

**EFFECT OF DIFFERENT LAND USES ON WATER
QUALITY OF DHARMPUR BLOCK OF SOLAN
DISTRICT OF HIMACHAL PRADESH**

Thesis

by

KAVITA GUPTA

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

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This is to certify that all the mistakes and errors pointed out by the external examiner have been incorporated in the thesis entitled, “**Effect of different land uses on water quality of Dharpur Block of Solan District of Himachal Pradesh**” submitted to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-Solan (H.P.) by **Ms. Kavita Gupta (F-2010-15-M)** in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE** in **Environmental Science**.

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ABBREVIATIONS

amsl	:	above mean sea level
BOD	:	biological oxygen demand
Ca	:	Calcium
Cl	:	Chloride
cm	:	centimeter
COD	:	Chemical oxygen demand
⁰ C	:	degree celcius
dS/m	:	desisiemen per meter
EC	:	Electrical conductivity
Fe	:	Iron
Ha	:	Hectare
Mg	:	Magnesium
mg	:	miligram
ml	:	mililitre
mm	:	milimeter
Mn	:	manganese
NO ₃	:	Nitrate
ppb	:	parts per billion
ppm	:	parts per million
TDS	:	Total dissolved solid
WQI	:	Water quality index
Zn	:	Zinc

Chapter-1

INTRODUCTION

Water is a major constituent of all living things and is needed for various purposes. The primary concern of people living in developing countries throughout the world is that of obtaining clean water. In spite of the enormous volume of the water on the planet, only a small portion of it is available for use. About 97 per cent of the total water is present in oceans and sea as saline water, which is not useful, while fresh water makes up only 2.6 per cent of which 4/5th is immobilized as ice (Karthick and Ramachandra, 2006). It is essential for sustaining all form of life, food production, economic development and for general well being.

Availability of water, fertile soils and other natural resources from historical times has attracted human settlements. Urbanisation and the unregulated growth of the population have altered the surface and sub-surface terrains of the many areas. Changes in local topography and drainage system directly affect both quality and quantity of the water (Vasanthavigar *et al.* 2010). Since the 1960s, quality of urban waters have declined, in part because of point and nonpoint source pollution. Most of our water resources are gradually becoming contaminated due to the addition of foreign materials from the surroundings. These include organic matter of plant and animal origin, land surface washing, industrial and sewage effluents. Certain nutrients are known to travel from agricultural and urban lands into rivers by means of runoff (Hynes, 1970; Smart *et al.* 1981; Osborne and Wiley, 1988; Zamora and Alba, 1999) and influence the distribution and abundance of macroinvertebrates depending on their tolerance or habitat requirements (Townsend *et al.* 1997). Apart from climate induced changes, anthropogenic modification of land cover such as agriculture, afforestation, mining, urbanization, industrialization and intervention on hydrological regimes like irrigation and damming have resulted in marked changes in water quality (Soman *et al.* 1997). The high value crops require intensive use of fertilizers as well as pesticides which enter into streams affecting water quality. Toxic heavy metals entering the ecosystem may lead to geoaccumulation, bioaccumulation and biomagnification. All these factors increase water pollution, add to potable water treatment costs and have adverse health effects. Therefore, it is clear that land management constitutes a pressure to stream physicochemical and biological quality. The changes especially conversion to agriculture affect ecological functions, disrupt

hydrological regimes, erodes the resource base and negatively impact water quality. Discharge of sewage and municipal waste into water bodies have negative impact on water quality (Mohapatra and Singh, 1999). It has been observed that human disturbance alters water quality, habitat structure, hydrological regime, energy flow and biological interactions of aquatic ecosystem (Karr and Dudley. 1981: Karr 1999). The quality of ground water is the resultant of all the processes and reactions that act on the water from the moment it is condensed in the atmosphere until it is discharged by a well or spring and varies with locality and depth of the water table (Jain *et al.*1995). Ground water is particularly important as it accounts for about 88 per cent safe drinking water in rural areas, where population is widely dispersed and the infrastructure needed for treatment and transportation of surface water does not exist (Kumar, 2004). Problems arising out of water quality deterioration are as severe as those related to water availability. According to Rao and Mamatha (2004) about 70 per cent of India's surface water resources are already contaminated.

Land use is likely to effect the hydrological cycle in terms of both water quantity and quality. It affects the rates of runoff, infiltration, water quality and vegetation of the watersheds (Tideman, 1996). The diminishing quality of water seriously delimits its use for human consumption and for aquatic life. The land-use patterns in the catchment areas play a major role in the health of the aquatic ecosystem. The change in ecology due to land development determines the aquatic organism assemblages in the water benthic macroinvertebrates indicate water conditions. Physico-chemical parameters, studied to determine condition of a water body, do not provide the integrative measure of overall health of a stream sometimes inadequately identify impaired waters (USEPA, 2005). The physico-chemical characteristics of an aquatic body provide information on diversity of an aquatic biota, water quality and pollution (Mir *et al.* 2004). Fluctuation in aquatic insect communities give quick information on water quality as they respond quickly to changes in physical and chemical environment (Singh, 1997). Benthic macroinvertebrates are good indicators of watershed health as they live in the water for most of their life and differ in their tolerance to amount and types of pollution/ habitat alteration. So the biological measures provide an integrated, comprehensive assessment of the health of a waterbody over time (Karr, 1999).

Himachal Pradesh situated between North latitude: 30° 22' 40" to 33° 12' 40" and East longitude : 75° 45' 55" to 79° 04' 20" is wholly mountainous with altitude ranging from 350 to 6975 meter above mean sea level. It receives on an average 1459 mm total annual rainfall and

temperature varied from 0°C to 38°C. During the last five years industrialisation has significantly progressed in the state. Presently it has about 33618 small scale and 356 medium and large scale units (Khajuria, 2010). The major industries established in the state, include pharmaceutical, chemical, ghee, food industry etc. The disposal of effluents generated by the industries into nearby water bodies or agricultural lands contribute to pollution in the environment. The Solan district of Himachal Pradesh has also come up as a hub for industries. Presently it has about 138 small scale and 6 large scale industries. The district receives annual rainfall of 1420.40 mm. It has 344 ground water sources, 1090 surface water sources, 1215 traditional sources and 316 other conventional sources (Anonymous, 2009).

Different types of land use patterns exist in Dharampur block of this district. The increase in various anthropogenic activities like construction of roads, establishment of industries, deforestation, change in cropping pattern and excessive use of agrochemicals for better crop production has led to deterioration of water quality in this block of Solan district. Studies on water quality, its seasonal variation, type and diversity of aquatic biota with special reference to aquatic insect fauna under present conditions are very scanty (Berka *et al.* 1995). Therefore monitoring of water quality is necessary for appropriate preventive and remedial measures. Keeping in view the above factors under consideration the present study was under taken with the following objectives.

OBJECTIVES:

- To assess surface and ground water quality in different seasons under different land use patterns.
- To record aquatic insect fauna in surface water under different land use patterns.

Chapter-2

REVIEW OF LITERATURE

Since the beginning of the twenty-first century, the Earth, with its diverse and abundant life forms, including over six billion humans, is facing a serious water crisis. The condition is getting worse and will continue, unless corrective measures are taken. This crisis is one of water governance, essentially caused by the ways in which we mismanage water. Though industrialization and development in agriculture helps to meet the basic requirements of people, but simultaneously it is necessary to protect and preserve the environment. In India, due to lack of sewage treatment plants, untreated effluents are either directly used for irrigation of agricultural lands or disposed off in nearby water bodies. Much of the traditional research on water quality focus on physicochemical characteristics, but recent research has taken more of an interdisciplinary approach by including the relationships between water quality and biodiversity (Gower et al. 1994; Tate and Heiny 1995). *The* literature pertaining to the research study is reviewed under the following heads:

- 2.0 Effect of land uses on physico-chemical parameters of water and aquatic insects**
- 2.1 Effect of land uses on physico-chemical parameters of surface and subsurface water**
- 2.2 Effect of land uses on aquatic insects in surface water**
- 2.1 EFFECT OF DIFFERENT LAND USES ON PHYSICO-CHEMICAL PARAMETERS OF SURFACE AND SUBSURFACE WATER**
- 2.1.1 Work done on effect of different land uses on physico-chemical parameters of surface and subsurface water in abroad**

Malkee and Volt (1963) reported the presence of toxic compounds like sodium carbonate, sodium sulphite, methyl mercaptans, hydrogen sulphide and formaldehyde in kraft pulp mill waste water in California State. Thompson *et al.* (1974) and Wells *et al.* (1975) reported high level of COD, TS and SS exceeding standard levels for raw sewage in surface water runoff entering lake at Lubbock, USA.

Livingston and Cox (1989) reported that surface water management system in Florida linked 85 percent of metals, 90 percent of oxygen demand material, > 50% of nutrients, and 99% of suspended solids entering surface water systems to stormwater runoff. Ostrowska et al. (1999) studied Na, K, Ca, Mg, Zn, Fe, Mn, P, NO₃, NH₄, Cl, SO₄ and pH content in water

samples from farm wells situated in six regions of Poland and reported that in wells of all provinces, an intolerable content of nitrate-nitrogen, potassium and manganese were present. Ren *et al.* (2003) studied the relationship between water quality, urbanization and changing patterns of land use in Shanghai, China and reported that rapid urbanization corresponds with rapid degradation of water quality and urban land uses are positively correlated with the decline in water quality.

Mastoi *et al.* (2008) carried out water analysis of Manchar Lake and MNVD (Main Nara Valley Drain) in Sindh (Pakistan). The pH of both Manchar Lake and MNVD waters and concentration of Pb in Manchar Lake and concentration of Cd in MNVD water were higher and water was not fit for drinking purpose. The water of both the lakes was unsuitable for drinking because of high pH and Pb concentration. Rafiu *et al.* (2007) reported cadmium and lead above acceptable limits in surface water and sediment along the Blaauwbanksprint, South Africa. Esmail *et al.* (2009) analyzed the groundwater sample of Mitm area, Ibb City, Yemen for various quality parameters and found that three out of five boreholes were contaminated. Ma *et al.* (2009) reported high salinity and nitrate in ground water of Western Wuwei basin of Shiyang river in NorthWest China.

Ehiagbonare and Ogunrinde (2010) analyzed water samples of concrete and earthen fish ponds at Okada, Edo State, Nigeria. Out of twenty-one parameters studied cadmium and lead were not detected in any of the samples studied. Charles and Okoro (2011) carried out physico - chemical analysis of sewage water of Port-Harcourt metropolis area and rivers at Nigeria. Most of the physical and chemical parameters of sewage water exceeded the ISI permissible level.

2.1.2 Work done on effect of different land uses on physio-chemical parameters of surface and subsurface water in India

Basu (1966) analyzed pulp and paper mill effluents at several discharge points in the Hooghly River estuary, India. The results indicated that the population load was 4×10^4 lbs of lignin per day. Dhaneshwar *et al.* (1970) analysed waste water from Titaghur paper mill, at Hooghly estuary, West Bengal and found that BOD and COD values of the effluent water ranged from 136 to 165 and 268 to 480 mg/l, respectively. Subbarao (1971) while studying the quality of distillery effluents at Tamil Nadu reported 8.0 to 8.4 pH, 10,000 to 86,000 mg/l total solids, 5000 to 13000 mg/l volatile solids, 2,000 to 45,000 mg/l BOD and 8,000 to 95,000 mg/l COD, respectively. Jadhav and Savant (1975) reported pH and electrical

conductivity of undiluted spent wash as 8.0 and 31.0 dSm⁻¹, respectively. The COD, TDS, mineral matter, Ca, Mg, K, N, P, bicarbonate and Cl were found to be 13000 mg/l, 45000 mg/l, 26000 mg/l, 100.0, 1700.0, 13600.0, 1400.0, 1225 mg/l 10,000.0 and 5500.0 mg/l, respectively in the undiluted spent wash. Saxena et al. (1979) reported 1500 and 710 mg/l of SS and BOD, respectively for effluents generated from rice straw and waste paper mill.

Ajmal et al. (1984) analyzed the quality of effluents discharged by Glaxo Laboratory, West Bengal. The values of pH, BOD, COD, Ca⁺⁺, Cl, Mg⁺⁺, N and P were 7.90, 698, 1128, 134, 101, 0.30 and 1.25 mg/l, respectively.

Mudri et al. (1984) reported the physico-chemical characteristics of Bengal pulp and paper mills in West Bengal. The pollution load of different drains with respect to BOD, COD, TSS was 10.9 mg/l, 38.4 mg/l and 59.1 kg/day, respectively.

Somashekar et al. (1984) analyzed the physico-chemical characteristics of effluent streams of a paper factory, a food and paper industry, a textile factory and an automobile industry, at Mysore (Karnataka). The results revealed that the effluent had objectionable levels of BOD, COD, dissolved solids, SS and residual chlorine as compared to ISI standards. The pH of all the effluents was alkaline being highest in paper mill effluent (10.5). Vijayram et al. (1988) assessed the effect of paper mill on water quality of Pagalur high-level channel, a tributary of river Cauvery, Tamil Nadu. The results revealed that both raw and treated effluents possessed high value of total solids, BOD, COD, chlorides etc. and these contributed to toxicity of the effluent. Tripathi *et al.* (1991) analyzed physico-chemical characteristics of sewage, discharged into river Ganga at different sites viz., Assi ghat, Shiwala ghat, Harishchandra ghat, Chauki ghat, Rajendra Prasad ghat, and Rajghat at Varanasi, India. They reported that higher concentration of sewage was discharged during May and June. Rajghat sewage was highly concentrated having highest pollution load, whereas, sewage at Assi ghat was least concentrated and polluted.

Naidu and Raman (1995) reported that pH of distillery effluent was 7.6 and color was dark brown. The distillery effluents had no dissolved oxygen, however BOD, TS, dissolved solids, undissolved solids, electrical conductivity were found 38,000 ppm, 40,000, 34,650, 5,350 ppm and 1,221 u mho /cm, respectively and chloride and oil contents were 4,600 and 60 ppm in the distillery effluent, respectively. Vaidhyanathan et al. (1995) studied the

physicochemical characteristics of distillery effluent. pH, dissolved solids and total solids ranged from 4.0 - 4.2, 90,000 - 1,11,000 mg/l and 86,1 - 1,10,000 mg/l, respectively. COD and BOD ranged from 1,15,000 - 1,20, mg/l and 42,000 - 50,000 mg/l, respectively. Total nitrogen, phosphates and chlorides were in the range of 1800 - 2000 mg/l, 30000 - 34,000 mg/l, 2000 - 2100 mg/l and 7000-8000 mg/l, respectively. Chakravorty et al. (1996) while studying the quality of pulp and paper mill effluent, reported BOD and TS ranging from 1286 to 1769 mg/l and 3200-6940 mg/l, respectively. The levels were well below the minimum national standards. Patil (1998) reported dark brown coloured spent wash. The pH, EC, BOD and COD contents of spent wash was 4.42, 21.56 dSm⁻¹, 30450 and 73600 mg/l, respectively. Whereas calcium, magnesium, sodium, potassium, nitrate, sulphate and chloride contents were 1603, 730, 3575, 7115, 4216, 3819, and 14250 mg/l, respectively.

Sivasubramani (1999) carried hydrological, physico-chemical and the biological analysis of river Periyar in Tamil Nadu. The analysis revealed that due to urbanization, the quality of Periyar river water has deteriorated. It has high values of hardness (90.5 to 220 mg/l), phosphorous (0.05 to 0.23 mg/l), conductivity (200 to 350.9 Nmhos), total coliform etc in the downstream area due to sewage contamination. Sarma and Bhattacharyya (2001) analyzed the quality of tube well water from different localities of Darrang district of Assam. The K⁺ and Mg⁺⁺ concentration were relatively lower than the Na and Ca⁺⁺ concentration, respectively, whereas Iron concentration was above permissible limit. The iron content of the water samples of Mangaldai sub division was slightly higher than those of Udalguri sub division. Bandela *et al.* (2002) investigated the polluting strength of sewage discharge into Barul dam in Maharashtra and reported maximum value of BOD (11.1 ppm) in the monsoon and minimum (3.2 ppm) in the winter season.

Kathikeyani *et al.* (2002) studied the water quality of the river Shanmuganadhi, Tamil Nadu and found the water unsuitable for drinking and irrigation purpose due to dispersal of sewage water from surrounding area. Latha *et al.* (2002) analyzed water quality parameters of 133 water samples at Coimbatore, Tamil Nadu, India. The electrical conductivity (EC) of water samples from Coimbatore areas ranged from 0.45- 4.50, 2.27-9.95 and 02-2.7 dSm⁻¹, respectively. Highest Sodium Adsorption Ratio (SAR) was found in Palladam samples (34.20). Srinivas *et al.* (2002) analyzed the physico-chemical characteristics of bore wells of industrial areas of Visakhapatnam, India. The water quality index of analyzed samples varied from 50.0-97.41 ppm indicating increased level of nutrient load and pollution in the bore

waters. The water quality did not conform the drinking standards. Moundiotiya *et al.* (2004) analyzed physico-chemical properties of water in Jamwa Ramgarh Lake, Jaipur. The pH varied from 6.8 to 8.5, electrical conductivity was maximum in summer and minimum in monsoon season (500 to 700 micromhos/ cm), whereas, total alkalinity was 102.6 to 215 mg/l.

Patel *et al.* (2004) reported that the COD of effluents from industries at Ankleshwar, Gujarat was extremely high (12810 mg/l), while BOD (560 mg/l) was within the safe limit. The heavy metals in the effluents were Fe (25.5 mg/l), Cu (0.70 mg/l), Mn (4.83 mg/l), Cd (0.10 mg/l), Ni (0.73 mg/l), Co (0.56 mg/l) and Cr (2.76 mg/l). Bhardwaj (2005) monitored 189 Rivers, 53 Lakes, 4 Tanks, 2 Ponds, 3 Creeks, 3 Canals, 9 Drains, 218 Wells of India for water quality analysis. High level of organic pollution in major rivers and almost all surface water sources were contaminated to some extent by coliform group of bacteria making it unfit for consumption. Chattopadhyay *et al.* (2005) monitored water quality in Chalakudy river basin in Kerala in different land use types during four seasons and reported that urban land use had poor water quality throughout the year which was linked to fluctuations of drainage discharge and changes in land use patterns.

Singh and Singh (2005) reported that effluent from paper mill having pH (7.9), electrical conductivity (2.19 dSm^{-1}), Organic Carbon (5.7 g/kg) and N, P and K contents were 2.0, 5.2 and 157.5 mg/l, respectively at Uttaranchal. The bacterial, fungal and actinomycetes load in effluent were 8.3×10^6 , 4.5×10^4 and 8.1×10^2 cfu / ml, respectively. Misra and Mishra (2006) analysed groundwater quality in shallow and deep aquifers at Saidabad in Uttar Pradesh and reported that the deep aquifers which supply water to borewells in the alluvial plain, have higher salinity than those of the dugwells from the shallow aquifers. The groundwater quality varied with depth and time span in shallow and deep aquifers.

Arasu *et al.* (2007) carried out physico-chemical analysis at sixteen locations of Tamirabarani river in South India. All the locations studied, did not exceed the set limit of the standards. Hazarika *et al.* (2007) reported that pulp and paper mill effluent at Assam, was alkaline (pH 7.6). It contained high levels of dissolved salts, bases and chloride. Bhandari and Nayal (2008) analysed physico-chemical parameters of water samples in pre monsoon, monsoon and post monsoon seasons in Kosi river at Uttarakhand during 2004 and 2005 and reported all the physicochemical parameters within the highest desirable limit set by WHO except turbidity and BOD which had a high value. Ravisankar and Poongothai (2008)

reported significant variations in water quality parameters of wells in Tsunami affected areas of Sirkazhi Taluk, Nagapattinam District, Tamilnadu, India. Tsunami contributed to agricultural and environmental degradation in the Sirkazhi taluk and Nagapattinam districts. Shyamala *et al.* (2008) reported groundwater of Telungupalayam, area in Coimbatore, India fit for domestic and drinking purpose but it was alkaline and needed treatment. Tikoo *et al.* (2008) carried out water analysis of Bichlari Nala at Banihal and Ramban, Jammu and Kashmir, India for heavy metals. All cations were below permissible limit except Fe, Mn and Ni and bicarbonates, sulfates, nitrates, total hardness and pH values were within safer levels while turbidity values were higher. Babushakila and Usha (2009) analyzed the tannery effluents of leather processing industry in Dindigul of Tamil Nadu. The concentrations of BOD, COD, dissolved solids and suspended solids were 35, 318, 17150 and 258 mg/l, respectively. Whereas, concentration of Na⁺, Ca⁺⁺ and Mg⁺⁺ was recorded to be 600, 432 and 5100 mg/l, respectively. Deepali *et al.* (2009) reported higher limits (above prescribed levels) of various physico-chemical parameters (pH, Ec, TS, TDS, Alkalinity, Hardness, Calcium, Magnesium, chloride, Bicarbonate, Nitrate, Fluoride, DO, BOD, COD) for tannery effluent from industries situated in Sansarpur and Anantpur villages of Roorkee. Kumar and Bahadur (2009) carried out physico-chemical analysis for three seasons in downstream of Kosi river at Rampur (U.P.) and reported alkaline pH (7.3 to 7.9), mild organic pollution (indicated by DO, 6.2-7.5 mg/l, BOD 5.0-6.0 mg/l) and industrial pollution (indicated by COD 25.0-40 mg/l).

Samantray *et al.* (2009) analyzed that water quality of Mahanadi and Atharabanki rivers and Taldanda canal in Paradip area, India for three seasons (summer, premonsoon and winter) and reported deterioration in water quality due to industrialisation and human activities.

Ramakrishnaiah *et al.* (2009) evaluated the Water Quality Index (WQI) for 12 parameters in the groundwater of Tumkur Taluk, Karnataka, India. It ranged from 89.21 to 660.56. The high value of WQI was mainly due to high concentration of iron, nitrate, total dissolved solids, hardness, fluorides, bicarbonate and manganese in the groundwater.

Vasanthavigar *et al.* (2010) also studied WQI for groundwater quality at Thirumanimuttar, Tamilnadu, India and reported Na>Mg>Ca>K for cations, Cl>HCO₃>SO₄ anions, alkalis (Na and K) exceed alkaline earths (Ca and Mg) and strong acids (Cl and SO₄) exceed weak acid (HCO₃). The pre-monsoon samples had poor quality as compared to post-

monsoon due to leaching of ions, over exploitation of groundwater, direct discharge of effluents and agricultural activities.

Dudeja *et al.* (2010) carried out water quality assessment of groundwater in Doon valley of Uttarakhand for pH, EC, bicarbonate, Ca, Mg, Na and K and reported pH 5.6 to 7.4, EC, 71 to 951 $\mu\text{mho/cm}$, bicarbonate 83 per cent, calcium and magnesium upto 88 per cent. Gokulakrishnan and Balamurigan (2010) studied ground water quality around tanning industries in Tamil Nadu and reported high variability in total alkalinity, total hardness, chloride and total dissolved solids. pH, dissolved oxygen, biological oxygen demand, chemical oxygen demand were insignificant and concluded that ground water was polluted in this area due to discharge of partially treated effluents. Gupta *et al.* (2010) while studying the physico-chemical parameters of various lakes of Jaipur, India reported high pollution in Jalmahal and Amer lake water as highly polluted, unsuitable for drinking, wildlife and fish culture, as compared to Galta Lake which was less polluted.

