51: 365-73.

Panobokke C R, Pathirana S R K and Wijekoon D. 2002. Water quality of agro well in the coastal sand aquifier in the Trinwlcenalee district. Proceedings symposium on the use of ground water for agriculture in Sri Lanka 30th of September 2002 (pp. 1-12) Peraeniya, Sri Lanka.

Pathak SK, Prasad S, Pathak T. 2015. Determination of water quality index River Bhagirathi in Uttarkashi, Uttarakhand, India. *International Journal of Research Granthaalayah: Acknowledge repository.* 3: 1-7.

Paul JM, Biju AS, George BM, Alex EC and Saranya R. 2015. Studies on Groundwater quality in and around Kothamangalam Taluk, Kerala, India. *Journal of Mechanical and Civil Engineering* 12: 41-45.

Paul JM, Jitto J, Liya AS, George M and Shayamkrishna PS. 2018. Evaluation of Water Quality Index of Surface Water in Kuroorthodu River, Kothamangalam, Kerala, India. *Journal of Mechanical and Civil Engineering* 15: 01-06.

Pawar SM, Bhansali AR, Dhomse SV, Jain AS, Jain MM and Nahar S. 2016. Determination of Water Quality Index of Khokad Talav and its percolated water in Rangmahal Vihir & Tubewell on Downstream at Chandwad. *International Journal of Modern Trends in Engineering and Research* 3: 556-61.

Pereira P, Pablo HD, Vale C, Franco V and Nogueira M. 2009. Spatial and seasonal variation of water quality in an impacted coastal lagoon (Obidos Lagoon, Portugal). *Environmental Monitoring and Assessment* 153: 281-92.

Phiri O, Momba P, Moyo RHZ and Kadewa W. 2005. Assessment of the impact of industrial effluents on water quality of receiving rivers in urban areas of Malavi.*International Journal of Environmental Science and Technology* 2: 237-44.

Potasznik A and Szymczyk S. 2015. Magnesium and Calcium concentrations in surface water and bottom deposits of a river-lake system. *Journal of Elementology* 20: 677-92.

Project Report. 2009. Developing District-wise land use of Himachal Pradesh. Centre for Geo-Informatics, Research and Training CSK Himachal Pradesh Agriculture University, Palampur, HP, India. 47p.

Pullanikkatil D, Palamulini LG and Ruhiiga TM. 2015. Impact of land use on water quality in the likangala catchment, Southern Malawi. *African Journal of Aquatic Sciences* 40: 277-86.

Puri R. 2011. Study regarding Lake Water Pollution with Heavy Metals in Nagpur City (India). *International Journal of Chemical, Environmental, and Pharmaceutical Research* 2: 34-39.

Qureshimatva UM, Gamit SB, Maurya RR, Patel RD and Solanki HA. 2015. Correlation of various physico-chemical parameters and water quality index (WQI) of Chandola lake, Ahmedabad, Gujrat, India. *International Research Journal of Pharmacy* 10: 01-12.

Rajankar PN, Tambekar DH and Water SR. 2011. Groundwater quality and water quality index at Bhandara District. *Environmental Monitoring and Assessment* 179: 619-25.

Ramakrishanaiah CR, Sadashivaiah C and Ranganna G. 2009. Assessment of Water Quality Index for the Groundwater in Tumur Taluk, Karnataka State, India. *E - Journal of Chemistry* 6: 523-30.

Ramesh K and Pavithra P. 2016. Groundwater Quality Assessment in hard rock terrain of Rasipuram Taluk, Namakkal District. *International Journal of Engineering Research and Applications* 6: 58-68.

Rana A, Bhardwaj SK, Thakur M and Verma S. 2016. Assessment of Heavy Metals in Surface and Ground Water Sources under Different Land Uses in Mid-hills of Himachal Pradesh. *International Journal of Bio-resource and Stress Management* 7: 461-65.

Rana A. 2012. Effect of Different Land Uses on water quality in Solan block of District Solan (HP). M.Sc.Thesis Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) 91p.

Rao CS, Rao BS and Hariharan AVLNSH. 2010. Analysis of heavy metals in groundwater from Guntur district (AP). *International Journal of Pharma World Research* 1: 1-11.