Jindal and Sharma (2010) carried out physicochemical water analysis of Sutlej river around Ludhiana during November 2006 to October 2007 and recorded relatively low values of TDS, turbidity, BOD, total alkalinity, total hardness, chlorides, nitrates, and phosphates at Ropar and Budha Nallah at Phillaour as compared to Budha Nallah at Ludhiana. Heavy metals (Pb, Zn, Cr, and Ni) were detected at Phillaour and Ludhiana and water of Phillaour and Ludhiana was unsafe for human consumption. Kumar *et al.* (2010) while studying the impact of industrial effluents on water quality of Behgul river Bareilly reported the water of Bairam Nagar as non polluted, Basai village site highly polluted whereas Thanpur village had mixed polluted water. Mahadev and Gholami (2010) reported high loads of arsenic, iron and nickel in upstream in Cauvery river water, Karnataka during 2008 and reported arsenic more than permissible level. Mahananda *et al.* (2010) reported the quality of surface and ground water below pollution level at Bargarh District, Orissa, India. The water was fit for domestic and agricultural purposes.

Mishra *et al.* (2010) suggested treatment of groundwater of Mahi and Sabamiati river (Gujarat) for domestic uses. Muduli and Panda (2010) while studying the physico chemical properties of water from Dhamra estuary recorded alkaline pH of water throughout the year. Salinity, conductance and hardness increased towards the river mouth as compared to inland stations; DO (8 mg/l), BOD (3 mg/l), nutrients (NO_3 , PO_4 , and NH_3) decreased from riverine to estuarine region, TDS was high in riverine, TSS was high during monsoon period, NO_3

was higher than NH_3 and PO_4 . Nagarajan et al. (2010) analysed ground water of Thanjavur City, Tamil Nadu in 90 per cent of groundwater samples, sodium and chloride were predominant cation and anion, respectively, and NaCl and Ca, Mg, Cl were major water types. Thirteen per cent of the samples had elevated nitrate content which was not suitable for drinking. Pawar and Kanvate (2010) studied the comparative physico-chemical characteristics of three dams in Nanded district, Maharashtra and reported suitability of dams for fish culture.

Rao *et al.* (2010) carried out physico – chemical analysis for different parameters in well and bore well water samples of Guntur, Andhra Pradesh. Water Quality Index from different sampling stations varied from 38.3 to 42.6. Reza and Singh (2010) studied ground water quality by using water quality index (WQI) in Angul-Talcher region of Orissa. The values of WQI were mainly affected by concentration of dissolved ions (F^- , NO_3^- , Ca^{2+} and Mg^{2+}) in ground water and WQI of the samples were in the range of 14-57 in summer season and 19-67 in post-monsoon season. Sharma *et al.* (2010) studied the water quality status of Gundolav Lake at Kishangarh, Rajasthan and reported high BOD (49.42 mg/l), COD (74.18 mg/l), chloride (282.75 mg/l), sulphate (277.20 mg/l), nitrate (4.32 mg/l), phosphate (12.27 mg/l) and low dissolved oxygen content (3.68 mg/l). The dominance of protozoan and rotiferan communities in the lake indicated deterioration of water quality. Thakre *et al.* (2010) reported degradation of water quality of Tapti pond at Multai district, Madhya Pradesh.

Kamble *et al.* (2011) analyzed physico chemical parameters of water samples from Bhandaradara reservoir, Maharashtra during the period of September to December 2008 and recorded all parameters within the permissible limits according to WHO (1984) guidelines. Murhekar (2011) while analysing status of ground water at Akot, Maharashtra reported contamination of water samples of Shri Shivaji College and Mahalaxmi Nagar. Whereas, the water quality of Keshvaoraj vetal, shaukatali chok and Ramtek pura was within the standards limits and fit for drinking purpose. Rai *et al.* (2011) studied water quality parameters for two seasons (Premonsoon and Post-monsoon) of river Ganga at Bihar and reported that samples from sites I (Pahalwan Ghat and Bans Ghat) and II (Krishna Ghat and Gandhi Ghat) were not of good quality and river Ganga was moderately polluted.

Raut *et al.* (2011) reported seasonal fluctuations in physico-chemical parameters (conductivity, pH, total dissolved solids (TDS), total suspended solids (TSS), nitrate, sulphate

and phosphate) of Ravivar Peth Lake at Ambajogai, India. Singh *et al.* (2011) studied ground water quality index for irrigation and drinking purpose in Lower Shiwaliks of Punjab. The water quality varied from moderate to good except in some areas where it is poor to unfit. Yadav and Srivastava (2011) studied physico-chemical properties of River Ganga at Patthar Ghat, Bada Mahadeva Ghat, Dadari Ghat, Collector Ghat and Chitnath Ghat during September 2005 to August 2007 and found depletion in the dissolved oxygen, and increase in temperature, total solids, electrical conductance, pH, biochemical oxygen demand, chemical oxygen demand, chloride, acidity, total alkalinity, total hardness, calcium, phosphate, nitrate, sodium and potassium.

2.2 EFFECT OF LAND USES ON AQUATIC INSECTS IN SURFACE WATER

2.2.1 Work done on effect of land uses on aquatic insects of surface water in abroad

Diversity and community similarity measures have been used in conjunction with multivariate analyses to evaluate relationships between macroinvertebrate diversity and water chemistry (Dyer 1978; Pedersen and Perkins 1986; Gower *et al.* 1994; Death 1995; Tate and Heiny 1995). The influence of physicochemical attributes on the structure and composition of invertebrate communities has been a dominant theme in aquatic ecology (Macan 1963; Hynes 1970; Rosenberg and Resh 1993). Nebeker and Lemke (1968) studied the relative sensitivity of twelve species of aquatic insects (Trichoptera, Diptera, Ephemeroptera, Plecoptera, Odonata) to heated waters and recorded that the lethal temperature ranged from 21°C, in winter to stoneflies to 33°C for dragonflies. Mason *et al.* (1971) studied the macroinvertebrate populations at Ohio River and Allegheny, Monongahela, Kanawha and Wabash Rivers during 1963-1967 and reported that diverse distinct difference in the abundance and diversity of macroinvertebrates in the middle and lower reaches of the Ohio River and also reported effect of pollution on macroinvertebrate. Nehring (1976) while studying impact of heavy metals (Cu, Pb, Ag, and Zn) on mayflies and stoneflies reported that level of heavy metal accumulation in insect was 100 times greater than the level of exposure.

Geomorphological features, water chemistry, and disturbance regimes influence spatial patterns of invertebrate community composition in lotic systems (Moss *et al.* 1987; Meyer *et al.* 1988; Corkum 1989; Death 1995). In lentic systems, trophic status as well as physicochemical characteristics were primary factors influencing invertebrate community composition (Rasmussen and Kalff 1987; Gowns *et al.* 1992; Wollheim and Lovvorn 1995).

Lynch *et al.* (1988) investigated trace metal contamination in Red river, New Mexico through insect species viz., mayflies, stoneflies, caddisflies, trueflies etc. and reported that insects detected episodic discharge of metals (Mo, Mn and Cu) from mill to environment. Eyre and Foster (1989) reported beetle distribution as good indicator of acidification, in static water. Cairns and Pratt (1993) reported that the macroinvertebrate species diversity and community composition was important for aquatic ecology studies and these attributes were used to evaluate environmental stress resulting from urbanization and industrialization.

Gower *et al.* (1994) studied the relationship between macroinvertebrate communities and environmental variables in metal-contaminated streams and reported that alkalinity, pH, dissolved organic matter, and algal cover were significantly correlated to abundances of aquatic macroinvertebrates in European streams. Oriola and Jeje (1999) monitored the impact of natural eutrophication and effluent discharge on plankton dynamics in between Awba reservoir and Ibadan (Nigeria) and found that the dissolved oxygen content, pH, conductivity and ammonia-nitrogen values indicated a deterioration in water quality at stations receiving organic or chemical effluents and reported that Simpson's diversity index at all stations was less than one. Miserendino and Pizzolon (2000) carried out rapid assessment of water quality using macroinvertebrates in Patagonian rivers and found that the mean annual values of the BMPS (Biotic Monitoring Patagonian Streams) were between 7 and 109.4, while the IAP (Andean Patagonic Index) mean values were between 2.5 and 9.75.

Lessard and Hayes (2003) studied the effect of summer temperature on downstream fish and macroinvertebrate communities in cold-water streams in Michigan's lower peninsula from a cooling of 1 °C to an increase of more than 5°C. Macroinvertebrates showed shifts in community composition below dams that had increased temperature. Graça *et al.* (2004) monitored substratum organic matter content, depth and the dominant size of substratum particles in correlation with number of taxa and individuals and environmental parameters (temperature, minimum size of substratum particles and pH) and reported North and Centre streams rich in taxa than Mediterranean streams in South, Portugal. Sharma *et al.* (2005) reported large scale death of aquatic life of Babai River, Nepal due to high-loading of organic content and presence of toxic substances. Brainwood and Burgin (2006) correlated physico-chemical parameters with communities and reported that habitats were influenced by water quality and by physical features of the habitat. Dhakal (2006) analyzed impact of water quality of Balkhu Khola, Kathmandu on aquatic ecosystem and reported negative correlation

of Oligochaetes, Diptera and Bivalvia with dissolved oxygen and positively correlation with carbon dioxide. The water was more polluted at downstream course of Khola, Nepal.

Duran (2006) monitored the water quality using benthic macroinvertebrate fauna of Behzat stream in Turkey. He reported that the upper section had more diverse community. Due to high values of phosphate and nitrogen ions, low macroinvertebrate abundance in the lower section of stream during summer was recorded. Oguzkurt and Ozhan (2008) carried out water analysis through benthic macroinvertebrate at Karakaya Dam in Turkey and reported that habitat heterogeneity, water chemistry particularly hardness, N and P concentrations influenced the composition of communities. Oz and Kazanci (2008) analyzed habitat quality of running waters of Western Black Sea Region through benthic macroinvertebrate and recorded seven classes (Platyhelminthes, Gastropoda, Bivalvia, Oligochaeta, Arachnida, Malacostraca and Insecta) of benthic macroinvertebrate. According to physico-chemical variables, biotic index and number of EPT taxa sampling sites were detected unpolluted, slightly polluted and moderately polluted.

Thani and Phalaraksh (2008) studied aquatic insect diversity and water quality of Mekong River, Thailand and found the highest number of aquatic insects of the family Ephemeroptera and the most abundant families were Baetidae and Caenidae. Kroll *et al.* (2009) analyzed physicochemical variables (conductivity, concentrations of ammonium, nitrite, nitrate, phosphate) and various benthic invertebrates indices (IBMWP, BMWQ and MCLM) for determining the influence of land use on water quality and macroinvertebrate biotic indices in rivers within Castilla-La Mancha Spain. The correlation analysis showed strong relationship between nutrients and biotic indices and the urban, forested and dry agriculture uses. For irrigated agriculture, low correlations were found for nutrients (nitrate and phosphate) and biotic indices.

Nkwoji *et al.* (2010) studied seasonal variations in the water chemistry and benthic macroinvertebrates of a South Western Lagoon at Nigeria representing wet and dry seasons and recorded higher dissolved oxygen values in wet season than in the dry season and reported populations of *Tellina nymphalis*, *Clibanarius africana*, and *Penaeus notialis* in dry season and *Crassostrea gazar* in wet season which was absent in the dry and defaunisation indicated pollution of the lagoon.

Parsons *et al.* (2010) studied the relationships between lake water chemistry and benthic macroinvertebrates in the Athabasca Oil Sands Region (AOSR), Alberta and

correlated lake acidity positively with Hyallellidae and negatively with Chironomidae and Oligochaeta. Theodoropoulos and Georgudaki (2010) reported that macroinvertebrate diversity was strongly correlated to pollution at South Western Greece. The sites with major physico-chemical and hydromorphological degradation had low taxonomic richness and diversity while non impacted sites had considerable higher diversity of Ephemeroptera, Plecoptera and Trichoptera (EPT). The study indicated significant impact of land use changes to the water quality, which consequently influence the distribution of biota. Chadwick *et al.* (2011) analysed the effects of urbanization on hydrology, water quality and macroinvertebrates in tributaries of the St. Johns River in the Atlantic Coastal Plain of Northeast Florida and found the impact of hydrologic factors (perennial vs. intermittent flow regimes) on invertebrate community structure in the urbanized streams. The effects of urbanization on hydrological and biological variables were apparent and influenced by site-specific conditions.

Petruck and Stoffler (2011) studied the history of chloride concentrations in the River Lippe (Germany) and the impact on macroinvertebrates by mining water discharge. Chloride concentrations upto 3500mg/l was recored in the last century; presently it is below 400mg/l. The macroinvertebrate community was dominated by freshwater species. Wahizatul *et al.* (2011) studied the impact of human disturbance and agricultural activity on aquatic insect communities in Sungai Peres and Sungai Bubu in Hulu Terengganu, Malaysia. Total abundance of aquatic insects was significantly higher at the upstream stations than downstream stations in both streams. The pollution-sensitive organism groups (EPT) were highly abundant and more diverse at the upstream stations and the Family Biotic Index (FBI), Biological Monitoring Work Party (BMWP) and Average Score Per Taxon (ASPT) indicated that water quality of both streams varied from clean-to-excellent.

2.2.2 Work done on effect of land uses on aquatic insects of surface water in India

Vaitakeril and Diwan (1991) studied community structure of benthic macroinvertebrates as indicator of pollution in Kshipra river, India and reported Diptera genus *Chironomous tentans* inversely corelated with species diversity which decreased in population with improvement in water quality. Sharma *et al.* (2004) analysed aquatic macroinvertebrate diversity in Nanda Devi Biosphere Reserve, India and reported highest (3.096 \pm 0.03) macroinvertebrate diversity in winter months (November–January) and lowest (2.816 \pm 0.02) in monsoon months (July–August). The high macroinvertebrates

diversity was due to low turbidity, highwater transparency, optimum water temperature, high dissolved oxygen, low water velocity and suitable composition of the bottom substrates. Subramanian *et al.* (2005) studied the impact of riparian land use on the stream insect community at Kudremukh National Park located within Western Ghats in India and reported that the diversity and community composition of stream insect varied across stream with different riparian land use types. Dinakaran and Anbalagan (2007) studied anthropogenic impacts on aquatic insects in six streams of South Western Ghats, India and found highest species richness and abundance in Monkey falls followed by Kumbakkarai falls and low in Shenbagadevi and Manimutharu falls.

Saksena *et al.* (2008) while studying the physico-chemical characteristics of Chambal river in National Chambal Sanctuary (Madhya Pradesh) reported pristine nature. Chambal river was placed under oligosaprobic category and was pollution free, can serve as good habitat for many aquatic animals including endangered species. Sharma *et al.* (2008) studied the aquatic insect diversity of Chandrabhaga river, Garhwal Himalayas, India and recorded maximum aquatic insect density in the month of March (4,165 ind./m²) and minimum in the month of August (680 ind./ m²) and reported significant impact of velocity of water, hydromedian depth, turbidity and dissolved oxygen, composition and texture of the bottom substrates on density and diversity of benthic insects. Nautiyal and Semwal (2009) studied macro invertebrate community in the mountain streams with respect to sub basin, forest type and altitude in Mandakini basin and found that the mean density of benthic macroinvertebrate was highest during winter and lowest during monsoon.

Gupta and Paliwal (2010) analyzed the role of aquatic insects in water analysis in relation to physico-chemical parameters in Yamuna River at Uttar Pradesh and found that water quality declined due to the direct discharge of domestic sewage, municipal wastes and industrial effluents from various areas of town which directly or indirectly effected the biotic community. Muralidharan *et al.* (2010) analysed macroinvertebrates as potential indicators of environmental quality and reported that the macroinvertebrate community indicated the effects of pollutant sources which may not have been detected by either physico-chemical sampling. Mishra and Nautiyal (2011) studied longitudinal variation in benthic macroinvertebrate fauna in Paisuni river in Central India. The current velocity, substratum and landuse were major environmental factors influencing the relative composition of macro-invertebrates.

Sharma and Bhardwaj (2011) investigated the physico-chemical parameters of Mahi River, India for Phytoplankton communities. The studies indicated that reduction in temperature, TS, TDS, TSS, BOD, COD, total hardness, total alkalinity, chloride, oil and grease, and rise in pH, DO, nitrate, phosphate and silicate were favourable conditions for plankton growth. Sharma and Chowdhary (2011) reported macroinvertebrate assemblages as biological indicators of pollution in Tawi River, Jammu and Kashmir which were greatly influenced by physico-chemical parameters of the river.

Chapter-3

MATERIALS AND METHODDS

The studies were conducted in the laboratory of Department of Environmental Science, College of Forestry, Dr. Y. S. Parmar University of Horticulture and Forestry Nauni, Solan, Himachal Pradesh during 2-11-2012. The details of materials used and methods employed during the present study are presented in this chapter.

3.1 GENERAL DESCRIPTION OF THE STUDY AREA AND SELECTION OF SITE

3.1.1 General description of study area

Dharampur block of Solan district of Himachal Pradesh is situated between $30^{\circ}54' 07''$ N to $30^{\circ}55' 83''$ N and $076^{\circ}49'47''$ E to $076^{\circ}57'88''$ E at an altitude of 417 to 1478 meter above mean sea level. The block has 29,132 ha geographical area out of which total cropped area is 5817 ha with crop intensity of 151 per cent and total forest area is 3,880 ha. The block has 136 large scale and 6 small scale industries. Major cropping systems in Dharampur block under unirrigated conditions are maize-wheat, maize+pulses-wheat, maize-barley and maize-pea whereas under irrigated condition the cropping pattern is vegetable and ginger based. The block has many rivers, nalas, kuhls, bawries and springs under different land use systems.

3.1.2 Climatic and weather conditions

Dharampur block of Solan district falls under sub-tropical climate which varied from low hills and valley areas to low mid hills. The winter season commences from October to March, summer season from April to June followed by the rainy season from July to September. Maximum precipitation occurs during the months from July to September. This block receive on an average 1450 mm annual rainfall with on an average of 64 number of rainy days. In the winter season precipitation as snowfall also occurs at the higher reaches (above 1000 m amsl) and as rainfall in low hills and valleys. Mean maximum and minimum temperature ranges from 4°C to 34°C .

3.1.3 Selection of study area in Dharampur Block

Micro level hydrological survey of Dharampur block was conducted to select four sites randomly. On the basis of survey the water sources under different land uses i.e.

agriculture, forest and urban/ suburban were identified and inventorized for collection of water samples from different sources and collection of aquatic insects from surface water. The details of selected locations latitude and longitude along with elevation is presented in the Table 3.1, Table 3.2, Table 3.3, Table 3.4.

Table 3.1 Sampling locations in Dharampur area

Code	Location	Latitude	Longitude	Elevation(m)
AS1	Kyar Village	N 30 ⁰ 54'78"	E 077 ⁰ 01'98"	1317
AS2	Dagroh Village	N 30 ⁰ 54'68"	E 077 ⁰ 02'10"	1366
AS3	Mohan Bawri	N 30 ⁰ 54' 53"	E 077 ⁰ 01'36"	1412
AG4	Kyar Village	N 30 ⁰ 54'76"	E 077 ⁰ 01'91"	1314
AG5	Kotla Village (Handpump)	N 30 ⁰ 54' 64"	E 077 ⁰ 01'78"	1330
AG6	Subbathu Road (Handpump)	N 30 ⁰ 54'33"	E 077 ⁰ 01'15"	1422
FS1	Dagsai Khad	N30 ⁰ 54'57"	E077 ⁰ 02'06"	1346
FS2	Pump House, Raudi Panchayat	N30 ⁰ 54'59"	E 077 ⁰ 02'07"	1349
FS3	Gethri Khad	N 30 ⁰ 54'58"	E 077 ⁰ 02'70"	1352
FG4	Kotla village (Handpump)	N 30 ⁰ 54'56"	E 077 ⁰ 01'47"	1349
FG5	Dhar ki Bedh	N 30 ⁰ 54'47"	E 077 ⁰ 01'26"	1419
FG6	Sanavar (Handpump)	N 30 ⁰ 53'56"	E 077 ⁰ 00'23"	1367
US1	Kasauli (Tap water)	N 30 ⁰ 54'07"	E 076 ⁰ 57'88"	1802
US2	Solan Bawri	N 30 ⁰ 54'39"	E 077 ⁰ 01'33"	1412
US3	Dharampur Tap water	N 30 ⁰ 54'22"	E 077 ⁰ 01'31"	1476
UG4	Dharampur (Handpump)	N 30 ⁰ 54'21"	E 077 ⁰ 01'30"	1426
UG5	Dharampur (Handpump)	N 30 ⁰ 54'21"	E 077 ⁰ 01'82"	1430
UG6	Dharampur (Handpump)	N 30 ⁰ 54'21"	E 077 ⁰ 01'39"	1432

Table 3.2 Sampling locations in Parwanoo area

Code	Location	Latitude	Longitude	Elevation
AS1	Bada Taksaal, Kasauli Road	N30 ⁰ 50'57"	E076 ⁰ 57'43"	815
AS2	Ambota Khad	N30 ⁰ 51'09"	E076 ⁰ 57'84"	910
AS3	Near Railway Track, Chota Taksaal	N30 ⁰ 50'58"	E076 ⁰ 57'44"	809
AG4	Bada Taksaal (Nalu)	N30 ⁰ 50'64"	E076 ⁰ 57'43"	850
AG5	Ambota, Bada Taksaal	N30 ⁰ 51'12"	E076 ⁰ 57'71"	933
AG6	Ambota, Bore well	N30 ⁰ 51'09"	E076 ⁰ 57'78"	931
FS1	Ambota Khad	N30 ⁰ 51.09"	E076 ⁰ 57'84"	910
FS2	Shivloti Bawari	N30 ⁰ 15'08"	E076 ⁰ 57'84"	911
FS3	Bada Taksaal	N30 ⁰ 12'04"	E076 ⁰ 45'39"	920
FG4	Bada Taksaal	N30 ⁰ 20'08"	E076 ⁰ 57'80"	912
FG5	Shivloki Mandir	N30 ⁰ 25'07"	E076 ⁰ 52'84"	915
FG6	Sanavara	N30 ⁰ 53'56"	E077 ⁰ 00'23"	1367
US1	Sec-1, Parwanoo	N30 ⁰ 50'41"	E076 ⁰ 57'53"	765
US2	Sec-2, MC Office Parwanoo	N30 ⁰ 52'13"	E076 ⁰ 56'72"	760
US3	Bada Taksaal	N30 ⁰ 50'64"	E076 ⁰ 57'42"	920
UG4	Near Petrol Pump, Parwanoo	N30 ⁰ 52'11"	E076 ⁰ 55'71"	755
UG5	Sec-1, NSU Office Parwanoo	N30 ⁰ 50'35"	E076 ⁰ 57'36"	768
UG6	Windsmoor Hotel, Parwanoo NH	N30 ⁰ 50'40"	E076 ⁰ 57'32"	784

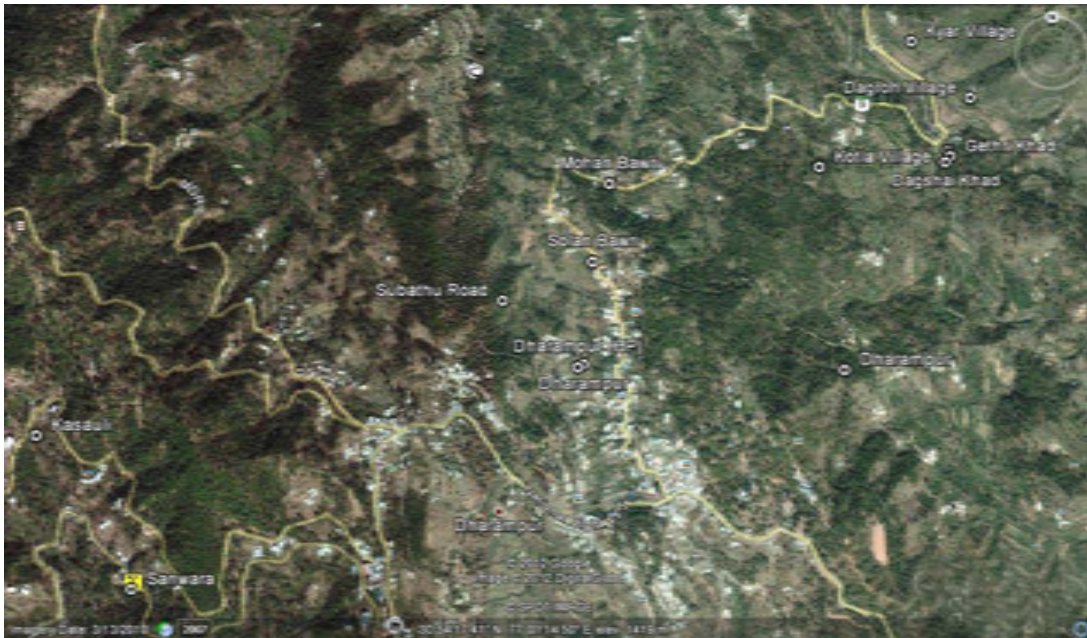


Plate 1 Sampling locations in Dharampur area



Plate 2 Sampling locations in Parwanoo area

Source: Google earth

Table 3.3 Sampling locations in Barotiwala area

Code	Location	Latitude	Longitude	Elevation
AS1	Bandh, Audda Khad	N30°57'10"	E076°55'90"	942
AS2	Bawari Khad, Patta	N30°56'87"	E076°55'52"	810
AS3	Patta	N30°57'67"	E076°54'64"	735
AG4	Kandhol Near Berghar	N30°56'47"	E076°52'81"	791
AG5	Patta	N30°57'26"	E076°54'18"	693
AG6	Chamiyan Bawari	N30°56'15"	E076°50'40"	1397
FS1	Patta, Bawari	N30°57'24"	E076°54'18"	701
FS2	Beja Khad, Shela Village	N30°57'07"	E076°54'18"	680
FS3	Thedpur	N30°56'45"	E076°045'34"	803
FG4	Patta (HP)	N30°57'07"	E076°54'13"	674
FG5	Haripur baweri	N30°55'59"	E076°52'69"	651
FG6	Thedpur	N30°56'84"	E076°053'51"	798
US1	Patta town tapwater	N30°57'47"	E076°54'60"	733
US2	Baguvala Khad	N30°53'87"	E076°50'32"	502
US3	Balahd khad, Lakar Depot	N30°55'83"	E076°49'47"	417
UG4	Satibala (Hp)	N30°54'98"	E076°51'43"	486
UG5	Satibala (HP)	N30°55'02"	E076°51'47"	484
UG6	Kandhol, gram panchayat patta Bawri	N30°56'54"	E076°52'86"	794

Table 3.4. Sampling locations in Chandi -Goyla Area

Code	Location	Latitude	Longitude	Elevation
AS1	Thada, Goyala	N31°01'28"	E076°53'29"	990
AS2	Goyala Khad, Batalbajtana	N31°02'00"	E076°52'95"	965
AS3	Solad, Basol	N30°58'30"	E076°57.42"	1127
AG4	Goyla (HP)	N31°01'52"	E076°53'19"	1139
AG5	Goyla	N31°01'84"	E076°52'97"	997
AG6	Badhal	N31°01'83"	E076°52'97"	993
FS1	Kuthar Khad	N30°57'70"	E076°57'68"	1070
FS2	Krisnagarh, Kuthar	N30°57'68"	E076°57'66"	1076
FS3	Sardighat, Saryal	N31°01'79"	E076°54'41"	1189
FG4	Goyla	N31°01'69"	E076°53'51"	1061
FG5	Basol, Kuthar	N30°58'30"	E076°57'41"	1130
FG6	Paplog, Goyala(HP)	N30°59'12"	E076°54'32"	798
US1	Goyla Tapwater	N31°01'78"	E076°53'11"	1137
US2	Chandi Tapwater	N31°01'14"	E076°54'99"	1169
US3	Chandi	N31°01'12"	E076°54'45"	1170
UG4	Goyla (HP)	N31°01'78"	E076°53'11"	998
UG5	Chandi (HP)	N31°01'14"	E076°34'99"	1185
UG6	Chandi (HP)	N31°01'13"	E076°54'99"	1181

AS- Agriculture surface

AG- Agriculture Underground

FS- Forest surface

FG- Forest Underground

US-Urban Surface

UG- Urban underground

3.2 COLLECTION AND PREPARATION OF SAMPLES

3.2.1 Collection and preparation of Water samples

Water samples were collected in glass bottles from different sources under different landuses (Agriculture, forest and urban land uses) during three seasons i.e., rainy, summer and winter from each site at different locations in three replications. Water sample of different sources viz. borewell, handpump, tapwater, bawari, nullah, khad and river were collected and preserved for quality analysis from each location. The pH, temperature, odour and color of water sample were recorded at sampling site which was further confirmed in the laboratory by using pH meter; electrical conductance meter and then samples were stored in the refrigerator at 4 °C for further analysis.

3.2.2 Collection, preservation and clearing of aquatic insect specimens.

The aquatic insects were collected by using the method of Subramanian and Sivarama Krishnan (2007). The aquatic insects from water body were collected by using aquatic insect net (Mesh size 40-80/cm²). All fresh specimens collected from surface water under different landuses were stored in 70 % ethanol for sorting and identification in the laboratory. After that insect specimens were transferred to 35% lactic acid in cavity blocks which were covered and kept at 35-40°C in oven for clearing of sample for a period of one week. The samples were mounted on slide in a Hoyer's media and covered with cover slips. The insects were identified by using a taxonomical key to the family level. The numbers of individuals in each family were counted.

3.2.3 Preparation of Hoyer's medium and mounting of specimens.

The cleared specimens were mounted in Hoyer's medium (Baker and Wharton, 1952). Hoyer's medium constituted:

- Distilled water (50 ml)
- Gum arabic (30ml)
- Chloral hydrate (200mg)
- Glycerine (20 ml)

Gum Arabic was dissolved in distilled water and slowly heated for about 15 minutes upto 70°C in 250ml flask. While heating the material was stirred continuously with a glass rod. Material was filtered to remove insoluble particles. Required amount of chloral hydrate

and glycerine were added to the filtrate and these contents were thoroughly mixed. The bottle was stoppered for further use.

For mounting, a single aquatic insect specimen was lifted with a needle from lactic acid in cavity block directly and placed in a droplet of Hoyer's medium onto a glass slide under stereoscope microscope. The specimen was oriented dorsoventrally and legs were spread with the help of needle. Cover slip was placed over the specimen to allow full expansion. The slide was gently heated until the solution began to show bubbles. This heat expanded and cleared the specimen. The specimens were scanned under binocular microscope for their orientation, which was corrected if required by gently moving the cover slip or by tapping. The slides were heat dried in flat position in an oven at 45-50 °C for 4 hours or until the Hoyer's medium was dry. The mounted slides were catalogued and later used for recording microscopic morphological features of mounted specimens recognized as taxonomic characters.

3.3 WATER QUALITY ANALYSIS

The water samples were analyzed for Physical, Chemical and Biological Parameters by applying the following procedure:

3.3.1 Physical Parameter

a) pH:

The pH was analyzed with help of pH strips at sampling site which was confirmed by EUTECH instrument pH 510 in laboratory.

b) EC:

EC was measured by the instrument microprocessor based conductivity/ TDS meter in the laboratory.

c) Colour

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

d) Odour

Odour was determined by smelling the water samples.

e) TDS (Total Dissolved Solids)

TDS was measured by the instrument microprocessor based conductivity/ TDS meter.

f) Temperature ⁰C:

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

3.3.2 Chemical Parameters

a) Biological Oxygen Demand:

BOD was calculated by using BOD-System Oxidirect. Samples were taken into the beaker and pH of samples was adjusted between 6.5 to 7.5 . Then 152ml of sample were poured into the BOD bottles, and 5-6 drops of nitrification inhibitor (ATH) was added with one magnetic stirrer. Then in the bottles gasket was kept, and 3-4 drops of KOH solution was added. After that sensor was attached to BOD bottle and bottles were loaded in the system. Finally BOD bottles loaded on BOD system was kept in incubator for five days at 20° C. The readings were recorded after 5 days.

b) Chemical oxygen demand:

COD was determined with the help of TR320 Spectroquant. For estimation of COD of water samples, 3ml of sample was pipette out and poured in COD Cell Test and then COD Solution A 0.3 ml and COD Solution B 2.3 ml was added into the sample and kept for digestion in spectroquant TR 320 at 146⁰C for two hours. After that samples were kept at room temperature to cool down and readings were taken in spectroquant pharo 300 of Merck made.

c) Ca:

Sample was prepared by pipetting out 0.50 ml sample into a test tube at 20 to 35 °C. Then 5 ml of Ca - 1 reagent was added and mixed with the prepared sample. Then 4 drops of Ca-2 reagent was added and mixed and at last 4 drops of Ca-3 reagent were added and mixed with the sample. Sample was left for eight minutes and then filled into a 10 mm cell. In alcoholic –alkaline solution calcium ion react with modified glyoxal- bis (2-hydroxyamil) to form a red- violet complex. The red violet complex is measured photometrically by using spectroquant phara 300 of Merck made.

d) Mg:

Mg was determined by Magnesium cell test. In this method one ml of sample was prepared at 20 to 30 °C which were poured into a reaction cell and mixed properly. Then 1ml of reagent Mg-IK was taken and mixed into reaction cell. Sample was left for three minutes for reaction. Then three drops of reagent Mg- 2K were added to the cell and were mixed. In neutral solution magnesium ions react with phthalein purple to form a violet dye that is determined photometrically by using spectroquant pharo 300 of Merck made.

e) Cl:

Chloride was estimated by pipetting out 5 ml of water sample into a test tube at 10 to 30 °C and after that 2.5 ml of Cl -1 reagent was added and mixed properly and then 0.5 ml Cl-2 reagent was added and left for one minute for reaction. Sample was filled in a 10 mm cell. In this method chloride ions react with mercury (II) thiocyanate to form slightly dissociated mercury (II) chloride. The thiocyanate released in the process in turn react with iron (III) ions to form red iron (III) thiocyanate that is determined photometrically by using Spectroquant pharo 300 of Merck made. This method is analogous to EPA 325.1 and US standard method

f) NO₃⁻ :

For nitrate estimation, one microspoon cap of NO₃ -1 reagent was taken and put into the dry test tube and then 5ml of NO₃ -2 reagent was added into test tube and test tube was shaken vigorously for one minute until NO₃ -1 were completely dissolved. Then 1.5 ml of pretreated sample was added slowly inside the tilted test tube into the reagent. After adding the sample it was again shaken vigorously. Now the sample was kept for ten minutes for the reaction to be occurred. In concentrated sulphuric acid nitrate ions react with benzoic acid derivatives to form a red nitro compound that is determined photometrically by using spectroquant pharo 300 of Merck made.

g) Heavy metals (Fe, Mn, Zn)

The samples were filtered by using whatman filter paper No.1. The filtered samples were injected into Inductively Coupled Plasma Absorption Spectrometer-6300 DUO (ICAP-6300 Duo) with the help of capillary tube of ICAP. The readings were measured by emission spectrometry method.

h) Permissible limits

Permissible limit followed for categorizing different parameters of domestic and drinking water are presented in Table 3.5

Table-3.5: Permissible limit of parameters of drinking water standard

Parameters	Permissible limit	Source
pH	6.5 to 8.5	WHO,1993
EC (dS/m)	NA	NA
Colour	NA	NA
Odour	Unobjectionable	ISI, 1992
Temperature (⁰ C)	NA	NA
TDS (mg/l)	500	ICMR, 1975
BOD (mg/l)	5	ICMR, 1975
COD(mg/l)	20	ICMR, 1975
Ca(mg/l)	75	ISI,1992
Mg(mg/l)	30	ISI, 1992
NO ₃ (mg/l)	45	ISI,1992
Cl (mg/l)	250	WHO,1993
Fe	0.30	ISI,1992
Mn	0.10	ISI, 1992
Zn	5.00	ISI,1992

3.3.3 Water Quality Index (WQI)

For calculating water quality index, the most important parameters viz. pH, TDS, BOD, COD, Calcium, Magnisium, Nitrate, Chloride were used. The method of Harkins (1974) was used for calculating WQI.

Water quality index (WQI) = $qiwi$

Where

qi - (Water quality rating) $100 \times (Va - Vi)/Vs - Vi$

Va - Actual value present in the water sample,

Vi - Ideal value (0 for all parameters except pH and DO which are 7.0 and 14.6 mg L⁻¹, respectively).

Vs - Standard value.

wi - (Unit weight) = K/Sn

K - (constant) $1/ Vs_1+1/Vs_2+-----+1/Vs_n$

Sn - Standard value.

The suitability of WQI values for human consumption according to Mishra & Patel (2001) is given in the Table 3.6

Table 3.6: Suitability of water quality index for human consumption

Range	Quality
0-24	Excellent
25-49	Good
50-74	Bad
75-100	Very Bad
>100	Unfit for human consumption

3.4 IDENTIFICATION OF AQUATIC INSECTS

All the aquatic insects found in surface water were identified upto family level by using the keys of Brues *et al.* (1954) and Dudgeon (2000).

3.4.1 Diversity index

For calculating the diversity of aquatic insects the following diversity index were calculated:

a) Simpson's Diversity Index (D)

Simpson's diversity index (D), was calculated by using the formula of Kirsch (1999) and Mandaville (1999).

$$D = 1 - \sum_{i=1}^s (pi)^2$$

where

pi - Proportion of individuals in the ith taxon of the community

s – Total number of taxa in the community

b) Biotic index

Biotic index was calculated by using formula of Hilsenhoff (1977) :

$$BI = \sum ni ai / N$$

Where

ni- Number of specimens in each taxonomic group

ai- Pollution tolerance score for that taxonomic group

N- Total number of organism in samples\

The water quality was evaluated by using the family level biotic index. The detail of biotic index, water quality and degree of pollution is presented in Table 3.7.

Table 3.7: Water quality by using biotic index

Biotic index	Water Quality	Degree of organic pollution
0.00-3.50	Excellent	No apparent organic pollution
3.51-4.50	Very good	Possible slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
6.51-7.50	Fairly Poor	Significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.0	Very poor	Severe organic pollution

- c) **EPT index:** EPT index was calculated by using the formula of NCDEHNR (1997).
 EPT Index = Total number of distinct taxa (Ephemeroptera, Placoptera, Tricoptera) within the groups. The detail of EPT rating is given in Table 3.8.

Table 3.8: EPT rating of EPT index.

Rating	Excellent	Good	Good-Fair	Fair	Poor
EPT	>27	21-27	14-20	7-13	0-6

3.5 STATISTICAL ANALYSIS

The data emanating from the above experiments were subjected to statistical analysis through Factorial Randomized Design (RBD) and the significance of each treatment was calculated as suggested by Cochran and Cox (1964).

Chapter-4

EXPERIMENTAL RESULTS

Present studies entitled, “Effect of different land uses on water quality of Dharampur Block of Solan District of Himachal Pradesh” were conducted in the Department of Environmental Science, College of Forestry, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh) during the years 2011-2012. In the present studies water samples were collected from surface and ground water and insects samples from surface water falling under agriculture, forest and urban/ suburban land uses of Dharampur block of Solan district during rainy, summer and winter seasons. The results so obtained are presented in this chapter.

4.1 EFFECT OF LAND USES ON PHYSICO- CHEMICAL PARAMETERS OF WATER DURING DIFFERENT SEASONS

4.1.1 Effect of land uses on physico- chemical parameters of water during different seasons at Dharampur

It is evident from Table 4.1 that the maximum pH (7.45) of surface water was recorded under urban land use which was statistically at par with agriculture land use (7.39) and significantly different from forest land use (7.25). The maximum pH (7.49) of surface water recorded during summer season was statistically different from rest of the seasons (rainy - 7.35, winter- 7.25). The maximum pH (7.76) of underground water was recorded under urban

Table 4.1: Effect of land uses on pH of surface and ground water at Dharampur during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	7.38	7.26	7.52	7.39	7.51	7.38	7.67	7.52
Forest	7.24	7.13	7.38	7.25	7.27	7.15	7.45	7.29
Urban/Suburban	7.43	7.37	7.56	7.45	7.68	7.61	8.00	7.76
Mean	7.35	7.25	7.49	7.36	7.49	7.38	7.70	7.52
CD (P=0.05)	Land use			0.09	Land use			0.12
	Season			0.09	Season			0.12
	Land use × Season			NS	Land use × Season			NS
	Water source				0.07			

land use which was statistically different from agriculture (7.52) and forest land use (7.29). The maximum pH (7.70) recorded during summer season was statistically different from rest of seasons (rainy- 7.49, winter- 7.38), the pH of last two seasons were at par with each other. The pH of underground water (7.52) and surface water (7.36) differed significantly with each other.

Data contained in Table 4.2 revealed that the maximum electrical conductivity (EC) (0.46 dS/m) of surface water recorded under urban land use was statistically at par with agriculture land use (0.44 dS/m) and significantly different from forest land use (0.25 dS/m). The maximum EC (0.45 dS/m) of surface water recorded during summer season was statistically different from rest of the seasons (rainy- 0.38 dS/m; winter- 0.32 dS/m), whereas rainy and winter seasons were statistically different from each other. The maximum EC of underground water was recorded under urban land use (0.59 dS/m) which was statistically at par with agriculture land use (0.54dS/m) and was statistically different from forest land use (0.48 dS/m). Maximum EC (0.59 dS/m) of underground water recorded during summer season was statistically at par with rainy season (0.53dS/m) and significantly different from winter season (0.49). The maximum EC recorded underground water (0.54 dS/m) differed statistically from surface water (0.38 dS/m).

Table 4.2: Effect of land uses on Electrical Conductivity (dS/m)of surface and ground water at Dharampur during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	0.42	0.38	0.52	0.44	0.52	0.52	0.59	0.54
Forest	0.25	0.2	0.29	0.25	0.49	0.38	0.57	0.48
Urban/Suburban	0.47	0.39	0.53	0.46	0.59	0.57	0.62	0.59
Mean	0.38	0.32	0.45	0.38	0.53	0.49	0.59	0.54
CD (P=0.05)	Land use			0.05	Land use			0.06
	Season			0.05	Season			0.06
	Land use × Season			NS	Land use × Season			NS
	Water source				0.03			

It is evident from Table 4.3 that the colour of the surface and ground water sample during different seasons under different land uses was colourless except surface water sample under urban land use during rainy season where colourless to light brown colour of water was observed.

Table 4.3: Effect of land uses on colour of surface and ground water at Dharampur during different seasons

Land Use	Water source					
	Surface			Underground		
	Season					
	Rainy	Winter	Summer	Rainy	Winter	Summer
Agriculture	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Forest	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Urban/Suburban	Light brown- Colourless	Colourless	Colourless	Colourless	Colourless	Colourless

Table 4.4 showed that the odour of surface and ground water samples during different seasons and land uses was odourless.

Table 4.4: Effect of land uses on odour of surface and ground water at Dharampur during different seasons

Land Use	Water source					
	Surface			Underground		
	Season					
	Rainy	Winter	Summer	Rainy	Winter	Summer
Agriculture	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
Forest	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
Urban/Suburban	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless

Data exhibited in Table 4.5 revealed that the maximum temperature (21.09 °C) of surface water was recorded under urban land use and minimum under forest land use (19.10°C). The maximum temperature (26.46°C) was recorded during summer season and minimum during winter season (11.83°C). Maximum temperature (28.10°C) was recorded from surface water under urban land use during summer season while minimum temperature (11.50°C) was under forest land use during winter season. Maximum temperature of

Table 4.5: Effect of land uses on temperature (°C) of surface and ground water at Dharampur during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	21.87	11.83	26.47	20.06	21.53	13.77	26.17	20.49
Forest	21.00	11.50	24.80	19.10	20.13	13.20	25.77	19.70
Urban/Suburban	23.00	12.17	28.10	21.09	22.83	14.83	26.63	21.43
Mean	21.96	11.83	26.46	20.08	21.50	13.93	26.19	20.54

underground water (21.43⁰C) was recorded under urban land use and minimum under forest land use (19.70⁰C). The maximum temperature (26.19⁰C) of underground water was recorded during summer season and minimum during winter season (13.93⁰C). The temperature of underground water was comparatively higher than surface water (20.54⁰C).

Data presented in Table 4.6 revealed that the maximum total dissolved solid (TDS) (355.33 mg/l) of surface water recorded under urban land use was statistically at par with agriculture (324.67 mg/l as well as forest land use (260.11 mg/l). The maximum TDS of surface water (365.78 mg/l) recorded during rainy season was statistically at par with summer season (317.44 mg/l) and significantly different from winter season (248.67 mg/l). The maximum TDS (401.89 mg/l) of underground water recorded under urban land use was statistically at par with agriculture land use (353.67 mg/l) and statistically different from forest land use (296.11 mg/l).

Table 4.6: Effect of land uses on total dissolved solid (mg/l) of surface and ground water at Dharampur during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	344.33	280.33	324.67	316.44	386.67	330.67	343.67	353.67
Forest	324.00	181.67	274.67	260.11	351.67	254.67	282.00	296.11
Urban/Suburban	429.00	284.00	353.00	355.33	458.00	374.67	373.00	401.89
Mean	365.78	248.67	317.44	310.63	398.78	320.00	332.89	350.56
CD (P=0.05)	Land use			96.88	Land use			85.75
	Season			96.88	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				NS			

Data presented in Table 4.7 revealed that the maximum biological oxygen demand (BOD) (1.60 mg/l) of surface water was recorded under urban land use which was statistically different from agriculture (1.37mg/l) and forest land use(1.07 mg/l). The maximum BOD (1.66 mg/l) of surface water was recorded during rainy season followed by summer season (1.47 mg/l) and winter season (0.87 mg/l). Maximum BOD (1.12 mg/l) of underground water was recorded under urban land use which was statistically at par with agriculture land use (0.96 mg/l) and statistically different from forest land use (0.83 mg/l). Maximum BOD (1.28mg/l) of underground water recorded during rainy season was statistically different from summer season (1.04 mg/l) as well as winter season (0.59 mg/l).

The BOD (1.33 mg/l) of surface water was statistically different from underground water (0.97mg/l).

Table 4.7: Effect of land uses on BOD (mg/l) of surface and ground water at Dharampur during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	1.70	0.90	1.50	1.37	1.33	0.53	1.00	0.96
Forest	1.23	0.77	1.07	1.02	1.03	0.57	0.90	0.83
Urban/Suburban	2.03	0.93	1.83	1.60	1.47	0.67	1.23	1.12
Mean	1.66	0.87	1.47	1.33	1.28	0.59	1.04	0.97
CD (P=0.05)	Land use			0.19	Land use			0.18
	Season			0.19	Season			0.18
	Land use × Season			NS	Land use × Season			NS
	Water source				0.10			

It is evident from Table 4.8 that the maximum chemical oxygen demand (COD) (11.53 mg/l) of surface water was recorded under urban land use which was statistically different from forest (10.84 mg/l) and agriculture land use (9.02mg/l). The maximum COD (10.88 mg/l) of surface water recorded during rainy season was statistically at par with summer season (10.66 mg/l) and significantly different from winter season (9.87 mg/l). The maximum COD (9.77 mg/l) of underground water was recorded under urban land use which was statistically different from rest of land uses (agriculture- 9.12 mg/l; forest- 8.66 mg/l). Maximum COD (9.56 mg/l) recorded during rainy season was statistically at par with summer season (9.33 mg/l) and statistically different from winter season (8.66 mg/l).

Table 4.8: Effect of land uses on COD (mg/l) of surface and ground water at Dharampur during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	11.27	10.33	10.93	10.84	9.40	8.77	9.20	9.12
Forest	9.33	8.53	9.20	9.02	9.00	8.20	8.77	8.66
Urban/Suburban	12.03	10.73	11.83	11.53	10.27	9.00	10.03	9.77
Mean	10.88	9.87	10.66	10.47	9.56	8.66	9.33	9.18
CD (P=0.05)	Land use			0.38	Land use			0.23
	Season			0.38	Season			0.23
	Land use × Season			NS	Land use × Season			NS
	Water source				NS			

Data contained in Table 4.9 revealed that the maximum calcium (Ca) content (102.38 mg/l) in surface water was recorded under urban land use which was statistically different from agriculture (90.78 mg/l) and forest land uses (86.33 mg/l). The calcium content (112.43 mg/l) recorded in underground water was statistically different from surface water (93.16 mg/l).