Rao NS. 2006. Seasonal variation of ground water quality in a part of Guntur District, Andhra Pradesh, India. *Environmental Geology* 49: 413-29.

Raveen R, Chennakrishnan C and Stephen A. 2008. Impact of pollution on the quality of water in three fresh water lakes of Sunderban Chennai. *Nature Environment and Pollution Technology* 7: 61-64.

Reddy V, Prasad KKL, Swamy M and Reddy R. 2009. Physico-chemical parameters of Pakhal lake of Warangal district Andhra Pradesh, India. *Journal of Aquatic Biology* 24: 77-80.

Reza R and Singh G. 2010. Assessment of ground water quality status by using water quality index method in Orrisa, India. *World applied sciences Journal* 9: 1392-97.

Rodriguez-Romero AJ, Rico-Sanchez AE, Mendoza-Martinez E, Gomez-Ruiz A, Sedeno-Diaz JE and Lopez-Lopez E. 2018. Impact of changes of Land Use on Water Quality, from Tropical Forest to Anthropogenic Occupation: A Multivariate Approach. *Water* 10: 01-16.

Rosli N, Gandaseca S, Gerusu GJ, Heng RKJ, Ahmed OH, Idris MH and Pazi AMM. 2020. Quality of Tropical river in different catchments of canopy cover. *The Malaysian Forester* 83: 128-48.

Rout C and Setia B. 2018. Assessment of ground water quality for suitability of industrial purposes. *International Research Journal of Environmental Sciences* 7: 8-16.

Rowe DR, Abdel-Magid IM. 1995. Handbook of wasterwater Reclamation and Reuse CRC Press, Boca Raton, Florida. 576 p.

Saini D and Dube KK. 2018. To study the water quality status of river Narmada with special reference to B.O.D and C.O.D at Jabalpur region in M.P (India). *International Journal of Research and Analytical Reviews* 5: 194-97.

Saleem M, Iqbal J Akther G and Shah MH. 2015. Spatial/Temporal Characterization and Risk Assessment of Trace metals in Mangla Reservoir, Pakistan. *Journal of Chemistry* 11p.

Sanap RR, Mohite AK, Pingle SD and Gunale VR. 2006. Evaluation of water qualities of Godavari river with reference to Physico-chemical parameters district Nasik (MS), India. *Pollution Research* 25: 775-78.

Sankar R,Ramkumar L, Rajkumar M, Sun J and Ananthan G. 2010. Seasonal variation in physico-chemical parameters and heavy metals in water and sediments of Uppanar estuary, Nagapattinam, India. *Journal of Environmental Biology* 31: 681-86.

Sarma J, Saikia MD, Bormudoi A. 2017. Analysis of Water Quality Index Parameters and its Seasonal Variations along the Kolong River, Assam, India. *International Research Journal of Engineering and Technology* 4: 2589-98.

Saxensa P, Dubey SK and Bassin JK. 2014. Seasonal Variation and Assessment of WQI of raw water quality in water treatment plants at Delhi, India. *International Journal of Plant, Animal and Environmental Sciences* 4: 49-59.

Shah KA and Joshi GS. 2017. Evaluation of Water Quality Index for River Sabarmati, Gujrat, India. *Applied Water Science* 7: 1349-58.

Shaik AM and Mandre PN. 2009. Seasonal study of Physico-chemical parameters of drinking water in Khed (lote) industrial area. *International Research Journal*. 2: 169-72.

Sharda AK and Sharma MP. 2013. Water quality assessment of Swan river in Himachal Pradesh, India. *International Journal of Environmental Sciences* 4: 402-14.

Sharma KK, Singh D and Sharma A. 2015. Seasonal Variations in the Water Quality Parameters from Manawar Tawi River in Rajouri District of J&K, India. *Indian Journal of Applied Research* 5: 759-63.

Shinde SD, Patil KA and Sadgir PA. 2016. Impact of polluted river water of agricultural area and its sustainability for irrigation. *Journal of Civil and Environmental Engineering* 6: 1-12.