Table 4.9: Effect of land uses on Ca (mg/l) content of surface and ground water at Dharampur during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	87.33	93.00	92.00	90.78	109.00	113.00	116.50	112.83
Forest	84.00	85.33	89.67	86.33	106.67	112.00	114.00	110.89
Urban/Suburban	100.00	102.00	105.13	102.38	110.00	113.67	117.00	113.56
Mean	90.44	93.44	95.60	93.16	108.56	112.89	115.83	112.43
CD (P=0.05)	Land use			8.01	Land use			NS
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				6.56			

It is evident from Table 4.10 that the maximum Mg (magnesium) content (11.00 mg/l) recorded in underground water was statistically different from surface water (7.34 mg/l).

Table 4.10: Effect of land uses on Mg (mg/l) content of surface and ground water at Dharampur during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	7.30	7.33	7.67	7.43	10.03	11.37	12.17	11.19
Forest	6.53	6.80	7.37	6.90	8.57	10.30	11.77	10.21
Urban/Suburban	7.40	7.40	8.23	7.68	11.07	11.37	12.37	11.60
Mean	7.08	7.18	7.76	7.34	9.89	11.01	12.10	11.00
CD (P=0.05)	Land use			NS	Land use			NS
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				0.75			

Data contained in Table 4.11 revealed that the maximum nitrate (NO₃) content (1.56 mg/l) of surface water was recorded in agriculture land use which was statistically different from forest land use (0.81 mg/l) and was statistically at par with urban land use (1.47 mg/l). The content of NO₃ was maximum (1.70 mg/l) during rainy season in surface water which was statistically different from rest of the seasons (winter- 0.62 mg/l; summer-1.70 mg/l). Maximum NO₃ (2.27 mg/l) recorded in surface water under agriculture land use during rainy season was statistically at par with urban land use (1.93 mg/l) and differed statistically from forest land use (0.90 mg/l) during same season, while 1.50 mg/l NO₃ content recorded in surface water under agriculture land use during summer season was statistically at par with urban land use (1.47 mg/l) and statistically different from forest land use (0.81 mg/l). Similarly maximum NO₃ content (0.90 mg/l) recorded from surface water of agriculture land use during winter season was statistically at par with urban (0.50 mg/l) and forest land use (0.47 mg/l) during same season. The maximum NO₃ content (2.78 mg/l) was recorded from underground water which was statistically different from surface water (1.19 mg/l).

Table 4.11: Effect of land uses on NO₃ (mg/l) content of surface and ground water at Dharampur during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	2.27	0.90	1.50	1.56	6.30	3.77	4.83	4.96
Forest	0.90	0.47	0.81	0.73	1.83	0.77	1.53	1.38
Urban/Suburban	1.93	0.50	1.47	1.30	2.83	1.27	1.93	2.01
Mean	1.70	0.62	1.26	1.19	3.66	1.93	2.76	2.78
CD (P=0.05)	Land use			0.29	Land use			NS
	Season			0.29	Season			NS
	Land use × Season			0.50	Land use × Season			NS
	Water source				1.41			

It is extrapolated from Table 4.12 that the maximum chloride (Cl) content (23.72 mg/l) of surface water was recorded under urban land use which was statistically at par with agriculture land use (18.24 mg/l) and significantly different from forest land use (10.38 mg/l). Significantly maximum Cl content (26.96 mg/l) was recorded in surface water as compared to underground water (17.45 mg/l). The Cl content recorded under different land uses during different seasons of surface water differed non-significantly.

Table 4.12: Effect of land uses on Cl (mg/l) content of surface and ground water at Dharampur during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	21.20	29.20	27.60	26.00	11.07	19.67	24.00	18.24
Forest	19.47	18.00	25.03	20.83	6.47	13.63	11.03	10.38
Urban/Suburban	33.37	34.03	34.73	34.04	17.30	28.13	25.73	23.72
Mean	24.68	27.08	29.12	26.96	11.61	20.48	20.26	17.45
CD (P=0.05)	Land use			NS	Land use			8.98
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				6.23			

It is clear from Table 4.13 that the maximum iron (Fe) content (5.44 ppb) of surface water was recorded under urban land use which was significantly different from agriculture land use (3.56 ppb) and forest land use (1.67 ppb). The maximum Fe (5.67 ppb) of surface water recorded during summer season was statistically different from rest of the seasons (rainy – 1.56 ppb; winter-3.44 ppb). The maximum Fe (6.22 ppb) of underground water recorded under urban land use was statistically at par with agriculture land use (5.00 ppb) and statistically different from forest land use (2.67 ppb). The maximum Fe content (7.11 ppb) recorded during summer season was significantly different from rest of seasons (rainy- 2.56 ppb; winter- 4.22 ppb). The Fe content (4.63 ppb) recorded in underground water was statistically different from surface water (3.56 ppb).

Table 4.13: Effect of land uses on Fe (ppb) content of surface and ground water at Dharampur during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	1.33	3.67	5.67	3.56	3.00	5.00	7.00	5.00
Forest	0.00	1.33	3.67	1.67	0.67	2.67	4.67	2.67
Urban/Suburban	3.33	5.33	7.67	5.44	4.00	5.00	9.67	6.22
Mean	1.56	3.44	5.67	3.56	2.56	4.22	7.11	4.63
CD (P=0.05)	Land use			0.41	Land use			2.27
	Season			0.41	Season			2.27
	Land use × Season			NS	Land use × Season			NS
	Water source				0.95			

It is clear from Table 4.14 that the content of manganese (Mn) differed non significantly under different land uses during different seasons.

Table 4.14: Effect of land uses on Mn (ppb) content of surface and ground water at Dharampur during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	0.73	0.00	1.03	0.59	0.17	0.53	1.87	0.86
Forest	0.40	0.67	0.57	0.54	0.47	0.47	0.27	0.40
Urban/Suburban	0.33	0.87	1.00	0.73	0.67	1.33	0.87	0.96
Mean	0.49	0.51	0.87	0.62	0.43	0.78	1.00	0.74
CD (P=0.05)	Land use			NS	Land use			NS
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				NS			

It is evident from Table 4.15 that the maximum zinc (Zn) content (0.44 ppt) of surface water was recorded under urban land use which was statistically different from forest land use (0.02 ppt) and statistically at par with agriculture land use (0.57 ppt). The maximum Zn content (0.65 ppt) of underground water recorded under urban land use which was statistically at par with agriculture (0.50 ppt) and statistically different from forest land use (0.02 ppt). The maximum Zn content (0.60 ppt) was recorded during summer season which was statistically different from rainy season (0.23 ppt) and statistically at par with winter season (0.33 ppt).

Table 4.15: Effect of land uses on Zn (ppt) content of surface and ground water at Dharampur during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	0.17	0.33	0.57	0.36	0.33	0.47	0.70	0.50
Forest	0.00	0.00	0.07	0.02	0.00	0.00	0.07	0.02
Urban/Suburban	0.33	0.40	0.60	0.44	0.37	0.53	1.03	0.65
Mean	0.17	0.24	0.41	0.50	0.23	0.33	0.60	0.50
(P=0.05)	Land use			0.29	Land use			0.29
	Season			NS	Season			0.29
	Land use × Season			NS	Land use × Season			NS
	Water source				NS			

4.1.2 Effect of land uses on physico- chemical parameters of water during different seasons at Parwanoo

It is extrapolated from Table 4.16 that the maximum pH (8.29) of surface water was recorded during summer season which was statistically different from rainy season (7.72) as well as winter season (7.61). Maximum pH (8.15) of underground water samples recorded from urban land use was statistically at par with agriculture land use (7.99) and significantly different from forest land use (7.80). Maximum pH of underground water (8.48) recorded during summer season was significantly different from rainy season (7.80) as well as from winter season (7.66).

Table 4.16: Effect of land uses on pH of surface and ground water at Parwanoo during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	7.76	7.62	8.26	7.88	7.80	7.66	8.49	7.99
Forest	7.60	7.57	8.15	7.77	7.66	7.41	8.31	7.80
Urban/Suburban	7.81	7.64	8.46	7.97	7.93	7.89	8.62	8.15
Mean	7.72	7.61	8.29	7.87	7.80	7.66	8.48	7.98
CD (P=0.05)	Land use			NS	Land use			0.26
	Season			0.34	Season			0.26
	Land use × Season			NS	Land use × Season			NS
Water source				NS				

Data contained in Table 4.17 revealed that the maximum electrical conductivity (EC) (0.61 dS/m) of surface water was recorded under urban land use which was statistically different from agriculture land use (0.37 dS/m), as well as forest land use (0.31 dS/m), the last two were statistically at par with each other. The maximum EC (0.50 dS/m) of surface water was recorded during summer season which was statistically at par with rainy season (0.46 dS/m) and statistically different from winter season (0.32 dS/m). Maximum EC (0.71 dS/m) of underground water was recorded under urban land use which was statistically at par with agriculture land use (0.59 dS/m) and statistically different from forest land use (0.42 dS/m). Significantly higher EC (0.57 dS/m) was recorded in underground water as compared to surface water (0.43 dS/m).

Table 4.17: Effect of land uses on EC (dS/m) of surface and ground water at Parwanoo during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	0.38	0.29	0.44	0.37	0.61	0.43	0.73	0.59
Forest	0.35	0.25	0.35	0.31	0.53	0.29	0.44	0.42
Urban/Suburban	0.66	0.44	0.72	0.61	0.82	0.55	0.75	0.71
Mean	0.46	0.32	0.50	0.43	0.66	0.42	0.64	0.57
CD (P=0.05)	Land use			0.10	Land use			0.22
	Season			0.10	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				0.09			

It is clear from Table 4.18 that the colour of surface and ground water during different seasons under different land uses was colourless except underground water under agriculture and urban land uses during rainy season where colourless to light brown colour was observed.

Table 4.18: Effect of land uses on colour of surface and ground water at Parwanoo during different seasons

Land Use	Water source					
	Surface			Underground		
	Season					
	Rainy	Winter	Summer	Rainy	Winter	Summer
Agriculture	Colourless	Colourless	Colourless	Light brown-colourless	Colourless	Colourless
Forest	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Urban/Suburban	Colourless	Colourless	Colourless	Colourless - Light brown	Colourless	Colourless

It is evident from Table 4.19 that the odour of surface and ground water samples during different seasons under different land uses was odourless except surface water during rainy season under agriculture land use where odour of the water was odourless to septic and that of underground water during rainy season was odourless to septic under agriculture land use. The water sample of underground water during rainy season under urban land use was odour less to soapy.

Table 4.19: Effect of land uses on odour of surface and ground water at Parwanoo during different seasons

Land Use	Water source					
	Surface			Underground		
	Season					
	Rainy	Winter	Summer	Rainy	Winter	Summer
Agriculture	Odourless-Septic	Odourless	Odourless	Odourless - Septic	Odourless	Odourless
Forest	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
Urban/Suburban	Odourless	Odourless	Odourless	Odourless - Soapy	Odourless	Odourless

Data contained in Table 4.20 reveals that the maximum temperature (22.62⁰C) of surface water was recorded under urban land use and minimum under forest land use (20.38⁰C). The maximum temperature (29.13⁰C) of surface water was recorded during summer season and minimum during winter season (12.02⁰C). Among all land uses, the maximum temperature of surface water samples was recorded under urban land use during all the three seasons (summer- 30.63⁰C; rainy- 25.00⁰C and winter- 12.37⁰C). Surface water samples of forest land use during winter season recorded lowest temperature (11.67⁰C). Maximum temperature (21.96⁰C) of underground water was recorded under urban land use and minimum in forest land use (19.96⁰C). The maximum temperature (26.34⁰C) of underground water was recorded during summer season and minimum during winter season (13.29⁰C). The temperature of surface water was higher (21.74⁰C) as compared to underground water (20.88⁰C).

Table 4.20: Effect of land uses on temperature (⁰C) of surface and ground water at Parwanoo during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	24.00	12.03	30.47	22.17	23.00	13.33	25.83	20.72
Forest	23.17	11.67	26.30	20.38	22.00	12.93	24.93	19.96
Urban/Suburban	25.00	12.37	30.63	22.67	24.00	13.60	28.27	21.96
Mean	24.06	12.02	29.13	21.74	23.00	13.29	26.34	20.88

Data presented in Table 4.21 revealed that the maximum total dissolved solid (TDS) (379.56 mg/l) of surface water recorded during rainy season was statistically at par with summer season (243.33 mg/l) and significantly different from winter season (168.89mg/l). The maximum TDS (491.56 mg/l) of underground water sample recorded under urban land use was statistically different from forest land use (220.89 mg/l) as well as agriculture land use (352.22 mg/l). Maximum TDS of underground water (509.33 mg/l) recorded during rainy season was statistically different from winter season (205. 89 mg/l) as well as summer season (349.44mg/l). Statistically higher TDS (354.89 mg/l) was recorded from underground water as compared to surface water (263.93mg/l).

Table 4.21: Effect of land uses on TDS (mg/l) of surface and ground water at Parwanoo during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	406.33	138.33	234.00	259.56	583.67	189.33	283.67	352.22
Forest	217.33	111.67	185.33	171.44	332.33	129.00	201.33	220.89
Urban/Suburban	515.00	256.67	310.67	360.78	612.00	299.33	563.33	491.56
Mean	379.56	168.89	243.33	263.93	509.33	205.89	349.44	354.89
CD (P=0.05)	Land use			NS	Land use			102.69
	Season			166.11	Season			102.69
	Land use × Season			NS	Land use × Season			NS
	Water source				78.93			

Data exhibited in Table 4.22 revealed that the maximum biological oxygen demand (BOD) (3.17 mg/l) of surface water was recorded under urban land use which was statistically different from agriculture land use (2.33 mg/l) as well as forest land use (1.70 mg/l). Maximum BOD (3.44 mg/l) of surface water recorded during rainy season was statistically different from summer season (2.68 mg/l) and winter season (1.08mg/l). Maximum BOD (1.41 mg/l) of underground water sample recorded under urban land use was statistically at par with agriculture land use (1.23 mg/l) and significantly different from forest land use (0.86 mg/l). Maximum BOD (1.77mg/l) of underground water recorded during rainy season was statistically different from winter season (0.72mg/l) as well as summer season (1.01mg/l). The BOD (2.40 mg/l) of surface water was statistically different from underground water (1.17mg/l).

Table 4.22: Effect of land uses on BOD (mg/l) of surface and ground water at Parwanoo during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	3.33	1.00	2.67	2.33	1.77	0.83	1.10	1.23
Forest	3.00	0.90	1.20	1.70	1.53	0.43	0.60	0.86
Urban/Suburban	4.00	1.33	4.17	3.17	2.00	0.90	1.33	1.41
Mean	3.44	1.08	2.68	2.40	1.77	0.72	1.01	1.17
CD (P=0.05)	Land use			0.73	Land use			0.22
	Season			0.73	Season			0.22
	Land use × Season			NS	Land use × Season			NS
	Water source							

It is evident from Table 4.23 that the maximum chemical oxygen demand COD (15.29 mg/l) of surface water was recorded under urban land use which was statistically different from agriculture land use (12.02 mg/l) and forest land use (9.10 mg/l). Maximum COD (13.60 mg/l) of surface water recorded during rainy season was followed by summer season (12.10 mg/l) and winter season (10.62 mg/l). Maximum COD (11.60 mg/l) of underground water recorded under urban land use was statistically different from agriculture land use (10.30 mg/l) and forest land use (7.97mg/l), the last two were statistically different from each other. Maximum COD of underground water (10.93mg/l) recorded during rainy season was statistically different from winter season (9.03 mg/l) as well as summer season (9.90mg/l). The COD of surface water (12.11mg/l) was statistically different from underground water (9.96mg/l).

Table 4.23: Effect of land uses on COD (mg/l) of surface and ground water at Parwanoo during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	13.67	10.67	11.73	12.02	11.00	9.53	10.37	10.30
Forest	9.73	8.20	9.10	9.01	8.47	7.43	8.00	7.97
Urban/Suburban	17.40	13.00	15.47	15.29	13.33	10.13	11.33	11.60
Mean	13.60	10.62	12.10	12.11	10.93	9.03	9.90	9.96
CD (P=0.05)	Land use			1.00	Land use			0.67
	Season			1.00	Season			0.67
	Land use × Season			NS	Land use × Season			NS
	Water source							

It is evident from Table 4.24 that the maximum calcium (Ca) content (108.00mg/l) of surface water was recorded under urban land use which was statistically different from agriculture land use (78.44 mg/l) and forest land use (61.98 mg/l). Calcium content (77.78mg/l) recorded in underground water was statistically different from surface water (62.64mg/l).

Table 4.24: Effect of land uses on Ca (mg/l) content of surface and ground water at Parwanoo during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	65.17	86.17	84.00	78.44	108.33	111.67	113.67	111.22
Forest	63.27	63.00	59.67	61.98	83.20	100.00	112.37	98.52
Urban/Suburban	96.07	102.93	125.00	108.00	120.50	123.07	109.00	117.52
Mean	74.83	84.03	89.56	62.64	104.01	111.58	111.68	77.78
CD (P=0.05)	Land use			20.74	Land use			NS
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
Water source				4.54				

Data presented in Table 4.25 revealed that the maximum magnesium (Mg) content (13.50mg/l) of underground water was recorded under urban land use which was statistically different from agriculture land use (11.09 mg/l) and forest land use (8.77mg/l). Maximum Mg content of underground water (16.30mg/l) recorded during summer season was statistically different from rainy season (7.00mg/l) as well as winter season (10.06mg/l). The maximum

Table 4.25: Effect of land uses on Mg (mg/l) content of surface and ground water at Parwanoo during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	6.60	6.63	13.33	8.86	6.67	10.70	15.90	11.09
Forest	5.37	5.63	8.27	6.42	5.70	8.47	12.13	8.77
Urban/Suburban	7.40	6.70	13.67	9.26	8.63	11.00	20.87	13.50
Mean	6.46	6.32	11.76	11.12	7.00	10.06	16.30	8.18
CD (P=0.05)	Land use			NS	Land use			1.23
	Season			NS	Season			1.23
	Land use × Season			NS	Land use × Season			2.13
Water source				1.05				

Mg (20.87 mg/l) recorded from water samples of underground water from urban land use during summer season was statistically different from rest of the seasons and land uses. The Mg content (11.12mg/l) recorded under surface water was statistically different from underground water (8.18mg/l).

It is extrapolated from Table 4.26 that maximum nitrate (NO₃) content (2.15 mg/l) of surface water samples recorded under agriculture land use was statistically at par with urban land use (1.44 mg/l) and significantly different from forest land use (0.83 mg/l). Maximum NO₃ (2.19mg/l) of surface water recorded during rainy season was statistically at par with summer season (1.42 mg/l) and significantly different from winter season (0.81 mg/l). The nitrate content recorded from underground water (3.41mg/l) was statistically different from surface water (1.47 mg/l).

Table 4.26: Effect of land uses on NO₃ (mg/l) content of surface and ground water at Parwanoo during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	3.43	1.20	1.83	2.15	6.07	5.77	5.62	5.82
Forest	1.20	0.43	0.85	0.83	1.47	1.63	1.16	1.42
Urban/Suburban	1.93	0.80	1.58	1.44	3.90	2.32	2.80	3.01
Mean	2.19	0.81	1.42	1.47	3.81	3.24	3.19	3.41
CD (P=0.05)	Land use			0.79	Land use			NS
	Season			0.79	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				0.57			

Data contained in Table 4.27 revealed that maximum chloride (Cl) content (32.40 mg/l) of surface water recorded under urban land use was statistically at par with agriculture land use (30.11 mg/l) and statistically different from forest land use (21.04 mg/l). Maximum Cl content (32.36 mg/l) of surface water recorded during summer season was statistically different from rest of seasons (winter; 28.36mg/l, rainy; 22.84 mg/l). Maximum Cl content (26.52 mg/l) of underground water sample recorded under urban land use was statistically different from forest land use (17.51 mg/l) as well as agriculture land use (17.79 mg/l). Maximum Cl content (24.14 mg/l) recorded from underground water during summer season was statistically different from winter season (19.72mg/l) as well as rainy season (17.96mg/l), the last two were statistically at par with each other. Statistically higher Cl content (27.85 mg/l) was recorded under surface water as compared to underground water (20.61 mg/l).

Table 4.27: Effect of land uses on Cl (mg/l) content of surface and ground water at Parwanoo during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	22.33	31.33	33.67	29.11	14.67	18.67	20.03	17.79
Forest	18.00	19.40	25.73	21.04	14.20	17.33	21.00	17.51
Urban/Suburban	28.20	34.33	37.67	33.40	25.00	23.17	31.40	26.52
Mean	22.84	28.36	32.36	27.85	17.96	19.72	24.14	20.61
CD (P=0.05)	Land use			2.74	Land use			2.58
	Season			2.74	Season			2.58
	Land use × Season			NS	Land use × Season			NS
	Water source				1.41			

It is evident from Table 4.28 that the maximum iron (Fe) content (6.44 ppb) of surface water was recorded under urban land use which was significantly different from agriculture land use (4.44 ppb) and forest land use (2.22 ppb). The maximum Fe content (6.67 ppb) of surface water recorded during summer season was statistically different from rest of the seasons (rainy - 2.11ppb, winter-4.33 ppb). The maximum Fe (7.11 ppb) of underground water recorded under urban land use was statistically at par with agriculture land use (6.00 ppb) and statistically different from forest land use (3.67 ppb). The maximum Fe (8.11ppb) recorded during summer season was significantly different from rest of seasons (rainy- 3.44 ppb; winter- 5.22 ppb), the Fe content of last two seasons were at par with each other. The Fe content recorded underground water (5.99 ppb) was statistically at par with surface water (4.37 ppb).

Table 4.28: Effect of land uses on Fe (ppb) content of surface and ground water at Parwanoo during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	2.00	4.67	6.67	4.44	4.00	6.00	8.00	6.00
Forest	0.00	2.00	4.67	2.22	1.67	3.67	5.67	3.67
Urban/Suburban	4.33	6.33	8.67	6.44	4.67	6.00	10.67	7.11
Mean	2.11	4.33	6.67	4.37	3.44	5.22	8.11	5.59
CD (P=0.05)	Land use			0.58	Land use			2.38
	Season			0.58	Season			2.38
	Land use × Season			NS	Land use × Season			NS
	Water source				1.01			

It is clear from Table 4.29 that the maximum manganese (Mn) content (0.74 ppb) of surface water recorded under urban land use was statistically different from agriculture land use (0.34 ppb) and forest land use (0.15 ppb), the last two were significantly at par with each other. The Mn content recorded in underground water (0.62 ppb) was statistically different from surface water (0.41 ppb).

Table 4.29: Effect of land uses on Mn (ppb) content of surface and ground water at Parwanoo during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	0.20	0.46	0.36	0.34	0.39	0.33	1.03	0.58
Forest	0.21	0.17	0.06	0.15	0.19	0.57	0.49	0.42
Urban/Suburban	0.63	0.56	1.03	0.74	0.97	0.74	0.91	0.87
Mean	0.35	0.40	0.48	0.41	0.51	0.55	0.81	0.62
CD (P=0.05)	Land use			0.27	Land use			NS
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				0.19			

It is extrapolated from Table 4.30 that the maximum zinc (Zn) content (0.62 ppt) of surface was recorded under urban land use which was statistically different from forest land use (0.06 ppt) and statistically at par with agriculture land use (0.53 ppt). The maximum Zn (0.66 ppt) of surface water recorded during summer season was statistically at par with winter season (0.32 ppt) and statistically different from rainy season (0.23ppt). The maximum Zn (0.92 ppt) of

Table 4.30: Effect of land uses on Zn (ppt) content of surface and ground water at Parwanoo during different seasons

Land Use System	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	0.23	0.47	0.90	0.53	0.53	0.77	1.03	0.78
Forest	0.00	0.00	0.17	0.06	0.00	0.00	0.23	0.08
Urban/Suburban	0.47	0.50	0.90	0.62	0.60	0.83	1.33	0.92
Mean	0.23	0.32	0.66	0.40	0.38	0.53	0.87	0.59
CD (P=0.05)	Land use			0.34	Land use			0.30
	Season			0.34	Season			0.30
	Land use × Season			NS	Land use × Season			NS
	Water source				NS			

underground water recorded under urban land use was statistically at par with agriculture land use (0.78 ppt) and statistically different from forest land use (0.08 ppt). The maximum Zn (0.87 ppt) recorded during summer season was statistically different from rest of the seasons (rainy- 0.53 ppt; winter- 0.38 ppt).

4.1.2 Effect of land uses on physico- chemical parameters of water during different seasons at Barotiwala

It is evident from Table 4.31 that the maximum pH (8.03) of surface water recorded under urban land use was significantly different from agriculture land use (7.81) as well as forest land use (7.75). Maximum pH (8.24) of surface water recorded during summer season was statistically different from rainy season (7.72) as well as winter season (7.65), the last two were statistically at par with each other. Maximum pH (8.28) of underground water samples recorded from urban land use was statistically at par with agriculture land use (8.20) and significantly different from forest land use (7.79). Maximum pH of underground water (8.55) recorded during summer season was significantly different from rainy season (8.01) as well as winter season (7.71). Significantly higher pH (8.09) was recorded in underground water as compared to surface water (7.87).

Table 4.31: Effect of land uses on pH of surface and ground water at Barotiwala during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	7.67	7.64	8.13	7.81	8.15	7.72	8.74	8.20
Forest	7.67	7.50	8.12	7.76	7.71	7.52	8.14	7.79
Urban/Suburban	7.81	7.81	8.47	8.03	8.17	7.90	8.77	8.28
Mean	7.72	7.65	8.24	7.87	8.01	7.71	8.55	8.09
CD (P=0.05)	Land use			0.16	Land use			0.19
	Season			0.16	Season			0.19
	Land use × Season			0.28	Land use × Season			NS
	Water source				0.10			

Data contained in Table 4.32 revealed that the maximum electrical conductivity (EC) (0.56 dS/m) of surface water was recorded under urban land use which was statistically different from agriculture land use (0.39 dS/m) and forest land use (0.29 dS/m). Maximum EC (0.84 dS/m) of underground water was recorded under urban land use which was statistically different from agriculture land use (0.61 dS/m) and forest land use (0.56 dS/m).

The EC (0.67dS/m) of underground water was statistically different from surface water (0.39 dS/m).

Table 4.32: Effect of land uses on EC (dS/m) of surface and ground water at Barotiwala during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	0.34	0.36	0.36	0.36	0.53	0.66	0.65	0.61
Forest	0.30	0.23	0.29	0.27	0.53	0.50	0.65	0.56
Urban/Suburban	0.56	0.44	0.67	0.56	0.84	0.75	0.93	0.84
Mean	0.40	0.34	0.44	0.39	0.63	0.64	0.74	0.67
CD (P=0.05)	Land use			0.12	Land use			0.11
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				0.07			

It is clear from Table 4.33 that the colour of the water samples of surface and ground water under different land uses was colourless except the colour of surface water under urban land use which varied from colourless to blackish during all the three seasons.

Table 4.33: Effect of land uses on colour of surface and ground water at Barotiwala during different seasons

Land Use	Water source					
	Surface			Underground		
	Season					
	Rainy	Winter	Summer	Rainy	Winter	Summer
Agriculture	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Forest	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Urban/Suburban	Colourless- Blackish	Colourless - Blackish	Colourless - Blackish	Colourless	Colourless	Colourless

Table 4.34 showed that the odour of surface water during rainy season and winter season under agriculture land use was odourless to septic where as it was odourless under forest. Under urban land use during rainy season odour was odourless to soapy where as it was odourless to soapy during winter season. Odourless to septic odour of surface water under urban land use during summer season was observed. Similarly odour of underground water during rainy season under agriculture land use was odourless to septic where as it was odourless to soapy under urban land use during summer season.

Table 4.34: Effect of land uses on odour of surface and ground water at Barotiwala during different seasons

Land Use	Water source					
	Surface			Underground		
	Season					
	Rainy	Winter	Summer	Rainy	Winter	Summer
Agriculture	Odourless-Septic	Odourless - Septic	Odourless	Odourless - Septic	Odourless	Odourless
Forest	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
Urban/Suburban	Odourless-Soapy	Odourless - Soapy	Odourless - Septic	Odourless	Odourless	Odourless-Soapy

Data contained in Table 4.35 reveals that the maximum temperature (24.55⁰C) of surface water was recorded under urban land use and minimum in agriculture land use (21.43⁰C). The maximum temperature (29.14⁰C) of surface water was recorded during summer season and minimum during winter season (11.19⁰C). Maximum temperature (32.57⁰C) recorded from surface water samples of urban land use during summer season. During rainy season, maximum temperature (29.50⁰C) was recorded under urban land use and minimum under agriculture land use (25.50⁰C). Similarly during winter season the maximum temperature (11.58⁰C) of surface water was recorded from urban land use and minimum from forest land use (10.90⁰C). Maximum temperature (21.31⁰C) of underground water was recorded under urban land use and minimum under forest land use (19.80⁰C). The maximum temperature (26.47⁰C) of underground water was recorded during summer season and minimum during winter season (12.79⁰C). During rainy season, maximum temperature (22.50⁰C) was recorded under urban land use and minimum under forest land use (21.83⁰C). Comparatively higher (22.54⁰C) temperature was recorded under surface water than underground water (20.44⁰C).

Table 4.35: Effect of land uses on temperature (⁰C) of surface and ground water at Barotiwala during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	25.50	11.08	27.70	21.43	21.87	12.85	25.93	20.22
Forest	26.83	10.90	27.17	21.63	21.83	12.17	25.40	19.80
Urban/Suburban	29.50	11.58	32.57	24.55	22.50	13.35	28.07	21.31
Mean	27.28	11.19	29.14	22.54	22.07	12.79	26.47	20.44

Data presented in Table 4.36 revealed that the maximum total dissolved solid (TDS) (414.78 mg/l) of surface water recorded under urban land use was statistically different from agriculture land use (322.11mg/l) as well as forest land use (203 mg/l). Maximum TDS (458.11mg/l) of surface water recorded during rainy season was statistically different from summer (272.67mg/l) as well as winter season (209.11mg/l), the last two were statistically at par with each other. Maximum TDS (647.67 mg/l) recorded in surface water of urban land use during rainy season was statistically different from all the land uses during all the seasons, while 350.67 mg/l TDS recorded in surface water samples of urban land use during summer season was statistically at par with agriculture land use (267.67 mg/l) during the same season, agriculture land use (223.00 mg/l) and urban land use of winter season as well as forest land use and agriculture land use (475.67 mg/l) during rainy season. Maximum TDS (563 mg/l) of underground water recorded under urban land use was statistically different forest land use (326.78mg/l) and was significantly at par with agriculture land use (465 mg/l). Maximum TDS of underground water (569.78 mg/l) recorded during rainy season was statistically different from winter season (344.89 mg/l) and was statistically at par with summer season (440.11mg/l). Significantly higher TDS (451.59 mg/l) was recorded from underground water was as compared to surface water (313.30mg/l).

Table 4.36: Effect of land uses on TDS (mg/l) of surface and ground water at Barotiwala during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	475.67	223.00	267.67	322.11	595.67	331.67	467.67	465.00
Forest	251.00	158.33	199.67	203.00	415.67	320.67	244.00	326.78
Urban/Suburban	647.67	246.00	350.67	414.78	698.00	382.33	608.67	563.00
Mean	458.11	209.11	272.67	313.30	569.78	344.89	440.11	451.59
CD (P=0.05)	Land use			76.27	Land use			165.40
	Season			76.27	Season			165.40
	Land use × Season			NS	Land use × Season			NS
	Water source				79.56			

Data exhibited in Table 4.37 revealed that the maximum biological oxygen demand (BOD)of surface water (16.61 mg/l) was recorded in urban land use which was statistically different from agriculture land use (7.88 mg/l) and forest land use (3.65 mg/l). Significantly maximum BOD (18.54 mg/l) of surface water was recorded during rainy season followed by summer season (8.03 mg/l) and winter season (1.57 mg/l). Maximum BOD (33.33 mg/l)

recorded in surface water of urban land use during rainy season was statistically different from all the land uses during rest of the seasons. BOD (14.33mg/l) recorded from surface water samples of urban land use during summer season was statistically at par with agriculture land use (8.17 mg/l) during same season and agriculture land use (14.00 mg/l) as well as forest land use (8.28 mg/l) during the rainy season and significantly different from forest land use (1.60 mg/l) of same season and all the land uses during winter season. Maximum BOD (7.17 mg/l) of underground water sample recorded under urban land use was statistically different from agriculture land use (4.09 mg/l) and forest land use (3.20 mg/l). Maximum BOD (9.52 mg/l) of underground water recorded during rainy season was followed by summer season (3.96 mg/l) and winter season (0.99 mg/l). Maximum BOD (12.67 mg/l) recorded from underground water samples of urban land use during rainy season was statistically different from agriculture (8.52 mg/l) and forest land uses (7.38 mg/l) during the same season and all the land uses during rest of the seasons. Maximum BOD (7.67 mg/l) recorded from underground water samples of urban land use during summer season was significantly different from agriculture land use (2.77 mg/l) and forest land use (1.43 mg/l) during same season as well as all the land uses of winter season and was statistically at par with agriculture land use (8.52 mg/l) and forest land use (7.38 mg/l) of rainy season. Significantly higher BOD (9.38 mg/l) was recorded under surface water as compared to underground water (4.82 mg/l).

Table 4.37: Effect of land uses on BOD (mg/l) of surface and ground water at Barotiwala during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	14.00	1.47	8.17	7.88	8.52	1.00	2.77	4.09
Forest	8.28	1.07	1.60	3.65	7.38	0.80	1.43	3.20
Urban/Suburban	33.33	2.17	14.33	16.61	12.67	1.17	7.67	7.17
Mean	18.54	1.57	8.03	9.38	9.52	0.99	3.96	4.82
CD (P=0.05)	Land use			5.65	Land use			1.19
	Season			5.65	Season			1.19
	Land use × Season			NS	Land use × Season			2.07
	Water source				2.26			

It is evident from Table 4.38 that the maximum chemical oxygen demand (COD) (78.44 mg/l) of surface water was recorded under urban land use which was statistically different from agriculture land use (20.48 mg/l) and forest land use (11.11 mg/l). Significantly maximum COD (27.44 mg/l) of underground water was recorded under urban

land use followed by agriculture land use (14.57 mg/l) and forest land use (8.82 mg/l). Maximum COD (19.20 mg/l) of underground water recorded during rainy season was statistically different from winter season (14.23 mg/l) and was at par with summer season (17.40 mg/l). Significantly higher COD (36.68 mg/l) was recorded under surface water as compared to underground water (16.94 mg/l).

Table 4.38: Effect of land uses on COD (mg/l) of surface and ground water at Barotiwala during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	28.00	15.67	17.77	20.48	15.57	13.33	14.80	14.57
Forest	12.33	10.00	11.00	11.11	9.37	8.37	8.73	8.82
Urban/Suburban	107.33	49.00	79.00	78.44	32.67	21.00	28.67	27.44
Mean	49.22	24.89	35.92	36.68	19.20	14.23	17.40	16.94
CD (P=0.05)	Land use			28.37	Land use			3.42
	Season			NS	Season			3.42
	Land use × Season			NS	Land use × Season			NS
	Water source				12.60			

Data contained in Table 4.39 revealed that the maximum calcium (Ca) content (81.10 mg/l) of surface water was recorded under urban land use which was statistically different from agriculture land use (60.06 mg/l) and forest land use (46.77 mg/l). Significantly maximum Ca content (76.33 mg/l) of surface water was recorded during summer season followed by winter season (70.30 mg/l) and rainy season (41.29 mg/l). The Ca content (90.84 mg/l) of underground water recorded under urban land use was statistically different from agriculture land use (75.96 mg/l) and forest land use (63.80 mg/l). Maximum Ca content (83.56 mg/l) of underground water recorded during summer season was statistically different from rainy season (64.79 mg/l) and was statistically at par with summer season (64.79 mg/l). Maximum Ca content (102.33 mg/l) recorded in underground water of urban land use during summer season was statistically different from agriculture land use and forest land use of the same season as well as winter season and all the land uses of rainy season and was statistically at par with urban land use of winter season (94.27 mg/l). Significantly higher Ca content (76.87 mg/l) was recorded in underground water as compared to surface water (62.64 mg/l).

Table 4.39: Effect of land uses on Ca (mg/l) content of surface and ground water at Barotiwala during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	32.23	68.60	79.33	60.06	73.43	77.43	77.00	75.76
Forest	32.20	53.43	54.67	46.77	45.00	75.07	71.33	63.80
Urban/Suburban	59.43	88.87	95.00	81.10	75.93	94.27	102.33	90.84
Mean	41.29	70.30	76.33	62.64	64.79	82.26	83.56	76.87
CD (P=0.05)	Land use			7.92	Land use			6.83
	Season			7.92	Season			6.83
	Land use × Season			NS	Land use × Season			11.82
	Water source				4.45			

It is extrapolated from Table 4.40 that the maximum magnesium (Mg) content (17.09 mg/l) of surface water was recorded under urban land use which was statistically different from agriculture land use (9.91 mg/l) and forest land use (4.02 mg/l), however Mg content of last two land uses were at par with each other. Significantly higher Mg content (18.33 mg/l) was recorded in underground water as compared to surface water (10.34 mg/l).

Table 4.40: Effect of land uses on Mg (mg/l) content of surface and ground water at Barotiwala during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	8.37	10.37	11.00	9.91	16.87	19.97	21.00	19.28
Forest	3.57	4.03	4.47	4.02	9.57	12.53	13.43	11.84
Urban/Suburban	15.37	16.03	19.87	17.09	21.70	24.60	25.33	23.88
Mean	9.10	10.14	11.78	10.34	16.04	19.03	19.92	18.33
CD (P=0.05)	Land use			7.11	Land use			NS
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				6.06			

Data presented in Table 4.41 revealed that the maximum nitrate (NO₃) content (2.70 mg/l) of underground water was recorded under urban land use which was statistically different from forest land use (1.03 mg/l) and was statistically at par with agriculture land use (2.08 mg/l). The content of NO₃ was maximum (3.29 mg/l) during rainy season in surface

water which was statistically different from rest of the seasons (winter- 1.14 mg/l; summer- 1.38 mg/l), the last two were statistically at par with each other. Maximum NO₃ content of surface water (5.41 mg/l) recorded under urban land use was statistically different from forest land use (1.97 mg/l) and statistically at par with agriculture land use (3.61 mg/l). Significantly higher NO₃ content (3.74 mg/l) was recorded under surface water as compared to underground water (1.94 mg/l).

Table 4.41: Effect of land uses on NO₃ (mg/l) content of surface and ground water at Barotiwala during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	3.10	1.30	1.83	2.08	3.57	3.83	4.10	3.83
Forest	2.27	0.38	0.43	1.03	2.93	1.45	1.53	1.97
Urban/Suburban	4.50	1.74	1.87	2.70	6.30	4.69	5.23	5.41
Mean	3.29	1.14	1.38	1.94	4.27	3.32	3.62	3.74
CD (P=0.05)	Land use			0.89	Land use			1.80
	Season			0.89	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				0.95			

It is evident from Table 4.42 that the maximum chloride (Cl) content (38.92 mg/l) of surface water recorded under urban land use was statistically different from agriculture land use (35.02 mg/l) and forest land use (26.12 mg/l). Maximum Cl content (37.06 mg/l) in surface water recorded during summer season was statistically at par with winter season (35.33 mg/l) and statistically different from rainy season (27.68 mg/l), the last two were statistically different from each other. Maximum Cl content (50 mg/l) recorded in surface water samples of urban land use during summer season was statistically different from agriculture land use (41.13 mg/l) and forest land use (20.03 mg/l) during same season and all the land uses of winter and rainy seasons. The Cl content (37.33 mg/l) of surface water samples of urban land use during winter season was statistically at par with agriculture (36 mg/l) and forest land use (32.67 mg/l) of the same season and agriculture land use (41.13 mg/l) of summer season and statistically different from all the land uses of rainy season and forest land use of summer season. Maximum Cl content (27.22 mg/l) of underground water recorded under urban land use was statistically different from agriculture land use (19.64 mg/l) and forest land use (13.67 mg/l). Maximum Cl content (26.81 mg/l) of underground water recorded during summer season was statistically different from winter season (19.66

mg/l) and rainy season (14.07 mg/l). The Cl content (33.36 mg/l) recorded under surface water was statistically different from underground water (20.18 mg/l).

Table 4.42: Effect of land uses on Cl (mg/l) content of surface and ground water at Barotiwala during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	27.93	36.00	41.13	35.02	13.00	18.67	27.27	19.64
Forest	25.67	32.67	20.03	26.12	5.33	17.13	18.53	13.67
Urban/Suburban	29.43	37.33	50.00	38.92	23.87	23.17	34.63	27.22
Mean	27.68	35.33	37.06	33.36	14.07	19.66	26.81	20.18
CD (P=0.05)	Land use			3.11	Land use			5.07
	Season			3.11	Season			5.07
	Land use × Season			NS	Land use × Season			NS
	Water source				2.49			

It is evident from Table 4.43 that the maximum iron (Fe) content (7.22 ppb) of surface water was recorded under urban land use which was statistically different from forest land use (3.78 ppb) and statistically at par with agriculture land use (5.77 ppb), the last two were significantly at par with each other.

Table 4.43: Effect of land uses on Fe (ppb) content of surface and ground water at Barotibala during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	4.67	6.67	5.97	5.77	4.67	8.00	10.33	7.67
Forest	1.67	3.33	6.33	3.78	2.67	5.67	7.33	5.22
Urban/Suburban	6.33	8.00	7.33	7.22	7.57	7.40	8.67	7.88
Mean	4.22	6.00	6.54	5.59	4.97	7.02	8.78	6.92
CD (P=0.05)	Land use			2.52	Land use			NS
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				NS			

It is clear from Table 4.44 that the maximum manganese (Mn) content (7.42 ppt) of surface was recorded under urban land use which was statistically different from forest land use (1.48 ppt) and statistically at at par with agriculture land use (3.37 ppt), the last two were

significantly at par with each other. The Mn content of underground water (6.24 ppb) was statistically different from surface water (4.09 ppb).

Table 4.44: Effect of land uses on Mn (ppb) content of surface and ground water at Barotiwala during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	1.97	4.57	3.57	3.37	3.90	3.29	10.33	5.84
Forest	2.11	1.68	0.63	1.48	1.87	5.67	4.93	4.16
Urban/Suburban	6.33	5.60	10.33	7.42	9.67	7.40	9.13	8.73
Mean	3.47	3.95	4.84	4.09	5.14	5.45	8.13	6.24
CD (P=0.05)	Land use			2.72	Land use			NS
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				1.89			

It is extrapolated from Table 4.45 that the maximum zinc (Zn) content (1.02 ppt) of surface was recorded under urban land use which was statistically different from forest land use (0.14ppt) and statistically at par with agriculture land use (0.78 ppt). The maximum Zn content (0.99 ppt) of surface water recorded during summer season was statistically different from winter season (0.57 ppt) and rainy season (0.38 ppt). The maximum Zn (1.29 ppt) of underground water recorded under urban land use was statistically at par with agriculture land use (1.11 ppt) and statistically different from forest land use (0.18 ppt).

Table 4.45: Effect of land uses on Zn (ppt) content of surface and ground water at Barotibala during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	0.40	0.73	1.20	0.78	0.80	1.17	1.36	1.11
Forest	0.00	0.10	0.31	0.14	0.00	0.17	0.37	0.18
Urban/Suburban	0.73	0.89	1.44	1.02	0.90	1.17	1.80	1.29
Mean	0.38	0.57	0.99	0.65	0.57	0.83	1.18	0.86
CD (P=0.05)	Land use			0.34	Land use			0.30
	Season			0.34	Season			0.30
	Land use × Season			NS	Land use × Season			NS
	Water source				NS			

4.1.2 Effect of land uses on physico- chemical parameters of water during different seasons at Chand- Goyla

It is evident from Table 4.46 that maximum pH (7.56) of surface water was recorded under urban land use and minimum under forest land use (7.07), all being statistically different from one another. Maximum pH (7.52) of surface water recorded during summer season was statistically different from rainy season (7.33) as well as winter season (7.16). Maximum pH (7.85) of surface water recorded under urban land use during summer season was statistically different from all the land uses of the same season as well as the rest of the seasons while 7.44 pH of surface water samples of urban land use during rainy season was statistically at par with agriculture land use during same season as well as urban land use of winter season and agriculture land use of summer season (7.44). Maximum pH (7.63) recorded in underground water of urban land use was statistically different from agriculture (7.44) and forest (7.18) land uses. Maximum pH (7.59) of underground water recorded during summer season was significantly different from rainy season (7.38) as well as winter season (7.28), the last two were statistically at par with each other. The pH (7.41) of underground water was statistically different from surface water (7.33).

Table 4.46: Effect of land uses on pH of surface and ground water at Chand-Goyla during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	7.43	7.27	7.44	7.38	7.45	7.39	7.49	7.44
Forest	7.12	6.81	7.27	7.07	7.13	7.03	7.37	7.18
Urban/Suburban	7.44	7.39	7.85	7.56	7.56	7.42	7.90	7.63
Mean	7.33	7.16	7.52	7.33	7.38	7.28	7.59	7.41
CD (P=0.05)	Land use			0.09	Land use			0.13
	Season			0.09	Season			0.13
	Land use × Season			NS	Land use × Season			NS
	Water source				0.06			

Data contained in Table 4.47 revealed that the maximum electrical conductivity (EC) (0.47 dS/m) of surface water was recorded under urban land use which was statistically at par with agriculture land use (0.36 dS/m) and significantly different with forest land use (0.32 dS/m). The EC (0.57 dS/m) of underground water was significantly higher as compared to surface water (0.38 dS/m).

Table 4.47: Effect of land uses on EC (dS/m) of surface and ground water at Chandi-Goyla during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	0.37	0.31	0.41	0.36	0.54	0.55	0.60	0.56
Forest	0.33	0.26	0.39	0.32	0.53	0.43	0.58	0.52
Urban/Suburban	0.48	0.39	0.53	0.47	0.61	0.64	0.67	0.64
Mean	0.39	0.32	0.44	0.38	0.56	0.54	0.62	0.57
CD (P=0.05)	Land use			0.11	Land use			NS
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				0.06			

It is clear from Table 4.48 that the colour of both the water sources (surface as well as underground water) under different land uses during different seasons was colourless.

Table 4.48: Effect of land uses on colour of surface and ground water at Chandi-Goyla during different seasons

Land Use	Water source					
	Surface			Underground		
	Season					
	Rainy	Winter	Summer	Rainy	Winter	Summer
Agriculture	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Forest	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Urban/Suburban	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless

Table 4.49 showed that the odour of the water samples of surface water and underground water during different seasons under different land uses was odourless.