Shirodkar VR, Gaonkara VS, Gaonkara VS, Chauhan K and Kankonkar VS. 2019. Determining Water Quality Index for the Evaluation of Water Quality of Kali River, Karnataka. *International Journal in IT and Engineering* 7: 13-29.

Singare PU, Lokhande RS and Jagtap AG. 2010. Study of physico-chemical quality of the industrial waste water effluent from Gove industrial area of Bhiwandi city, Maharashtra, India. *Interdisciplinary Environmental Review* 11: 263-73.

Singh A, Meetei NS, Meetei LB. 2013. Seasonal Variation of Some Physico-Chemical Characteristics of Three Major Rivers in Imphal, Manipur: A comparative Evaluation. *Current World Environment.* 8: 93-102.

Singh G and Kamal RK. 2014. Application of water quality index for assessment of surface water quality status in Goa. *Current World Environment.* 9: 994-1000.

Singh MR, Gupta A and Beeteswari KH. 2010. Physico-chemical properties of water sample from Manipur river system, India. *Journal of Applied Science and Environment Management.* 14: 85-89.

Sliva L and Williams DD. 2001. Buffer zone versus whole catchment approaches to studying land use impact on river water quality. *Water Research* 35: 3462 - 72.

Solanki HA, Verma PU and Chandawat DK. 2011. Evaluating the water quality of Malav Lake by mean of physico-chemical analysis. *Life Sciences Leaflets* 20: 944-55.

Srivastava R K, Sinha A K, Pande DP, Singh KP and Chandra H. 1996. *Environmental Toxicology and Water Quality: An International Journal* 11: 1-5.

Srivastava V, Prasad C, Gaur A, Goel DK and Verma A. 2016. Physico-Chemical and Biological Parameters Investigation of River Ganga: from Source to Plain of Allahabad in India. *European Journal of Experimental Biology*. 6: 6-15.

Sudarshan P, Mahesh MK and Ramachandra TV. 2019. Assessment of Seasonal Variation in Water Quality and Water Quality Index (WQI) of Hebbal Lake, Bangalore, India. *Environment and Ecology* 37: 309-17.

Tareen AK, Sultan IN, Parakulsuksatid P, Safi M, Khan A, Khan MW and Hussain S. 2014. Detection of Heavy Metals (Pb, Sb, Al, As) through atomic absorption spectroscopy from drinking water of District Pishin, Balochistan, Pakistan, *International Journal of Current Microbiology and Applied Sciences* 3: 299-308.

Tareq SM, Rahaman MS, Rikta SY, Islam SMN and Sultana MS. 2013. Seasonal Variations in Water Quality of the Ganges and Brahmaputra River, Bangladesh. *Jahangirnagar University Environmental Bulletin.* 2: 71-82.

Taskeena H, Saltanat P, Bilal NB and Uzma A. 2017. Seasonal variation in Water Quality Parameters of River Yamuna, India. *International Journal of Current Microbiology and Applied Science and Applied Science* 5: 694-712.

Tiwari S, Dwivedi HP and Dwivedi A. 2017. Physico-chemical analysis of Hydrosphear water quality of Deosar block Distric-Singrauli, Madhya Pradesh, India. *International Journal of Advanced Research in Chemical Science* 4: 22-26.

Toscano CAR, Villanueva RAC, Martinez RC, Bermea OM, Alvarez EH, Delgado OB and Olivera JAA. 2020. Hydrogeochemical characteristics and Assessment of Drinking water quality in the urban area of Zanora, Egypt. *Water* 12: 1-26.

Trivedi P, Bajpai A and Thareja S. 2010. Comparative study of Seasonal variation in Physico-chemical characteristics in drinking water quality of Kanpur, India with reference to 200 MLD filtration Plant and ground water. *Nature and science* 8: 11-17.

Utang PB and Akpan HE. 2012. Water quality impediments to sustainable aquaculture development along selected segments of the new calabar river, Niger Delta, Nigeria. *Research Journal of Environmental and earth sciences* 4: 34-50.