Table 4.49: Effect of land uses on odour of surface and ground water at Chandi-Goyla during different seasons

Land Use	Water source					
	Surface			Underground		
	Season					
	Rainy	Winter	Summer	Rainy	Winter	Summer
Agriculture	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
Forest	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
Urban/Suburban	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless

Data presented in Table 4.50 reveals that the maximum temperature (23.68⁰C) of surface water was recorded under urban land use and minimum (20.91⁰C) under forest land use. The maximum temperature (28.48⁰C) of surface water was recorded during summer

season and minimum during winter season (12.42⁰C). Urban land use recorded maximum temperature during all the seasons (summer- 29.53⁰C; winter-12.83⁰C and rainy - 28.67⁰C). Similarly maximum temperature (22.57⁰C) of underground water was recorded under urban land use and minimum under forest land use (19.57 ⁰C). The maximum temperature of underground water (25.79⁰C) was recorded during summer season and minimum during winter season (13.83⁰C). Comparatively higher temperature was recorded in surface water (22.34 ⁰C) than underground water (20.89⁰C).

Table 4.50: Effect of land uses on temperature (⁰C) of surface and ground water at Chandi-Goyla during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	26.00	12.43	28.83	22.42	22.17	14.00	25.47	20.54
Forest	23.67	12.00	27.07	20.91	21.33	13.03	24.33	19.57
Urban/Suburban	28.67	12.83	29.53	23.68	25.67	14.47	27.57	22.57
Mean	26.11	12.42	28.48	22.34	23.06	13.83	25.79	20.89

Data contained in Table 4.51 revealed that the maximum total dissolved solid (TDS) of surface water (263.66 mg/l) recorded during rainy season was statistically at par with summer season (220.62 mg/l) and significantly different from winter season (184.91 mg/l). Maximum TDS (496.26 mg/l) of underground water recorded under urban land use was statistically different from agriculture land use (361.56 mg/l) as well as forest land use (331.94 mg/l). However the TDS of agriculture and forest land uses were at par with each other. Significantly higher TDS (396.59 mg/l) was recorded in underground water as compared to surface water (223.06 mg/l).

Table 4.51: Effect of land uses on TDS (mg/l) of surface and ground water at Chandi-Goyla during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	249.17	195.87	224.33	223.12	428.67	304.00	352.00	361.56
Forest	244.67	152.73	207.00	201.47	374.40	269.80	351.63	331.94
Urban/Suburban	297.13	206.13	230.53	244.60	523.13	468.50	497.13	496.26
Mean	263.66	184.91	220.62	223.06	442.07	347.43	400.26	396.59
CD (P=0.05)	Land use			NS	Land use			99.11
	Season			46.78	Season			NS
	Land use × Season			81.02	Land use × Season			NS
	Water source				41.43			

Data exhibited in Table 4.52 revealed that the maximum biological oxygen demand (BOD) (1.61 mg/l) of surface water was recorded under urban land use which was statistically different from agriculture land use (1.34 mg/l) and forest land use (1.03 mg/l). Maximum BOD (1.71 mg/l) of surface water recorded during rainy season was followed by summer season (1.42 mg/l) and winter season (0.86 mg/l). Maximum BOD (1.18 mg/l) of underground water recorded under urban land use was statistically different from agriculture land use (0.94 mg/l) and forest land use (0.74 mg/l). Maximum BOD (1.28 mg/l) of underground water recorded during rainy season was followed by summer season (1.04 mg/l) and winter season (0.54 mg/l). Significantly higher BOD (1.33 mg/l) was recorded under surface water as compared to underground water (0.96 mg/l).

Table 4.52: Effect of land uses on BOD (mg/l) of surface and ground water at Chandigoyla during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	1.77	0.80	1.47	1.34	1.20	0.63	1.00	0.94
Forest	1.30	0.70	1.10	1.03	1.07	0.30	0.87	0.74
Urban/Suburban	2.07	1.07	1.70	1.61	1.57	0.70	1.27	1.18
Mean	1.71	0.86	1.42	1.33	1.28	0.54	1.04	0.96
CD (P=0.05)	Land use			0.23	Land use			0.15
	Season			0.23	Season			0.15
	Land use × Season			NS	Land use × Season			NS
	Water source				0.11			

Data contained in Table 4.53 revealed that the maximum chemical oxygen demand (COD) (9.44 mg/l) of surface water was recorded under urban land use which was statistically at par with agriculture land use (9.03 mg/l) and statistically different from forest land use (7.86 mg/l). The maximum COD (9.38 mg/l) of surface water recorded during rainy season was statistically different from summer season (8.86 mg/l) and winter season (8.08 mg/l). Maximum COD (8.51 mg/l) of underground water was recorded under urban land use followed by agriculture land use (7.79 mg/l) and forest land use (6.68 mg/l), all were statistically different from one another. Maximum COD of underground water (8.30 mg/l) recorded during rainy season was statistically different from summer season (7.76 mg/l) and winter season (6.92 mg/l). Significantly higher COD (8.78 mg/l) was recorded under surface water as compared to underground water (7.66 mg/l).

Table 4.53: Effect of land uses on COD (mg/l) of surface and ground water at Chandi-Goyla during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	9.83	7.97	9.30	9.03	8.40	7.20	7.77	7.79
Forest	8.30	7.43	7.83	7.86	7.50	5.60	6.93	6.68
Urban/Suburban	10.00	8.83	9.50	9.44	9.00	7.97	8.57	8.51
Mean	9.38	8.08	8.88	8.78	8.30	6.92	7.76	7.66
CD (P=0.05)	Land use			0.47	Land use			0.30
	Season			0.47	Season			0.30
	Land use × Season			NS	Land use × Season			NS
	Water source				0.23			

Data exhibited in Table 4.54 revealed that the maximum calcium (Ca) content (97.13 mg/l) of surface water was recorded under urban land use which was statistically different from agriculture land use (88.22 mg/l) and forest land use (82.67 mg/l). Significantly maximum Ca content (93.36 mg/l) of surface water was recorded during summer season followed by winter season (89.11 mg/l) and rainy season (85.56 mg/l). Maximum Ca content (109.34 mg/l) of underground water recorded under urban land use was statistically different from agriculture land use (100.94 mg/l) and forest land use (98.76 mg/l). Maximum Ca content (107.82 mg/l) of underground water recorded during summer season was statistically different from winter (102.33 mg/l) and rainy season (98.89 mg/l). Significantly higher Ca content (103.01 mg/l) was recorded in underground water as compared to surface water (89.34 mg/l).

Table 4.54: Effect of land uses on Ca (mg/l) content of surface and ground water at Chandi-Goyla during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	85.67	88.00	91.00	88.22	96.33	100.33	106.17	100.94
Forest	78.33	83.00	86.67	82.67	96.00	98.33	101.93	98.76
Urban/Suburban	92.67	96.33	102.40	97.13	104.33	108.33	115.37	109.34
Mean	85.56	89.11	93.36	89.34	98.89	102.33	107.82	103.01
CD (P=0.05)	Land use			3.19	Land use			4.74
	Season			3.19	Season			4.74
	Land use × Season			NS	Land use × Season			NS
	Water source				2.39			

It is extrapolated from Table 4.55 that the maximum magnesium (Mg) content (7.34 mg/l) of surface water was recorded in urban land use which was statistically different from agriculture land use (6.21 mg/l) and forest land use (5.38 mg/l). Significantly maximum Mg content (7.00 mg/l) of surface water was recorded during summer season followed by winter season (6.38 mg/l) and rainy season (5.56 mg/l). Maximum Mg content (10.04 mg/l) of underground water recorded under urban land use was statistically different from agriculture land use (9.10 mg/l) and forest land use (7.82 mg/l). Maximum Mg content (9.82 mg/l) of underground water recorded during summer season was statistically different from winter (9.09 mg/l) and rainy season (8.06 mg/l) and all were statistically different from one another. Significantly higher Mg content (8.99 mg/l) was recorded in underground water as compared to surface water (6.31 mg/l).

Table 4.55: Effect of land uses on Mg (mg/l) content of surface and ground water at Chandi-Goyla during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	5.50	6.33	6.80	6.21	8.37	9.17	9.77	9.10
Forest	4.57	5.57	6.00	5.38	7.07	7.93	8.47	7.82
Urban/Suburban	6.60	7.23	8.20	7.34	8.73	10.17	11.23	10.04
Mean	5.56	6.38	7.00	8.99	8.06	9.09	9.82	6.31
CD (P= 0.05)	Land use			0.43	Land use			0.71
	Season			0.43	Season			0.71
	Land use × Season			NS	Land use × Season			NS
	Water source				0.50			

Data contained in Table 4.56 revealed that the maximum nitrate (NO₃) content (2.36 mg/l) of surface water was recorded in agriculture land use which was statistically different from both the land uses (urban: 1.83 mg/l, forest: 1.69 mg/l). The content of NO₃ was maximum (2.19 mg/l) during rainy season in surface water sample which was statistically at par with summer season (1.93mg/l) and statistically different from winter season (1.76 mg/l). Maximum NO₃ content (3.42 mg/l) of underground water was recorded in agriculture land use which was statistically different from rest of the land uses (urban: 2.14 mg/l, forest: 1.81 mg/l). The NO₃ content was maximum (2.77 mg/l) during rainy season in underground water which was statistically different from summer (2.42 mg/l) as well as winter season (2.19 mg/l). Significantly maximum NO₃ content (2.46 mg/l) was recorded in underground water samples as compared to surface water (1.96 mg/l).

Table 4.56: Effect of land uses on NO₃ (mg/l) of surface and ground water at Chandi-Goyla during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	2.57	2.17	2.33	2.36	3.83	3.03	3.40	3.42
Forest	1.90	1.50	1.67	1.69	2.03	1.63	1.77	1.81
Urban/Suburban	2.10	1.60	1.80	1.83	2.43	1.90	2.10	2.14
Mean	2.19	1.76	1.93	1.96	2.77	2.19	2.42	2.46
CD (P= 0.05)	Land use			0.27	Land use			0.33
	Season			0.27	Season			0.33
	Land use × Season			NS	Land use × Season			NS
	Water source				0.24			

It is evident from Table 4.57 that maximum chloride (Cl) content (31.97 mg/l) of surface water was recorded under urban land use which was statistically at par with agriculture land use (24.96 mg/l) and statistically different from forest land use (18.96 mg/l). Maximum Cl content (21.82 mg/l) of underground water recorded under urban land use was statistically different from agriculture land use (14.80 mg/l) and forest land use (12.67 mg/l) whereas agriculture land use and forest land use were statistically at par with each other. Maximum Cl content (19.72 mg/l) recorded in underground water during summer season was statistically at par with winter season (17.96 mg/l) and significantly different from rainy season (11.61 mg/l). Significantly higher Cl content (25.29 mg/l) was recorded under surface water samples as compared underground water (16.43 mg/l).

Table 4.57: Effect of land uses on Cl (mg/l) content of surface and ground water at Chandi-Goyla during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	21.20	22.33	31.33	24.96	11.07	14.67	18.67	14.80
Forest	19.47	18.00	19.40	18.96	6.47	14.20	17.33	12.67
Urban/Suburban	33.37	28.20	34.33	31.97	17.30	25.00	23.17	21.82
Mean	24.68	22.84	28.36	25.29	11.61	17.96	19.72	16.43
CD (P = 0.05)	Land use			7.46	Land use			4.70
	Season			NS	Season			4.70
	Land use × Season			NS	Land use × Season			NS
	Water source				3.34			

Data contained in Table 4.58 reveals that the maximum Fe content (2.08 ppb) of surface water was recorded under urban land use which was significantly different from agriculture land use (1.22 ppb) and forest land use (0.22 ppb). The maximum Fe content (3.11 ppb) of underground water recorded under urban land use was statistically different from agriculture (1.22 ppb) and forest land use (0.67 ppb).

Table 4.58: Effect of land uses on Fe (ppb) content of surface and ground water at Chandi- Goyla during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	0.00	1.67	2.00	1.22	1.00	1.67	1.00	1.22
Forest	0.00	0.00	0.67	0.22	0.00	0.33	1.67	0.67
Urban/Suburban	1.67	1.33	3.23	2.08	1.67	3.00	4.67	3.11
Mean	0.56	1.00	1.97	1.17	0.89	1.67	2.44	1.67
CD (P = 0.05)	Land use			1.43	Land use			1.34
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				NS			

It is evident from Table 4.59 that the manganese (Mn) content differed non significantly under different land uses during different seasons.

Table 4.59: Effect of land uses on Mn (ppb) content of surface and ground water at Chandi- Goyla during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	0.73	0.00	1.03	0.59	0.17	0.53	2.00	0.90
Forest	0.40	0.67	0.57	0.54	0.47	0.47	0.53	0.49
Urban/Suburban	0.33	0.87	1.33	0.84	0.67	1.33	1.20	1.07
Mean	0.49	0.51	0.98	0.66	0.43	0.78	1.24	0.82
CD (P = 0.05)	Land use			NS	Land use			NS
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				NS			

It is extrapolated from Table 4.60 that the zinc (Zn) content (0.46 ppt) of underground water recorded under urban land use was statistically at par with agriculture land use(0.36 ppt) where as under forest land use zinc content was below detectable limit.

Table 4.60: Effect of land uses on Zn (ppt) content of surface and ground water at Chandi- Goyla during different seasons

Land Use	Water source							
	Surface				Underground			
	Season							
	Rainy	Winter	Summer	Mean	Rainy	Winter	Summer	Mean
Agriculture	0.10	0.20	0.37	0.22	0.23	0.30	0.53	0.36
Forest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urban/Suburban	0.27	0.33	0.37	0.32	0.27	0.30	0.80	0.46
Mean	0.12	0.18	0.25	0.18	0.17	0.20	0.44	0.27
CD (P = 0.05)	Land use			NS	Land use			0.25
	Season			NS	Season			NS
	Land use × Season			NS	Land use × Season			NS
	Water source				NS			

4.1.5 Effect of different land uses and seasons on physico-chemical parameters of surface and ground water of Dharampur block

It is evident from Table 4.61 that the pH of surface water of Dharampur block varied between 7.47 to 7.75. The maximum pH of surface water was recorded under urban land use (7.75) and minimum under forest land use (7.47). The overall pH of surface water of Dharampur block was 7.61. The EC of surface water varied between 0.29 (dS/m) to 0.53(dS/m). The maximum EC (0.53dS/m) was recorded under urban land use which was statistically different from agriculture (0.38) and forest land use (0.29 dS/m). On an average the EC of surface water was 0.18 dS/m. The temperature of surface water under different land uses varied between 20.51⁰C to 23.00⁰C. The maximum temperature (23.00⁰C) of surface water was recorded under urban land use and minimum under forest land use (20.51⁰C). The overall mean temperature of surface water was 21.70⁰C. The TDS of surface water varied between 209.1 to 343.87 mg/l. Maximum TDS (343.87 mg/l) was recorded under urban land use which was statistically different from agriculture land use (280.31 mg/l) as well as forest land use (209.01 mg/l). The overall mean value of TDS of surface water was 277.73. The BOD of surface water under different land uses differed non significantly with each other. The COD of surface water varied between 9.25 to 13.90 mg/l. The maximum content COD (19.25 mg/l) of surface water was recorded under urban land use which was statistically different from agriculture (13.90 mg/l) and forest land use (9.25 mg/l). On an average the COD of surface water was 14.46 mg/l. The Ca content of surface water of Dharampur block varied between 69.44 to 97.15 mg/l. Maximum Ca content (97.15 mg/l) of surface water was recorded under urban land use was statistically different from agriculture land use (79.38

mg/l) and forest land use (69.44mg/l). The overall mean value of Ca content of surface water was 81.99 mg/l. The Mg content of surface water varied between 5.68 to 10.34 mg/l. The maximum Mg content (10.34 mg/l) of surface water was recorded under urban land use which was statistically at par with agriculture land use (8.10 mg/l) and statistically different from forest land use (5.68 mg/l). The overall mean value of Mg of surface water was 8.04 mg/l. The NO₃ content of surface water varied between 1.07 to 2.04 mg/l. Maximum NO₃ content (2.04 mg/l) was recorded under agriculture land use which was statistically at par with urban land use (1.82mg/l) and statistically different from forest land use (1.07 mg/l). The overall mean value of NO₃ of surface water was 1.64 mg/l. The Cl content of surface water varied between 21.74 to 34.58 mg/l. Maximum Cl content (34.58 mg/l) of surface water was recorded under urban land use which was statistically different from agriculture (28.77 mg/l) and forest land use (21.74 mg/l). The overall mean value of Cl content of surface water was 28.36 mg/l.

Table 4.61: Overall effect of land uses on physico-chemical parameters of surface water of Dharampur Block

Land use	pH	EC (dS/m)	Temperature (°C)	TDS (mg/l)	BOD (mg/l)	COD (mg/l)	Ca (mg/l)	Mg (mg/l)	NO ₃ (mg/l)	Cl (mg/l)
Agriculture	7.62	0.38	21.52	280.31	3.23	13.09	79.38	8.10	2.04	28.77
Forest	7.47	0.29	20.51	209.01	1.85	9.25	69.44	5.68	1.07	21.74
Urban/ suburban	7.75	0.53	23.00	343.87	5.75	28.68	97.15	10.34	1.82	34.58
Mean	7.61	0.40	21.70	277.73	3.61	17.01	81.99	8.04	1.64	28.36
CD (P = 0.05)	0.08	0.05		47.9	NS	14.46	7.29	2.28	0.37	3.35

It is evident from Table 4.62 that pH of surface water of Dharampur block varied between 7.52 to 7.96. The maximum pH (7.96) of underground water samples was recorded from urban land use and minimum in forest land use (7.52), all being statistically different from one another. On an average the pH of underground water of Dharampur block was 7.75. The EC of underground water varied between 0.50 (dS/m) to 0.70(dS/m).The maximum EC (0.70 dS/m) was recorded under urban land use which was statistically different from agriculture (0.58 dS/m) and forest land use (0.50 dS/m). On an average the EC of surface water was 0.59 dS/m. The temperature of underground water under different land uses varied between 19.76⁰C to 21.82⁰C. The maximum temperature (21.82⁰C) of underground water was recorded from urban land use and minimum under forest land use (19.76⁰C). The overall mean temperature of underground water was 20.70⁰C .The TDS of surface water varied between 293.93 to 488.18 mg/l. Maximum TDS (488.18 mg/l) was recorded under urban land

use which was statistically different from agriculture land use (383.11 mg/l) as well as forest land use (293.93 mg/l). The overall mean value of TDS of surface water was 388.41mg/l. The BOD of underground water varied between 1.41 to 2.72 mg/l. The maximum BOD of underground water (2.72 mg/l) was recorded under urban land use which was statistically at par with agriculture land use (1.81 mg/l) and was statistically different from forest land use (1.14 mg/l). The overall mean value of BOD of underground water was 1.98 mg/l. The COD of underground water varied between 8.03 to 14.33 mg/l. The maximum COD (14.33 mg/l) was recorded in urban land use which was statistically different from agriculture (10.45 mg/l) and forest land use (8.03 mg/l). On an average the COD of underground water was 10.94 mg/l. The Ca content of underground water of Dharampur block varied between 92.99 to 107.61 mg/l. Maximum Ca content (107.61 mg/l) of underground water was recorded under urban land use which was statistically different from agriculture land use (100.45 mg/l) and forest land use (92.99 mg/l). The overall mean value of Ca content of underground water was 100.35 mg/l. The Mg content of underground water varied between 9.66 to 14.76 mg/l. The maximum Mg content (14.76 mg/l) of underground water was recorded under urban land use which was statistically different from agriculture land use (12.67 mg/l) and forest land use (9.66 mg/l). The overall mean value of Mg of underground water was 12.36 mg/l. The NO₃ content of underground water varied between 1.65 to 4.51 mg/l. Maximum NO₃ content (4.51 mg/l) was recorded in agriculture land use, which was statistically different from urban land use (3.14 mg/l) and forest land use (1.65 mg/l). The overall mean value of NO₃ of underground water was 3.10 mg/l. The Cl content of underground water varied between 13.56 to 24.82 mg/l. Maximum Cl content (24.82 mg/l) of underground water was recorded under urban land use which was statistically different from agriculture (17.62 mg/l) and forest land use (13.56 mg/l). The overall mean value of Cl content of underground water was 18.67 mg/l.

Table 4.62: Overall effect of land uses on physico-chemical parameters of underground water of Dharampur Block

Land use	pH	EC (dS/m)	Temperature (°C)	TDS (mg/l)	BOD (mg/l)	COD (mg/l)	Ca (mg/l)	Mg (mg/l)	NO ₃ (mg/l)	Cl (mg/l)
Agriculture	7.79	0.58	20.49	383.11	1.81	10.45	100.45	12.67	4.51	17.62
Forest	7.52	0.50	19.76	293.93	1.41	8.03	92.99	9.66	1.65	13.56
Urban/ suburban	7.96	0.70	21.82	488.18	2.72	14.33	107.61	14.76	3.14	24.82
Mean	7.75	0.59	20.70	388.41	1.98	10.94	100.35	12.36	3.10	18.67
CD (P = 0.05)	0.07	0.06		52.2	0.94	3.46	6.37	2.00	0.95	2.29

It is extrapolated from Table 4.63 the pH of surface water of Dharampur block varied between 7.42 to 7.89. The maximum pH (7.89) of surface water recorded during summer season was statistically different from rainy season (7.53) as well as winter season (7.42). On an average the pH of underground water of Dharampur block was 7.61. The EC of surface water varied between 0.33 (dS/m) to 0.46(dS/m).The maximum EC (0.46 dS/m) of surface water was recorded during summer season which was statistically different from rainy season (0.041 dS/m) and winter season (0.33 dS/m). On an average the EC of surface water was 0.40 dS/m. The temperature of surface water during different seasons varied between 11.87⁰C to 28.30⁰C. The maximum temperature (28.30⁰C) of surface water was recorded during summer season and minimum during winter season (11.87⁰C). The overall mean temperature of surface water was 21.70⁰C . TDS of surface water varied between 202.90 to 366.78 mg/l. The maximum TDS of surface water (366.78 mg/l) recorded during rainy season was statistically different from summer season (263.52 mg/l) and winter season (202.90 mg/l). The overall mean value of TDS of surface water was 277.73 mg/l. The BOD of surface water varied between 6.34 to 1.10 mg/l. Significantly maximum BOD (6.34 mg/l) of surface water was recorded during rainy season which was statistically at par with summer season (3.40 mg/l) and statistically different from winter season (1.10 mg/l). The overall mean value of BOD of surface water was 3.61mg/l. The Ca content of surface water of Dharampur block varied between 73.03 to 88.71 mg/l. Significantly maximum Ca content (88.71 mg/l) of surface water was recorded during summer season followed by winter season (84.22mg/l) and rainy season (73.03 mg/l). The overall mean value of Ca content of surface water was 81.99 mg/l. The Mg content of surface water varied between 7.05 to 9.58 mg/l. Significantly maximum Mg content (9.58 mg/l) of surface water was recorded during summer season followed by winter season (7.51 mg/l) and rainy season (7.05 mg/l). The overall mean value of Mg content of surface water was 8.04 mg/l. The NO₃ content of surface water varied between 1.08 to 2.34 mg/l. The content of NO₃ (2.34 mg/l) was maximum during rainy season of surface water which was statistically different from summer season (1.50mg/l and winter season (1.08 mg/l). The overall mean value of NO₃ of surface water was 1.64 mg/l. The Cl content of surface water varied between 24.97 to 31.73 mg/l. The maximum Cl content (31.73 mg/l) recorded in surface water during summer season was statistically at par with winter season (28.40 mg/l) and statistically different from rainy season (24.97 mg/l). The overall mean value of Cl content of surface water was 28.36 mg/l.

Table 4.63: Overall effect of different seasons on physico-chemical parameters of surface water of Dharampur Block

Season	pH	EC (dS/m)	Temp. (°C)	TDS (mg/l)	BOD (mg/l)	COD (mg/l)	Ca (mg/l)	Mg (mg/l)	NO ₃ (mg/l)	Cl (mg/l)
Rainy	7.53	0.41	24.85	366.78	6.34	20.77	73.03	7.05	2.34	24.97
Winter	7.42	0.33	11.87	202.90	1.10	13.37	84.22	7.51	1.08	28.40
Summer	7.89	0.46	28.30	263.52	3.40	16.89	88.71	9.58	1.50	31.73
Mean	7.61	0.4	21.70	277.73	3.61	17.01	81.99	8.04	1.64	28.36
CD (P = 0.05)	0.08	0.03		49.72	3.83	NS	7.29	1.16	0.40	3.66

Data contained in Table 4.64 revealed that the pH of underground water of Dharampur block varied between 7.51 to 8.08. The maximum pH of underground water (8.08) recorded during summer season was statistically different from rainy season (7.67) as well as winter season (7.51), the last two were statistically at par with each other. On an average the pH of underground water of Dharampur block was 7.75. The EC of underground water varied between 0.52 (dS/m) to 0.65(dS/m). The maximum EC (0.65 dS/m) of underground water was recorded during summer season which was statistically at par with rainy season (0.60 dS/m) and statistically different from winter season (0.52 dS/m). On an average the EC of surface water was 0.59 dS/m. The temperature of underground water during different seasons varied between 13.46⁰C to 26.20⁰C. The maximum temperature (26.20⁰C) of underground water was recorded during summer season and minimum during winter season (13.93⁰C). The overall mean temperature of underground water was 20.70⁰C . TDS of underground water varied between 304.55 to 479.99 mg/l. The maximum TDS of underground water (479.99 mg/l) recorded during rainy season was statistically different from summer season (380.68 mg/l) and winter season (304.55 mg/l). The overall mean value of TDS of underground water was 388.41 mg/l. The BOD of underground water varied between 0.71 to 3.46 mg/l. Significantly maximum BOD (3.46 mg/l) of underground water was recorded during rainy season which was statistically different from summer season (1.76 mg/l) and winter season (0.71 mg/l). The overall mean value of BOD of surface water was 1.98 mg/l. The COD of underground water varied between 9.71 to 12.00 mg/l. Maximum COD recorded during rainy season (12.00 mg/l) was statistically at par with summer season (11.10 mg/l) and statistically different from winter season (9.71 mg/l). The overall mean value of COD of underground water was 10.94 mg/l. The Ca content of underground water of Dharampur block varied between 94.06 to 104.72 mg/l. Significantly maximum Ca content (104.72 mg/l) of underground water was recorded during summer season followed by winter season

(102.27 mg/l) and rainy season (94.06 mg/l). The overall mean value of Ca content of underground water was 100.35 mg/l. The Mg of surface water varied between 10.25 to 14.54 mg/l. Significantly maximum Mg content (14.54 mg/l) of underground water was recorded during summer season followed by winter season (12.30 mg/l) and rainy season (10.25 mg/l). The overall mean value of Mg of underground water was 12.36 mg/l. The NO₃ of surface water varied between 2.67 to 3.63 mg/l. The content of NO₃ (3.63 mg/l) was maximum during rainy season in underground water which was statistically different from summer season (3.00 mg/l and winter season (2.67 mg/l). The overall mean value of NO₃ of underground water was 3.10 mg/l. The Cl of underground water varied between 19.46 to 22.73 mg/l. Maximum Cl content (22.73 mg/l) recorded in underground water during summer season was statistically different from winter season (19.46 mg/l) and rainy season (13.81 mg/l). The overall mean value of Cl content of underground water was 18.67 mg/l.

Table 4.64: Overall effect of different seasons on Physico-chemical parameters of underground water of Dharampur Block

Season	pH	EC (dS/m)	Temp. (°C)	TDS (mg/l)	BOD (mg/l)	COD (mg/l)	Ca (mg/l)	Mg (mg/l)	NO ₃ (mg/l)	Cl (mg/l)
Rainy	7.67	0.60	22.41	479.99	3.46	12.00	94.06	10.25	3.63	13.81
Winter	7.51	0.52	13.46	304.55	0.71	9.71	102.27	12.30	2.67	19.46
Summer	8.08	0.65	26.2	380.68	1.76	11.10	104.72	14.54	3.00	22.73
Mean	7.75	0.59	20.70	388.41	1.98	10.94	100.35	12.36	3.10	18.67
CD (P = 0.05)	0.13	0.06		58.88	1.62	1.31	5.51	1.57	0.38	2.42

It is evident from Table 4.65 that maximum Fe content (5.30 ppb) of surface water was recorded from urban land use and minimum under forest land use (1.97 ppb). The iron content in surface water ranged from 1.97 to 5.30 ppb. The maximum Mn (2.43 ppb) content recorded under urban land use was statistically at par with agriculture (1.22 ppb) and statistically different from forest land use (0.68 ppb). The concentration of Mn content in water sample ranged from 0.68 to 2.43 ppb. The Maximum Zn content (0.60 ppt) of surface water recorded under urban land use was statistically at par with forest land use (0.47 ppt) and statistically different from agriculture land use (0.05 ppt). The concentration of Zn content in surface water ranged from 0.05 to 0.60 ppt. The maximum Fe content (7.88 ppb) of underground water samples was recorded from urban land use and minimum under forest land use (7.42 ppb) and its concentration in ground water ranged from 7.42 to 7.88 ppb. The maximum Mn content (2.91 ppb) was recorded in underground water under urban land use

which was statistically at par with agriculture land use (2.05 ppb) and statistically different from forest land use (1.37 ppb). The Maximum Zn content (0.83 ppt) of underground water recorded under urban land use which was statistically different from forest (0.69 ppt) and agriculture land use (0.07 ppt). On an average the heavy metal concentration viz. Fe, Mn, Zn in surface water and underground water was 3.67 ppb, 1.44 ppb, 0.38 ppt and 7.61ppb, 2.11 ppb, 0.53 ppt, respectively.

Table 4.65: Overall effect of different land uses on heavy metals of surface water and ground water of Dharampur Block

Land use	Water source					
	Surface			Underground		
	Fe (ppb)	Mn (ppb)	Zn (ppt)	Fe (ppb)	Mn (ppb)	Zn (ppt)
Agriculture	3.75	1.22	0.47	7.53	2.05	0.69
Forest	1.97	0.68	0.05	7.42	1.37	0.07
Urban/ suburban	5.30	2.43	0.60	7.88	2.91	0.83
Mean	3.67	1.44	0.38	7.61	2.11	0.53
CD (P = 0.05)	0.64	1.31	0.13	0.11	1.24	0.16

It is extrapolated from Table 4.66 that maximum Fe content (5.21 ppb) of surface water recorded during summer season was statistically different from winter season (3.69 ppb) as well as rainy season (2.11 ppb). The maximum Mn content (1.79 ppb) was recorded during summer season and minimum during rainy season (1.20 ppb). The iron content in surface water ranged from 1.97 to 5.30. The maximum Zn (0.58 ppt) of surface water was recorded during summer season which was statistically different from winter season (0.33 ppt) and rainy season (0.23 ppt). The maximum Fe content (7.75 ppb) of underground water recorded during summer season was statistically different from winter season (7.46 ppb) as well as rainy season (7.62 ppb). The maximum Mn content (2.80 ppb) of underground water was recorded during summer season which was statistically at par with winter (1.89 ppb) and statistically different from rainy season (1.63 ppb). The maximum Zn content (0.77 ppt) of underground water was recorded during summer season which was statistically different from winter (0.48ppt) and rainy season (0.34 ppt). On an average the heavy metal concentration viz. Fe, Mn, Zn in surface water and underground water was 3.67 ppb, 1.44 ppb, 0.38 ppt and 7.61ppb, 2.11 ppb, 0.53 ppt, respectively.

Table 4.66: Overall effect of different seasons on heavy metals of surface water and ground water of Dharampur Block

Season	Water source					
	Surface			Underground		
	Fe (ppb)	Mn (ppb)	Zn (ppt)	Fe (ppb)	Mn (ppb)	Zn (ppt)
Rainy	2.11	1.20	0.23	7.62	1.63	0.34
Winter	3.69	1.34	0.33	7.46	1.89	0.48
Summer	5.21	1.79	0.58	7.75	2.80	0.77
Mean	3.67	1.44	0.38	7.61	2.11	0.53
CD (P=0.05)	0.78	NS	0.12	0.08	1.09	0.12

4.1.6: Effect of land uses and seasons on water quality index (WQI) of Dharampur block

It is evident from Table 4.67 that the maximum Water quality index (WQI) (21.10) of surface water was recorded under urban land use and minimum under forest land use (9.02) where as under agriculture land use it was 13.40. Similarly water quality index of underground water was maximum (15.93) under urban land use and minimum under forest land use (8.89). However, the water quality index of agriculture land use of underground water was 12.34.

Table 4.67: Overall effect of different land uses on WQI for Dharampur Block

Parameter	Water source					
	Surface			Underground		
	Season					
	Agriculture $S_1 (q_i w_i)$	Forest $S_3 (q_i w_i)$	Urban $S_5 (q_i w_i)$	Agriculture $S_2 (q_i w_i)$	Forest $S_4 (q_i w_i)$	Urban $S_6 (q_i w_i)$
pH	4.88	3.69	5.97	6.25	4.09	7.58
TDS	0.05	0.04	0.06	0.07	0.05	0.09
BOD	5.87	3.36	10.44	3.28	2.56	4.94
COD	1.49	1.05	3.26	1.19	0.91	1.63
Ca	0.64	0.56	0.78	0.81	0.75	0.87
Mg	0.41	0.29	0.52	0.64	0.49	0.74
NO ₃	0.05	0.02	0.04	0.10	0.04	0.07
Cl	0.02	0.02	0.03	0.01	0.01	0.02
WQI	13.40	9.02	21.10	12.34	8.89	15.93

It is evident from Table 4.68 that the maximum water quality index (WQI) (19.16) of surface water was recorded during rainy season followed by summer season (16.42) and winter season (7.96), while in underground water maximum WQI (14.76) was recorded during summer season followed by rainy season (14.42) and winter season (7.99).

Table 4.68: Overall effect of different seasons on WQI for Dharampur Block

Parameter	Water source					
	Surface			Underground		
	Season					
	Rainy $S_1 (q_i w_i)$	Winter $S_3 (q_i w_i)$	Summer $S_5 (q_i w_i)$	Rainy $S_2 (q_i w_i)$	Winter $S_4 (q_i w_i)$	Summer $S_6 (q_i w_i)$
pH	4.20	3.31	7.02	5.31	4.03	8.57
TDS	0.07	0.04	0.05	0.09	0.06	0.07
BOD	11.51	1.99	6.18	6.29	1.29	3.20
COD	2.36	1.52	1.92	1.36	1.10	1.26
Ca	0.59	0.68	0.72	0.76	0.83	0.85
Mg	0.36	0.38	0.48	0.52	0.62	0.73
NO ₃	0.05	0.02	0.03	0.08	0.06	0.07
Cl	0.02	0.02	0.02	0.01	0.01	0.02
WQI	19.16	7.96	16.42	14.42	7.99	14.76

Data contained in Table 4.69 revealed that the maximum water quality index (WQI) (31.32) was recorded at Barotiwala and minimum at Chandi- Goyla (9.52), while the WQI for Dharampur and Parwanoo area was 10.98 and 18.98, respectively.

Table 4.69: Overall effect of land uses and seasons on WQI at different locations of Dharampur block

Parameters	Dhrampur $S_1 (q_i w_i)$	Parwanoo $S_2 (q_i w_i)$	Barotiwala $S_3 (q_i w_i)$	Chandi-goyla $S_4 (q_i w_i)$
pH	6.31	13.04	13.74	5.19
TDS	0.06	0.06	0.07	0.06
BOD	2.11	3.27	13.04	2.09
COD	1.13	1.27	3.08	0.94
Ca	0.84	0.78	0.57	0.79
Mg	0.47	0.49	0.73	0.39
NO ₃	0.05	0.06	0.06	0.05
Cl	0.02	0.02	0.02	0.02
WQI	10.98	18.98	31.32	9.52

4.2 EFFECT OF LAND USES ON AQUATIC INSECTS UNDER SURFACE WATER DURING DIFFERENT SEASONS

It is evident from Table 4.70 that the distribution and abundance of aquatic insects were influenced by land uses and seasons. A total 160 individuals of aquatic insects under 6 families and 5 orders were recorded under surface water at Dharampur. A total of 53 individuals of aquatic insects were recorded under agriculture land use. Maximum number of aquatic insects (10 individuals) were recorded during winter season of Batidae family of Ephemeroptera followed by Hydropsychidae of Trichoptera and Leuctridae of Plecoptera (both 9 individuals) during the same season. Minimum number of aquatic insects (4 individuals) of Gerridae family of Hemiptera were recorded during winter season. The highest number of aquatic insects (59 individuals) were recorded under forest land use. Maximum number (11 individuals) of aquatic insects of Hydropsychidae family of Trichoptera were recorded during winter season whereas its number was only 3 individuals during rainy season. The lowest number (48 individuals) of aquatic insects were recorded under urban land use. Maximum number (9 individuals) of aquatic insects were of Leuctridae family of Plecoptera order followed by Hydropsychidae (8 individuals) of Trichoptera during the winter season. Maximum number (105 individuals) of aquatic insects were recorded during winter season followed by summer season (35 individuals) and rainy season (20 individuals).

Table 4.70: Effect of land uses on distribution and abundance of aquatic insects (individuals) of surface water at Dharampur during different seasons

Land Use	Order	Family	Rainy	Winter	Summer	Total
Agriculture	Trichoptera	Hydropsychidae	2	9	4	53
	Odonata	Cordullidae	0	0	0	
	Ephemeroptera	Batidae	1	10	5	
	Plecoptera	Leuctridae	1	9	3	
	Hemiptera	Gerridae	0	4	0	
		Notonectidae	2	3	0	
Forest	Trichoptera	Hydropsychidae	3	11	4	59
	Odonata	Cordullidae	0	0	0	
	Ephemeroptera	Batidae	2	8	6	
	Plecoptera	Leuctridae	1	6	4	
	Hemiptera	Gerridae	2	8	0	
		Notonectidae	0	4	0	
Urban	Trichoptera	Hydropsychidae	2	8	3	48
	Odonata	Cordullidae	0	0	0	
	Ephemeroptera	Batidae	1	6	3	
	Plecoptera	Leuctridae	1	9	3	
	Hemiptera	Gerridae	1	6	0	
		Notonectidae	1	4	0	
		Total	20	105	35	160

It is clear from Table 4.71 that the distribution and abundance of aquatic insects were influenced by land uses and seasons . A total number of 118 individuals of aquatic insects under 6 families and 5 orders were recorded under surface water at Parwanoo. A total of 39 individuals of aquatic insects were recorded under agriculture land use. Maximum number (6 individuals of each Batidae: Ephemeroptera and Hydropsychidae: Trichoptera) of aquatic insects were recorded during winter season, followed by Cordullidae (4 ind.ividuals) of Odonata and Leuctridae (3 individuals) of Plecoptera.Only one individual of Gerridae family of Hemiptera was recorded during rainy season as well as winter season. Maximum number (48 individuals) of aquatic insects were recorded under forest land use. Highest number (8 individuals) of aquatic insects of Hydropsychidae family of Trichoptera followed Baetidae of Ephemeroptera, Leuctridae of Plecoptera (both 6 individuals) , Cordullidae (4 ind.ividuals) of Odonata and Gerridae and Notonectidae of Hemiptera (both 1 individuals) were recorded during winter season.The lowest number (31 individuals) of aquatic insects were recorded under urban land use. Maximum number (4 individuals) of aquatic insects of Hydropsychidae of Trichoptera and Batidae (4 individuals) of Ephemeroptera followed by Leuctridae (3 individuals) of Plecoptera , Cordullidae (3 individuals) of Odonata , Gerridae and Notonectidae (both 1 individual) of Hemiptera were recorded under urban land use during winter season. Maximum number (62 individuals) of aquatic insects were recorded during winter season followed by summer season (34 individuals) and rainy season (22 individuals).

Table 4.71: Effect of land uses on distribution and abundance of aquatic insects (individuals) of surface water at Parwanoo during different seasons

Land Use	Order	Family	Rainy	Winter	Summer	Total
Agriculture	Trichoptera	Hydropsychidae	2	6	4	39
	Odonata	Cordullidae	0	4	0	
	Ephemeroptera	Batidae	2	6	4	
	Plecoptera	Leuctridae	2	3	4	
	Hemiptera	Gerridae	1	1	0	
		Notonectidae	0	0	0	
Forest	Trichoptera	Hydropsychidae	3	8	2	48
	Odonata	Cordullidae	0	4	3	
	Ephemeroptera	Batidae	3	6	5	
	Plecoptera	Leuctridae	3	6	3	
	Hemiptera	Gerridae	0	1	0	
		Notonectidae	0	1	0	
Urban	Trichoptera	Hydropsychidae	2	4	3	31
	Odonata	Cordullidae	0	3	0	
	Ephemeroptera	Batidae	3	4	3	
	Plecoptera	Leuctridae	1	3	3	
	Hemiptera	Gerridae	0	1	0	
		Notonectidae	0	1	0	
		Total	22	62	34	118

It is extrapolated from Table 4.72 that the distribution and abundance of aquatic insects were influenced by land uses and seasons . A total of 85 individuals of aquatic insects under 6 families and 5 orders were recorded under surface water at Barotiwala. A total of 28 individuals of aquatic insects were recorded under agriculture land use . Maximum number (5 individuals) of aquatic insects were recorded during winter season of Batidae family of Ephemeroptera followed by Hydropsychidae (4 individuals) of Trichoptera, Leuctridae (3 individuals) of Plecoptera. Only one individual of Gerridae family of Hemiptera was recorded during summer season while during rest of seasons the number was zero. Maximum number (36 individuals) of aquatic insects were recorded under forest land use . The highest number (6 individuals) of aquatic insects of Batidae family of Ephemeroptera followed by Hydropsychidae (4 individuals) of Trichoptera and Leuctridae (4 individuals) of Plecoptera were recorded during winter season. Maximum numbers (7 individuals) of aquatic insects of Gerridae family of Hemiptera was recorded during summer season. The lowest number (21 individuals) of aquatic insects were recorded under urban land use at Barotiwala. Hydropsychidae of Trichoptera, Batidae of Ephemeroptera and Leuctridae of Plecoptera were represented by 3 individuals each during winter season. Maximum number (35 individuals) of aquatic insects were recorded during winter season and minimum (20 individuals) during rainy season where as summer season was represented by 30 individuals of aquatic insects.

Table 4.72: Effect of land use on distribution and abundance of aquatic insects (individual) of surface water at Barotibala during different seasons

Land use	Order	Family	Rainy	Winter	Summer	Total
Agriculture	Trichoptera	Hydropsychidae	3	4	2	28
	Odonata	Cordullidae	0	0	1	
	Ephemeroptera	Batidae	2	5	2	
	Plecoptera	Leuctridae	2	3	3	
	Hemiptera	Gerridae	0	0	1	
		Notonectidae	0	0	0	
Forest	Trichoptera	Hydropsychidae	3	4	2	36
	Odonata	Cordullidae	0	0	0	
	Ephemeroptera	Batidae	3	6	2	
	Plecoptera	Leuctridae	3	4	2	
	Hemiptera	Gerridae	0	0	7	
		Notonectidae	0	0	0	
Urban	Trichoptera	Hydropsychidae	0	3	2	21
	Odonata	Cordullidae	0	0	1	
	Ephemeroptera	Batidae	2	3	2	
	Plecoptera	Leuctridae	2	3	2	
	Hemiptera	Gerridae	0	0	1	
		Notonectidae	0	0	0	
		Total	20	35	30	85

Data contained in Table 4.73 reveal that the distribution and abundance of aquatic insects were influenced by land uses and seasons . A total of 179 individuals of aquatic insects under 6 families and 5 orders were recorded under surface water at Chandi- Goyla. A total of 59 individuals of aquatic insects were recorded under agriculture land use. Hydropsychidae family of Trichoptera, Batidae of Ephemeroptera and Leuctridae of Plecoptera, each were represented by 9 individuals during the winter season . During winter season ,Gerridae and Notonectidae families of Hemiptera were represented by 5 and 4 individuals of aquatic insects, respectively. Under agriculture land use during winter season the Notonectidae family of Hemiptera were represented by 4 individuals whereas during summer season and rainy season the number was zero.The highest number (70 individuals) of aquatic insects were recorded under forest land use . Maximum number (10 individuals) of aquatic insects of Gerridae family of Hemiptera followed by Baetidae of Ephemeroptera and Leuctridae of Plecoptera (both 9 individuals), Hydropsychidae (8 individuals) of Trichoptera, and Cordullidae (1 individual) of Odonata were recorded during winter season. The lowest number of individuals (50 individual) were recorded under urban land use. Maximum number (9 individuals) of aquatic insects of Batidae of Ephemeroptera followed by Hydropsychidae of Trichoptera and, Leuctridae of Plecoptera (both 6 individuals), Gerridae (5 individuals) and Notonectidae (3 individuals) of Hemiptera were recorded during winter season. Maximum number (109 individuals) of aquatic insects were recorded during winter season followed by summer season (43 individuals) and rainy season (27 individuals).

Table 4.73: Effect of land uses on distribution and abundance of aquatic insects (individual) of surface water at Chandi- Goyla during different seasons

Land use	Order	Family	Rainy	Winter	Summer	Total
Agriculture	Trichoptera	Hydropsychidae	3	9	5	59
	Odonata	Cordullidae	2	0	0	
	Ephemeroptera	Batidae	2	9	4	
	Plecoptera	Leuctridae	2	9	3	
	Hemiptera	Gerridae	0	5	2	
		Notonectidae	0	4	0	
Forest	Trichoptera	Hydropsychidae	3	8	5	70
	Odonata	Cordullidae	3	1	0	
	Ephemeroptera	Batidae	2	9	4	
	Plecoptera	Leuctridae	2	9	7	
	Hemiptera	Gerridae	0	10	0	
		Notonectidae	0	7	0	
Urban	Trichoptera	Hydropsychidae	3	6	0	50
	Odonata	Cordullidae	3	0	2	
	Ephemeroptera	Batidae	2	9	5	
	Plecoptera	Leuctridae	0	6	5	
	Hemiptera	Gerridae	0	5	1	
		Notonectidae	0	3	0	
		Total	27	109	43	179

Data contained in Table 4.74 reveal that the Simpson 's Diversity Index (D) ranged from 0.88- 0.91. The maximum (0.91) Simpson 's Diversity Index (D) was equal 0.91 at Dharampur and Chandi- Goyla whereas at Barotiwala it was 0.88.

Table 4.74: Simpson's Diversity Index (D)

Site	D
Dharmpur	0.91
Parwanoo	0.90
Barotibala	0.88
Chandi- Goyala	0.91

Data presented in Table 4.75 showed that EPT index ranged from 27.33- 43.67. Maximum EPT index was worked out at Chandi- Goyla (43.67) and minimum at Barotiwala (27.33). On the basis of EPT index the water quality was rated as excellent at all the locations

Table 4.75: EPT index (Ephemeroptera, Placoptera, Tricoptera)

Site	EPT index
Dharmpur	41.67
Parwanoo	32.67
Barotibala	27.33
Chandi- Goyala	43.67

It is extrapolated from Table 4.76 that family biotic index ranged from 2.31- 2.73. The maximum family biotic index was at Barotiwala (2.73) and minimum at Dharampur (2.31). On the basis of family biotic index the water quality was rated excellent at all the locations.

Table 4.76: Family Biotic Index (FBI)

Site	FBI
Dharmpur	2.31
Parwanoo	2.49
Barotibala	2.73
Chandi- Goyala	2.45

Chapter-5

DISCUSSION

The primary concern of people living in developing countries throughout the world is that of obtaining clean water. Most of our water resources are gradually becoming contaminated due to addition of foreign materials from the surroundings. Apart from climatic induced changes, anthropogenic modification of land cover such as agriculture, afforestation, mining, urbanization, industrialization and intervention on hydrological regimes like irrigation and damming have resulted in marked changes in water quality. Problems arising out of water quality deterioration are as severe as those related to water availability. The diminishing quality of water seriously delimits its use for human consumption and for aquatic life. Keeping this in view, the present study was carried out to know the Effect of different land uses on water quality. The result emanated from the present study have been discussed under following heads.