Vasanthavigar M, Srinivasamoorthy K, Vijayaragavan K, Ganthi RR, Chidambaram S, Anandhan P, Manivannan R and Vasudevan S. 2010. Application of water quality index for groundwater quality assessment: Thirumanimuttar sub basin, Tamil Nadu, India. *Environmental Monitoring and Assessment* 171:595-609.

Viman OV, Oroian I andFleseriu A. 2010. Types of water pollution: point source and non-point source. *Aquaculture, Aquarium, Conservation and Legislation International Journal of the Bioflux Society* 3: 393-97.

Wagh V, Kharjule S, Mukate S, Pawar R, Aamalawar M and Varade AM. 2019. Assessment of Groundwater Quality in Aundha Nagnath Town, Maharashtra using Water Quality Index. *Journal of Geosciences Research* 4: 61-66.

Xu G, Li P, Lu K, Tantai Z, Zhang J, Ren Z, Wang X, Yu K, Shi P and Cheng Y. 2019. Seasonal changes in water quality and its main influencing factors in the Dan river basin. *Catena* 173: 131-40.

Year Book. 2018. Ground water Year Book Himachal Pradesh (2016-2017). Northern Himalayan Region, Dharamshala (HP), Central Ground Water Board, Ministry of water Resources, Government of India. 20p.

Yogendra K and Puttaiah ET. 2008. Determination of Water Quality Index and Suitability of an Urban Waterbody in Shimoga Town, Karnataka. In M Sengupta and R Dalwani (Eds.) Proceedings of Taal 2007: The World lake conference (pp.- 342-346).

Yong STY and Chen W. 2002. Modelling the relationship between land use and surface water quality. *Journal of Environmental Management* 66: 377-93.

Zhang Y, Dudgeon D, Cheng D, Thoe W, Fok L, Wang Z and Joseph HWL. 2010. Impacts of land use and water quality on micro invertebrate communities in the Pearl river drainage basin, China. *Hydrobiologia* 652:71-88.

Zhu J, Yu L, Xu T, Wei X and Yang K. 2018. Comparison of water quality in two catchments with different forest types in the headwater region of the Hun river, Northeast China. *Journal of Forestry Research* 30: 565-76.

Zongo B, Zongo F, Toguyeni A and Boussin JL. 2017. Water quality in forest and village ponds in Burkina Faso (Western Africa). *Journal of Forestry Research* 28: 1039-48.

APPENDIX-I

Table 1: Seasonal Variation of Temperature in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	7.042		
Land Uses	2	122	61	825.846
Water sources	1	26.694	26.694	361.402
Land Uses x Water sources	2	1.556	0.778	10.53
Seasons	1	812.25	812.25	10,996.62
Land uses x Seasons	2	2.167	1.083	14.667
Water sources x Seasons	1	2.778	2.778	37.607
Land Uses x Water sources x Seasons	2	0.389	0.194	2.632
Error	22	1.625	0.074	
Total	35	976.5		

Table 2: Seasonal Variation of Turbidity in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	2.722		
Land Uses	2	32.722	16.361	49.458
Water sources	1	1.361	1.361	4.115
Land Uses x Water sources	2	0.722	0.361	1.092
Seasons	1	2.25	2.25	6.802
Land uses x Seasons	2	0.167	0.083	0.252
Water sources x Seasons	1	0.028	0.028	0.084
Land Uses x Water sources x Seasons	2	0.389	0.194	0.588
Error	22	7.278	0.331	
Total	35	47.639		

Table 3: Seasonal Variation of pH in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	0.066		
Land Uses	2	3.661	1.831	372.778
Water sources	1	0.863	0.863	175.728
Land Uses x Water sources	2	0.157	0.079	16.007
Seasons	1	0.83	0.83	168.936
Land uses x Seasons	2	0.103	0.052	10.524
Water sources x Seasons	1	0.002	0.002	0.482
Land Uses x Water sources x Seasons	2	0.089	0.044	9.049
Error	22	0.108	0.005	
Total	35	5.88		

Table 4: Seasonal Variation of EC in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	1,209.72		
Land Uses	2	1,156,861.06	578,430.53	532.827
Water sources	1	51,000.69	51,000.69	46.98
Land Uses x Water sources	2	2,556.06	1,278.03	1.177
Seasons	1	8,433.36	8,433.36	7.768
Land uses x Seasons	2	498.389	249.194	0.23
Water sources x Seasons	1	103.361	103.361	0.095
Land Uses x Water sources x Seasons	2	678.722	339.361	0.313
Error	22	23,882.94	1,085.59	
Total	35	1,245,224.31		

Table 5: Seasonal Variation of TDS in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	1,532.68		
Land Uses	2	496,363.98	248,181.99	452.219
Water sources	1	29,733.53	29,733.53	54.178
Land Uses x Water sources	2	5,040.16	2,520.08	4.592
Seasons	1	2,067.50	2,067.50	3.767
Land uses x Seasons	2	1,526.74	763.37	1.391
Water sources x Seasons	1	877.852	877.852	1.6
Land Uses x Water sources x Seasons	2	1,789.74	894.872	1.631
Error	22	12,073.80	548.809	
Total	35	551,005.98		

Table 6: Seasonal Variation of BOD in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0.195		
Land Uses	2	21.174	10.587	109.599
Water sources	1	0.798	0.798	8.261
Land Uses x Water sources	2	0.071	0.036	0.368
Seasons	1	10.049	10.049	104.029
Land uses x Seasons	2	0.1	0.05	0.517
Water sources x Seasons	1	0.086	0.086	0.891
Land Uses x Water sources x Seasons	2	0.09	0.045	0.468
Error	22	2.125	0.097	
Total	35	34.689		

Table 7: **Seasonal Variation of COD in ground and surface water sources under dominant land uses**

ANOVA

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	2,524.67		
Land Uses	2	72,875.17	36,437.58	55.193
Water sources	1	15,170.03	15,170.03	22.979
Land Uses x Water sources	2	11,926.06	5,963.03	9.032
Seasons	1	6,162.25	6,162.25	9.334
Land uses x Seasons	2	367.167	183.583	0.278
Water sources x Seasons	1	56.25	56.25	0.085
Land Uses x Water sources x Seasons	2	205.167	102.583	0.155
Error	22	14,524.00	660.182	
Total	35	123,810.75		

Table 8: **Seasonal Variation of Calcium in ground and surface water sources under dominant land uses**

ANOVA

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	325.389		
Land Uses	2	22,907.06	11,453.53	352.937
Water sources	1	2,352.25	2,352.25	72.484
Land Uses x Water sources	2	547.167	273.583	8.43
Seasons	1	992.25	992.25	30.576
Land uses x Seasons	2	20.167	10.083	0.311
Water sources x Seasons	1	0.25	0.25	0.008
Land Uses x Water sources x Seasons	2	27.167	13.583	0.419
Error	22	713.944	32.452	
Total	35	27,885.64		

Table 9: Seasonal Variation of Magnesium in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	27.438		
Land Uses	2	5,093.32	2,546.66	286.527
Water sources	1	262.981	262.981	29.588
Land Uses x Water sources	2	8.152	4.076	0.459
Seasons	1	659.629	659.629	74.216
Land uses x Seasons	2	6.107	3.054	0.344
Water sources x Seasons	1	0.082	0.082	0.009
Land Uses x Water sources x Seasons	2	18.562	9.281	1.044
Error	22	195.536	8.888	
Total	35	6,271.80		

Table 10: Seasonal Variation of Chloride in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	332.167		
Land Uses	2	26,438.00	13,219.00	64.428
Water sources	1	6,032.11	6,032.11	29.4
Land Uses x Water sources	2	4,641.56	2,320.78	11.311
Seasons	1	1,653.78	1,653.78	8.06
Land uses x Seasons	2	59.556	29.778	0.145
Water sources x Seasons	1	4	4	0.019
Land Uses x Water sources x Seasons	2	38	19	0.093
Error	22	4,513.83	205.174	
Total	35	43,713.00		

Table 11: Seasonal Variation of Nitrate in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	41.312		
Land Uses	2	1,407.71	703.852	136.829
Water sources	1	104.721	104.721	20.358
Land Uses x Water sources	2	138.407	69.204	13.453
Seasons	1	70.001	70.001	13.608
Land uses x Seasons	2	43.184	21.592	4.198
Water sources x Seasons	1	4.272	4.272	0.83
Land Uses x Water sources x Seasons	2	11.49	5.745	1.117
Error	22	113.168	5.144	
Total	35	1,934.26		

Table 12: Seasonal Variation of Cadmium in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	0		
Land Uses	2	0.002	0.001	709.909
Water sources	1	0	0	147.256
Land Uses x Water sources	2	0	0	36.52
Seasons	1	0	0	28.666
Land uses x Seasons	2	0	0	3.903
Water sources x Seasons	1	0	0	0.742
Land Uses x Water sources x Seasons	2	0	0	3.88
Error	22	0	0	
Total	35	0.002		

Table 13: Seasonal Variation of iron in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0		
Land Uses	2	0.34	0.17	317.217
Water sources	1	0.015	0.015	27.446
Land Uses x Water sources	2	0.008	0.004	7.535
Seasons	1	0.006	0.006	10.487
Land uses x Seasons	2	0	0	0.014
Water sources x Seasons	1	0	0	0.771
Land Uses x Water sources x Seasons	2	0	0	0.324
Error	22	0.012	0.001	
Total	35	0.381		

Table 14: Seasonal Variation of Lead in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Replication	2	0		
Land Uses	2	0.003	0.001	400.639
Water sources	1	0	0	140.222
Land Uses x Water sources	2	0.001	0	105.02
Seasons	1	0	0	31.484
Land uses x Seasons	2	0	0	25.077
Water sources x Seasons	1	0	0	20.069
Land Uses x Water sources x Seasons	2	0	0	7.601
Error	22	0	0	
Total	35	0.004		

Table 15: Seasonal Variation of Zinc in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	0.001		
Land Uses	2	0.029	0.015	245.581
Water sources	1	0.004	0.004	66.071
Land Uses x Water sources	2	0.001	0.001	10.493
Seasons	1	0.001	0.001	19.919
Land uses x Seasons	2	0.001	0	4.185
Water sources x Seasons	1	0	0	4.195
Land Uses x Water sources x Seasons	2	0	0	2.907
Error	22	0.001	0	
Total	35	0.039		

Table 16: Seasonal Variation of Nickel in ground and surface water sources under dominant land uses

ANOVA

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**
Replication	2	0.058		
Land Uses	2	0.258	0.129	8.202
Water sources	1	0.043	0.043	2.759
Land Uses x Water sources	2	0.027	0.013	0.85
Seasons	1	0.093	0.093	5.913
Land uses x Seasons	2	0.042	0.021	1.35
Water sources x Seasons	1	0.02	0.02	1.276
Land Uses x Water sources x Seasons	2	0.032	0.016	1.028
Error	22	0.346	0.016	
Total	35	0.92		

APPENDIX-II

Unit weight of different parameters *w.r.t.* to standard values and their ideal values

Sr. No.	Parameter	Sn	Ideal Value (Vi)	K	(Unit weight) Wi
1	EC	300	0	1.66703	0.00556
2	TDS	500	0	1.66703	0.00333
3	pH	8.5	7	1.66703	0.19612
4	Turbidity	5	0	1.66703	0.33341
5	BOD	5	0	1.66703	0.33341
6	COD	250	0	1.66703	0.00667
7	Ca	75	0	1.66703	0.02223
8	Mg	30	0	1.66703	0.05557
9	Cl	250	0	1.66703	0.00667
10	Nitrate	45	0	1.66703	0.03705
	∑wi				1.00

Water Quality Index of ground and surface water sources under dominant land uses.

Parameters	**Ground water**			**Surface Water**		
	Urban/peri-urban (qiwi)	**Agriculture (qiwi)**	**Forest (qiwi)**	**Urban/Peri-urban (qiwi)**	**Agriculture (qiwi)**	**Forest (qiwi)**
EC	1.30028	0.96225	0.45473	1.12926	0.81191	0.35779
TDS	0.30384	0.21771	0.09474	0.25205	0.17070	0.07856
pH	0.88216	0.21650	-1.00329	1.72317	0.51030	0.00500
Turbidity	25.56112	16.67030	7.77947	25.56112	20.00436	12.22489
BOD	18.19285	13.89192	5.89017	20.25997	16.55916	7.55720
COD	0.29340	0.17515	0.12136	0.53878	0.23383	0.14581
Ca	2.19801	3.00806	1.20520	2.35113	3.66994	1.82756
Mg	7.90296	8.59138	3.67981	8.84452	9.33537	4.56581
Cl	0.18715	0.12136	0.08268	0.34185	0.14892	0.10758
Nitrate	0.61330	1.21014	0.34850	0.64623	1.94693	0.42122
∑qiwi	57.44	45.06	18.65	61.65	53.39	27.29
∑wi	1.00	1.00	1.00	1.00	1.00	1.00
WQI	57.44	45.06	18.65	61.65	53.39	27.29

Water Quality Index of ground and surface water sources in different seasons.

Parameters	**Ground Water**		**Surface water**	
	Winter (qiwi)	**Monsoon (qiwi)**	**Winter (qiwi)**	**Monsoon (qiwi)**
EC	0.87426	0.93724	0.74111	0.79153
TDS	0.19709	0.21378	0.16253	0.17168
pH	-0.33764	0.40122	0.41506	1.07726
Turbidity	14.81804	18.52255	17.78165	20.74526
BOD	9.31314	16.00349	10.94312	18.64110
COD	0.16507	0.22820	0.26791	0.34437
Ca	2.29515	1.97903	2.76933	2.46309
Mg	7.52633	5.92310	8.22196	6.94184
Cl	0.11321	0.14759	0.18048	0.21842
Nitrate	0.63754	0.81042	0.86164	1.14794
∑qiwi	35.60	45.17	42.34	52.54
∑wi	1.00	1.00	1.00	1.00
WQI	35.60	45.17	42.34	52.54

APPENDIX-III

Pattern of Statistical analysis (RBD Factorial)

Sources **Land Use**	**W_1**	**W_2**	**Mean (L×S)**	**W_1**	**W_2**	**Mean (L×S)**	**Land Use and Water Sources Interaction**		
	S_1			**S_2**			**W_1**	**W_2**	**Mean**
L_1	$L_1W_1S_1$	$L_1W_2S_1$	L_1S_1	$L_1W_1S_2$	$L_1W_2S_2$	L_1S_2	L_1W_1	L_1W_2	L_1
L_2	$L_2W_1S_1$	$L_2W_2S_1$	L_2S_1	$L_2W_1S_2$	$L_2W_2S_2$	L_2S_2	L_2W_1	L_2W_2	L_2
L_3	$L_3W_1S_1$	$L_3W_2S_1$	L_3S_1	$L_3W_1S_2$	$L_3W_2S_2$	L_3S_2	L_3W_1	L_3W_2	L_3
Mean	W_1S_1	W_2S_1	-	W_1S_2	W_2S_2	-	W_1	W_2	-
Mean of Season	-	-	S_1	-	-	S_2	-	-	-

L_1 (Urban/Peri-Urban Land Use), **L_2** (Agriculture Land Use), **L_3** (Forest Land Use)

W_1 (Ground Water Source), **W_2** (Surface Water Source)

S_1 (Winter Season), **S_2** (Monsoon Season)

Dr Yashwant Singh Parmar University of Horticulture and Forestry
Nauni-173230, Solan, HP
Department of Environmental Science

Title of Thesis	:	**Impact of Land Uses on Water Quality in Bilaspur District of Himachal Pradesh**
Name of student	:	Deeksha Sharma
Admission number	:	F-2018-12-M
Major Discipline	:	Forestry
Minor Discipline	:	Environmental Management
Date of Thesis Submission	:	
Total pages of the Thesis	:	**65+x**
Total words in abstract	:	499
Major advisor	:	**Dr MK Brahmi**

ABSTRACT

The present investigation entitled **"Impact of Land Uses on Water Quality in Bilaspur District of Himachal Pradesh"** was conducted in Bilaspur district of Himachal Pradesh by taking three dominant land uses namely urban/peri-urban, agriculture and forest, two water sources i.e. surface and ground water and two seasons i.e. winter and monsoon season. Samples were analyzed for physico-chemical parameters *viz.* temperature, colour, odour, turbidity, pH, EC, TDS, BOD, COD, cations and anions (Ca^{2+}, Mg^{2+}, Cl^-, and NO_3^-) and heavy metals. Under all the land uses, the colour of water sources varied from clear to light brown and all the samples were odour free. Higher turbidity (4.33 NTU) was recorded under urban/peri-urban land use in monsoon season. The pH of water sources ranged from 6.96 to 8.59. The highest value of EC (723.67 µS cm^{-1}) was recorded under urban/peri-urban land use in monsoon season. TDS was found between 101.23 - 480.67 mg l^{-1}. Higher TDS (480.67 mg l^{-1}) was recorded under urban/peri-urban land use in monsoon season. Higher BOD value (3.65 mg l^{-1}) was recorded in monsoon season under urban/peri-urban land use. Higher COD value (215.67 mg l^{-1}) was recorded under urban/peri-urban land use in monsoon season. Calcium content in water sources ranged from 35.33 to 129.67 mg l^{-1}. Highest Ca^{2+} content (129.67 mg l^{-1}) was recorded under agriculture land use in winter season. Higher Mg^{2+} content (55.33 mg l^{-1}) was recorded under agriculture land use in winter season. Chloride concentration in water sources was found between 25 – 137.67 mg l^{-1}. Higher chloride content (137.67 mg l^{-1}) was recorded under urban/peri-urban land use in monsoon season. NO_3^- content in both the water sources varied from 3.67 to 27.73 mg l^{-1}. Higher NO_3^-content (27.73 mg l^{-1}) was recorded under agriculture land use in monsoon season. Cadmium content was found between 0-0.024 mg l^{-1}. Highest Cadmium content (0.024 mg l^{-1}) was recorded under urban/peri-urban land use in winter season. The iron content of water sources ranged from 0.01 to 0.29 mg l^{-1}. Higher Fe content (0.29 mg l^{-1}) was observed under urban/peri-urban land use in monsoon season. Lead concentration ranged from 0 to 0.038 mg l^{-1}. Higher Zn content (0.120 mg l^{-1}) was recorded under agriculture land use in winter season. Higher Ni content (0.360 mg l^{-1}) was observed under agriculture land use in monsoon season. Highest WQI (61.65) was recorded under urban/peri-urban land use which was rated as poor quality. In monsoon season highest WQI (52.54) was recorded and water quality rated as poor. The study indicated that the land uses *viz.* urban/peri-urban and agriculture have started impacting the quality of surface and ground water sources. In the district, urbanization and agricultural practices have resulted poor surface water quality as compared to forest, wherein it was good. The urbanization has also impacted ground water quality in the region. Surface water quality has also negatively influenced during monsoon season. Therefore, there is urgent need to regulate urbanization and agricultural practices in the district by promoting environmental friendly development and practices for healthy ecosystem.

Signature of Student	**Signature of Major advisor**
Name: Deeksha Sharma	**Name: Dr MK Brahmi**
Date:	**Date:**

Countersigned

Professor and Head
Department of Environmental Science

BRIEF BIO-DATA

Name : Ms Deeksha Sharma
Father's Name : Shri Ram Lal Sharma
Mother's Name : Smt Kiran Bala
Date of Birth : 18-04-1997
Sex : Female
Permanent Address : Village Balh, P.O. Tantha, Tehsil Ghumarwin, District Bilaspur, Himachal Pradesh-174003.

Academic Qualifications:

Certificate/Degree	Year	School/College	Board/ University	Percentage/ OGPA
Matriculation/10th	2012	Rishikul Vidyapeeth, Sonipat, Haryana	CBSE, New Delhi	9.4
10+2	2014	Rishikul Vidyapeeth, Sonipat, Haryana	CBSE, New Delhi	83.8
B.Sc. (Honors) Forestry	2018	College of Forestry	Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, (HP)	7.36

Whether sponsored by some state/ Central Govt./Univ./SAARC : NA

Scholarship/ Stipend/ Fellowship, any : NA

(DEEKSHA SHARMA)