5.1 Effect of land uses on physico-chemical parameters of surface and underground water during different seasons

5.2 Effect of land uses on aquatic insects during different seasons

5.1 EFFECT OF LAND USES ON PHYSICO- CHEMICAL PARAMETERS OF SURFACE AND UNDERGROUND WATER DURING DIFFERENT SEASONS

Water samples from surface and underground water sources under different land uses were collected from different locations during different seasons and analyzed for quality parameters. The overall pH of surface water and underground water ranged from 7.47 to 7.75 and 7.52 to 7.96, respectively under different land uses with on an average mean of 7.61 of surface water and 7.75 of ground water (Table 4.61- 4.62). The highest pH of surface and ground water was observed under urban land use followed by agriculture and forest land use. The highest pH (7.95) of surface water was recorded at Parwanoo (Table 4.16) under urban land use and minimum (7.07) at Chandi- Goyla under forest land use (Table 4.46). The maximum pH (8.28) of underground water was recorded under urban land use at Barotiwala (Table 4.31) and minimum (7.18) under forest land use at Chandi- Goyla (Table 4.46). The maximum pH recorded under unban land use may be due to addition of industrial effluents, sewage waste. In the present investigations lower pH of both the water sources was recorded

under forest land use which may be due to thick forest vegetation. These findings corroborate the findings of Calmels *et al.* (2006) who reported that thick forest vegetation produces surplus soil CO₂ by root respiration and by organic decay. Season wise the overall pH of surface and ground water varied from 7.42 to 7.89 and 7.51 to 8.08, respectively during different seasons with overall mean pH of 7.61 of surface water and 7.75 of ground water (Table 4.63- 4.64). Irrespective of land use, the pH of Surface and underground water were maximum during summer season and minimum during winter season. The highest pH (8.29) of surface water was recorded at Parwanoo during summer season (Table 4.16) and minimum (7.16) at Chandi- Goyla during winter season (Table 4.46). The maximum pH (8.55) of underground water was recorded at Barotiwala during summer season (Table 4.31) and minimum (7.28) at Chandi- Goyla during winter season (Table 4.46). The maximum pH during summer season may be due to decreased volume of water by evaporation and minimum in winter season may be due to short day length and decrease in evaporation rate. Similar to present findings Salve and Hiware (2006) also reported maximum pH during summer and minimum during winter with slight increase in monsoon. The pH of Dharampur block was within permissible limit (<6.5-8.5).

The highest EC (0.53dS/m) of surface water was observed under urban land use followed by agriculture (0.38 dS/m) and forest land use (0.29 dS/m). The maximum EC (0.70 dS/m) of ground water was also observed under urban land use followed by agriculture (0.58 dS/m) and forest land use (0.50 dS/m). The overall mean value of EC for surface and underground water was 0.40 dS/m and 0.59 dS/m, respectively (Table 4.61- 4.62). The highest EC (0.61 dS/m) of surface water was recorded at Parwanoo under urban land use (Table 4.17) and minimum (0.25 dS/m) of surface water was at Dharampur under forest land use (Table 4.2). The highest EC (0.84 dS/m) of underground water was recorded at Barotiwala under urban land use (Table 4.32) and minimum (0.42 dS/m) of underground water at Parwanoo under forest land use (Table 4.17). In the present investigations the maximum EC of surface water was recorded under urban land use and minimum under forest land use. Higher values of conductivity under urban land use may be due to increase in pollution load by addition of nutrients, agricultural runoff, industrial effluents, and organic matter in water. The present findings are in confirmation with the findings of Sharpley and Menzel (1987); Gupta *et al.* (2003) and Sanap *et al.* (2006) who reported that the conductance of water increases under urban land use which might be due to enrichment of organic conducting species from soaps and detergents of the bathing places. Similar results

were also reported by Gopalsami *et al.* (2003) and Vijayaram *et al.* (1990). Higher EC recorded in ground water may be due to the leaching off or washing out of the large parts of solutes in the soil. The present findings corroborates the results of Panabokke (2002). The maximum EC (0.46 dS/m) of surface water was recorded during summer season followed by rainy (0.41 dS/m) and winter season (0.33 dS/m). Similarly the maximum EC (0.65 dS/m) of ground water was observed during summer season followed by rainy (0.60 dS/m) and winter season (0.52 dS/m). The overall mean value of EC for surface and underground water was 0.40 dS/m and 0.59 dS/m, respectively (Table 4.63- 4.64). The highest EC (0.50 dS/m) of surface water was recorded at Parwanoo during summer season (Table 4.17) and minimum (0.32 dS/m) at Chandi- Goyla during winter season (Table 4.47). The highest EC (0.74 dS/m) of underground water was recorded at Barotiwala during summer season (Table 4.32) and minimum (0.42 dS/m) at Chandi- Goyla during winter season (Table 4.47). The maximum EC recorded during summer season may be due to evaporation of water. Similar results were also observed by Chandrashekhar and Kodarkar (1996) who reported that maximum EC was recorded during summer and minimum during winter season which may be due to evaporation of water during summer season and short day length with low temperature during winter season.

The colour of surface water and underground water under different land uses varied between colourless to blackish and colourless to light brown, respectively. The more intense colour of both water sources was recorded in rainy season followed by winter and summer seasons. Higher intense colour in urban land use during rainy season may be due to runoff of industrial effluents and organic matter in water. The present findings are in confirmation with the findings of Kumar *et al.* (2010) that the colour of Behgul river varied from colourless to blackish colour.

The odour of both water sources (surface and underground water) under different land uses varied between odourless to septic. The strong odour of both water sources was recorded in urban land use followed by agriculture land use. Septic and soapy odour in urban land use may be due to enrichment of organic waste, domestic waste, soaps and detergents in water. The present findings are in confirmation with the findings of Kumar *et al.* (2010) who reported that the odour of Behgul river water varied from odourless to pungent smell.

The temperature of surface water and underground water under different land uses varied between 20.51⁰C to 23.00⁰C and 19.76⁰C to 21.82⁰C, respectively. The highest temperature of both water sources was recorded in urban land use followed by agriculture and forest land use. The overall mean value for surface and underground water was 21.68⁰C and 20.70⁰C, respectively (Table 4.61- 4.62). The highest temperature (24.55⁰C) of surface water was recorded at Barotiwala under urban land use (Table 4.35) and minimum (19.10⁰C) at Dharampur under forest land use (Table 4.5). The highest temperature (22.57⁰C) of underground water under urban land use as well as minimum (19.57⁰C) under forest land use was recorded at Chandi- Goyla (Table 4.50). In the present investigations the maximum temperature was recorded under urban land use and minimum under forest land use which may be related with variation in the temperature of atmosphere and weather conditions. Similarly Sawyer *et al.* (1994) reported that the variations in atmospheric temperature and weather conditions are responsible for variation in temperature. The temperature of surface water and underground water varied between 11.87⁰C to 28.30⁰C and 13.46⁰C to 26.20⁰C during summer season and winter season, respectively. The highest temperature of both water sources was recorded during summer season followed by rainy and winter season. The overall mean value for surface and underground water was 21.68⁰C and 20.70⁰C, respectively (Table 4.63- 4.64). Both, the highest temperature (29.14⁰C) and lowest temperature (11.19⁰C) of surface water was recorded during summer season and winter season at Barotiwala, respectively (Table 4.35). Similarly, the highest temperature (29.47⁰C) and lowest temperature (12.49⁰C) of underground water was recorded during summer season and winter season at Barotiwala, respectively. The lower water temperature recorded during winter season may be due to dry spell as well as scarce rainfall, cold weather and low atmospheric temperature. Higher temperature during summer season may be due to longer photoperiod, bright sunshine, dry wind and other weather conditions. The present findings are in confirmation with the findings of Welch (1952) who reported that the water temperature was higher during summer season and relatively lower in rainy and winter seasons.

The overall TDS of surface water and underground water of Dharampur block under different land uses ranged from 209.01 to 343.87 mg/l and 293.93 to 488.18 mg/l, respectively with an average of 277.73 mg/l of surface water and 388.41 mg/l of ground water (Table 4.61-4.62). The maximum TDS of surface and ground water was observed under urban land use followed by agriculture and forest land use. The highest TDS of surface

water (414.78 mg/l) and underground water (563.00 mg/l) was recorded under urban land use at Barotiwala (Table 4.36), whereas minimum TDS of surface water (171.44 mg/l) as well as underground water (220.89 mg/l) was recorded under forest land use at Parwanoo (Table 4.21). Higher TDS recorded in ground water under urban land use may be originated from natural sources, sewage, domestic waste, urban run-off and industrial wastes. Season wise the overall TDS of surface and ground water varied from 202.90 to 366.78 mg/l and 304.55 to 479.99 mg/l, respectively during different seasons with overall mean of TDS 388.41 mg/l of surface water and 277.73 mg/l of ground water (Table 4.63-4.64). The maximum TDS of surface and ground water was observed during rainy season followed by summer and winter season. The highest TDS of surface water (458.11 mg/l) and underground water (569.78 mg/l) was recorded at Barotiwala during rainy season (Table 4.36) and minimum TDS of surface water (168.89 mg/l) and underground water (205.89 mg/l) was recorded at Parwanoo during winter season (Table 4.21). TDS was maximum during rainy and minimum during winter season. This pattern of fluctuations in TDS is in conformity with those of Jawale and Patil (2009);Salve and Hiware (2006) who reported low total dissolved solids in winter season and high in monsoon season which may be due to addition of dissolved solids from surface run off. The value of TDS were within permissible limits except Barotiwala. The permissible limit of TDS is 500 mg/l .

The highest BOD (5.75 mg/l) of surface water was observed under urban land use followed by agriculture BOD (3.23 mg/l) and forest land use (1.85 mg/l). The maximum BOD (2.72 mg/l) of ground water was also observed under urban land use followed by agriculture (1.81 mg/l) and forest land use (1.41 mg/l). The overall mean value for surface and underground water was 3.61mg/l and 1.98 mg/l, respectively (Table 4.61- 4.62). The highest BOD (16.61 mg/l) of surface water was recorded at Barotiwala under urban land use (Table 4.37) and minimum (1.02 mg/l) at Dharampur under forest land use (Table 4.7). The highest BOD (7.17 mg/l) of underground water was recorded at Barotiwala under urban land use (Table 4.37) and minimum (0.74 mg/l) at Chandi Goyla under forest land use (4.52). The maximum BOD was recorded under urban land use and minimum under forest land use may be due to enrichment of organic waste, domestic waste, soaps and detergents which lead to low oxygen concentration. The present investigations corroborate the findings of Trivedi and Goel (1986) who observed that low O₂ concentrations were associated with heavy contamination by organic matter. The maximum BOD (6.34 mg/l) of surface water was recorded during rainy season followed by summer (3.40 mg/l) and winter season (1.10 mg/l).

Similarly the maximum BOD (3.46 mg/l) of underground water was also observed during rainy season followed by summer (1.76 mg/l) and winter season (0.71 mg/l). The overall mean value for surface and underground water was 3.61mg/l and 1.98 mg/l, respectively (Table 4.63- 4.64). The highest BOD of surface water (18.54 mg/l) and underground water (9.52 mg/l) was recorded at Barotiwala during rainy season (Table 4.37) and minimum BOD of surface water (0.86 mg/l) and underground water (0.54 mg/l) was recorded at Chandi-Goyla during winter season (Table 4.52). Decrease in BOD during winter season may be due to higher solubility of oxygen at lower temperature which resulted low BOD, similar to the present findings Verma and Rani, (1984) also reported that decrease in BOD during winter may be due higher solubility of oxygen at lower temperature.

The highest COD (28.68 mg/l) of surface water was observed under urban land use followed by agriculture (13.09 mg/l) and forest land use (9.25 mg/l). Similarly the maximum COD (14.33mg/l) of ground water was observed under urban land use followed by agriculture (10.43 mg/l) and forest land use (8.03 mg/l). The overall mean value for surface and underground water was 17.01 mg/l and 10.94 mg/l, respectively (Table 4.61- 4.62). The highest COD of surface water (78.44 mg/l) as well as underground water (27.44 mg/l) was recorded at Barotiwala (4.38) under urban land use and minimum of surface water (7.86 mg/l) and underground water (6.68 mg/l) at Chandi Goyla (Table 4.53) under forest land use. The highest values of COD under urban land use may be due to discharge of industrial effluents, sewage waste and other wastes. Similar result were also reported by Srivastava and Sinha, (1996). The maximum COD (20.77 mg/l) of surface water was recorded during rainy season followed by summer (16.89 mg/l) and winter season (13.37 mg/l). The maximum COD (12.00 mg/l) of underground water was also observed during rainy season followed by summer (11.10 mg/l) and winter season (9.71 mg/l). The overall mean value of COD for surface and underground water was 17.01 mg/l and 10.94 mg/l, respectively (Table 4.63- 4.64). The highest COD of surface water (49.22 mg/l) and underground water (19.20 mg/l) was recorded during rainy season at Barotiwala (Table 4.38) where as minimum COD of surface water (8.08 mg/l) and underground water (6.92 mg/l) was recorded during winter season at Chandi- Goyla (Table 4.53). Highest value of COD during rainy season may be due to large scale disposal of untreated waste water, surface runoff, soil erosion runoff into the water source. High value of COD indicated high degree of organic pollution. Upkar and Vyas, (1992) also reported that high value of COD may be due to high degree of organic pollution. The COD recorded during present study are above the permissible limit (20 mg/l)

at Barotiwala under urban land use which may be due to discharge of industrial and sewage waste.

The overall Ca content of surface water and underground water ranged from 69.44 to 97.15 mg/l and 92.99-107.61 mg/l, respectively under different land uses with an average of 81.99 mg/l of surface water and 100.35 mg/l of ground water (Table 4.61- 4.62). The highest Ca content (97.15 mg/l) of surface water was observed under urban land use followed by agriculture (79.38 mg/l) and forest land use (69.44 mg/l). The maximum Ca content (107.61 mg/l) of ground water was also observed under urban land use followed by agriculture (100.45 mg/l) and forest land use (92.99 mg/l). The maximum Ca (108.00 mg/l) of surface water was recorded at Parwanoo (Table 4.24) under urban land use and minimum (46.77 mg/l) at Barotiwala under forest land use (Table 4.39). The maximum Ca (117.52 mg/l) of underground water was recorded at Parwanoo (Table 4.24) under urban land use and minimum (110.89 mg/l) at Dharampur under forest land use (Table 4.9). The calcium is one of the most abundant substances of natural water being present in high quantities in the rocks. Higher calcium content in urban land use in underground water may be due to sewage, industrial wastes and landfill leachates which are enriched with Ca^{2+} ions. The present findings are in confirmation with the finding of Hackley *et al.* (1996) who also recorded that landfill leachates were enriched in Ca^{2+} , Mg^{2+} , Na^+ , Cl^- and other anions and cations. The maximum Ca content (88.71 mg/l) of surface water was recorded during summer season followed by winter (84.22 mg/l) and rainy season (73.03 mg/l). Similarly the maximum Ca content (104.72 mg/l) of underground water was observed during summer season followed by winter (102.27 mg/l) and rainy season (94.06 mg/l). The overall mean value for surface and underground water was 81.99 mg/l and 100.35 mg/l, respectively (Table 4.63- 4.64). The highest Ca content (95.60 mg/l) of surface water was recorded at Dharampur during summer season (Table 4.9) and minimum (41.29 mg/l) at Barotiwala during rainy season (Table 4.39). The highest Ca (115.83 mg/l) of underground water was recorded at Dharampur during summer season and minimum (108.56 mg/l) at Dharampur during rainy season (Table 4.9). In the present findings the maximum value of Ca was recorded during summer and minimum during rainy season. In the present findings the Ca content was higher than permissible limits (75 mg/l). The lowest values of calcium content during rainy season may be due to the increase in dilution by rain water. The present results are in agreement with the findings of Pande and Sharma (1998) who observed same trend at Moradabad.

The Mg content of surface water under different land uses varied between 5.68 to 10.34 mg/l and of underground water between 9.66 to 14.76 mg/l. The highest Mg content of both water sources was recorded under urban land use followed by agriculture and forest land use. The overall mean value of Mg for surface and underground water was 8.04 mg/l and 12.36 mg/l, respectively (Table 4.61- 4.62). The maximum Mg (17.09 mg/l) of surface water was recorded at Barotiwala under urban land use and minimum (4.02 mg/l) at Barotiwala under forest land use (Table 4.40). The maximum Mg (23.88 mg/l) of underground water was recorded at Barotiwala under urban land use (Table 4.40) and minimum (7.82 mg/l) at Chandi- Goyla under forest land use (Table 4.55). Higher magnesium in urban land use may be due to urban landfill leachates and other wastes that may be the source of Mg^{2+} cations. The present findings are in accordance with the findings of Hackley *et al.* (1996). During different seasons the Mg content of surface water varied between 7.05 to 9.58mg/l and 10.25 to 14.54 mg/l in ground water. The highest Mg in water samples of both water sources was recorded during summer season followed by winter and rainy season. The overall mean value for surface and underground water of Dharampur block was 8.04 mg/l and 12.36 mg/l, respectively (Table 4.63- 4.64). The highest Mg (19.92 mg/l) of surface water was recorded at Barotiwala during summer season (Table 4.40) and minimum (5.56 mg/l) at Chandi- Goyla during rainy season (Table 4.55). The highest Mg content (19.92 mg/l) of underground water was recorded at Barotiwala during summer season (Table 4.40) and minimum (7.00 mg/l) of underground water at Parwanoo during rainy season (Table 4.25). Magnesium contents were higher during summer season and minimum in rainy season. The highest Mg content during summer season may be due to evaporation and high atmospheric temperature which lead to increase in concentration of ions. The lowest Mg content in rainy season may be attributed to the increase in dilution by rains water. Similar results were also reported by Pande and Sharma (1998) for Ramganga river at Moradabad. The Mg content of both the water sources under different land uses was below permissible limit (30 mg/l).

The highest NO_3 content (2.04 mg/l) of surface water was observed under agriculture land use followed by urban (1.82 mg/l) and forest land use (1.07 mg/l). The maximum NO_3 (4.51 mg/l) in underground water was observed under agriculture land use followed by urban (3.14 mg/l) and forest land use (1.65 mg/l). The overall mean value of NO_3 content for surface and underground water was 1.64 mg/l and 3.10 mg/l, respectively (Table 4.61- 4.62). The maximum NO_3 content (2.70 mg/l) of surface water was recorded at Barotiwala (Table 4.41) under urban land use and minimum (0.73 mg/l) at Dharampur under forest land use

(Table 4.11). The maximum NO₃ (5.82 mg/l) of underground water was recorded at Parwanoo (Table 4.26) under urban land use and minimum (1.77 mg/l) at Chandi Goyla under forest land use (Table 4.56). The increased NO₃ value in agriculture land use may be due to runoff, land drainage and input of fertilizers from adjacent agricultural fields and oxidation of ammonia. Similar results have been reported by Anbazhagan (1988). However, igneous rocks, land drainage, plant and animal debris are also the sources of nitrate derived from natural processes in most fresh waters. In well oxygenated waters ammonium ions can be converted into nitrate (ENDS, 1982; ENDS, 1992). The leachate of crop nutrients and nitrate fertilizers from agricultural lands may be responsible for higher content of NO₃ under agriculture land use. These results corroborate the findings of Simeonov *et al.* (2003). In urban land use the higher nitrate concentration may be due to sewage and industrial waste water, which contain higher concentrations of NO₃⁻. Similar results were reported by Zacharias *et al.* (2002) and Gupta and Hamid (2003). The maximum NO₃ (2.34 mg/l) of surface water was recorded during rainy season followed by summer (1.50 mg/l) and winter season (1.08 mg/l). Similarly the maximum NO₃ (3.63 mg/l) of ground water was also observed during rainy season followed by summer (3.00 mg/l) and winter season (2.67 mg/l). The overall mean value of NO₃ for surface and underground water was 1.64 mg/l and 3.10 mg/l, respectively (Table 4.63- 4.64). The highest NO₃ of surface water (3.29 mg/l) and underground water (4.27 mg/l) was recorded during rainy season at Barotiwala (Table 4.41) whereas minimum NO₃ of surface water (0.60 mg/l) and underground water (1.93 mg/l) was recorded during winter season at Dharampur (Table 4.11). The maximum nitrate was recorded in rainy season and minimum in winter season which may be due to the runoff of nutrients in surface water and leaching of nutrient to ground water. Irene (1991) also observed highest value of nutrient during rainy season and was with a view that it may be due to runoff of nutrient by rains. The nitrate content in present findings was below permissible limit (45mg/l).

The overall chloride (Cl) of surface water and underground water ranged from 21.74 to 34.58 mg/l and 13.56 to 24.82 mg/l, respectively under different land uses with an average of 28.36 mg/l of surface water and 18.657 mg/l of ground water (Table 4.61- 4.62). The maximum Cl (34.58 mg/l) in surface water was observed under urban land use followed by agriculture (28.77 mg/l) and forest land use (21.74 mg/l). The maximum Cl (24.82 mg/l) in underground water was also observed under urban land use followed by agriculture (17.62 mg/l) and forest land use (13.56 mg/l). The maximum Cl (38.92 mg/l) of surface water was

recorded at Barotiwala (Table 4.42) under urban land use and minimum (18.96 mg/l) at Chandi Goyla under forest land use (Table 4.57). The maximum Cl (27.22 mg/l) of underground water was recorded at Barotiwala (Table 4.42) under urban land use and minimum (10.38 mg/l) at Parwanoo under forest land use (Table 4.27). The higher content of chlorides under urban land use may be due to city sewage and domestic waste, man and animals excrete which contain higher quantity of chloride. Similar results were also reported by Dwivedi and Odi (2003) and Sanap *et al.* (2006). In Dharampur block the maximum Cl content (31.75 mg/l) of surface water was recorded during summer season followed by winter (28.40 mg/l) and rainy season (24.97 mg/l). The maximum Cl (22.73 mg/l) in underground water was observed during summer season followed by winter (19.46 mg/l) and rainy season (13.81 mg/l). The overall mean value for surface and underground water was 3.66 mg/l and 2.42 mg/l, respectively (Table 4.63- 4.64). The highest Cl of surface water (37.06 mg/l) and underground water (26.81 mg/l) was recorded during summer season at Barotiwala (Table 4.42) where as minimum Cl of surface water (22.84 mg/l) and underground water (11.62 mg/l) was recorded during rainy season at Chandi- Goyla (Table 4.57). The lowest values in rainy season can be attributed due to the increase dilution by rain water. The results corroborate the findings of Reddy *et al.*, (2009) for Pakhal Lake. The Cl content in water samples were below the permissible limit (250 mg/l).

The overall iron content of surface water and underground water ranged from 5.30 to 1.97 ppb and 7.88 to 7.42 ppb, respectively under different land uses with on an average of 3.67 ppb of surface water and 7.61 ppb of ground water (Table 4.65). The maximum Fe content (5.30 ppb) of surface water was observed under urban land use followed by agriculture (3.75 mg/l) and forest land use (1.97 ppb) where as the maximum Fe content (7.88 ppb) of ground water was also observed under urban land use followed by agriculture (7.53 ppb) and forest land use (7.42 ppb) (Table 4.65). The highest value of Fe content in surface water (7.22 ppb) and underground water (7.88 ppb) was recorded under urban land use at Barotiwala (Table 4.43) where as minimum Fe content in underground water (0.22 ppb) and underground water (0.67 ppb) was recorded under forest land use at Chandi- Goyla (Table 4.58). Higher value of iron in urban land use may be due to washing activities, recreational activities, vehicle washing, weathering of minerals and soils, atmospheric deposition, storm water runoff resulting from rainfall, and sewage. Puri (2011) reported that more iron in water may be caused due to activities of iron-reducing bacteria which preferentially reduces least crystalline Fe-Mn oxyhydroxide phases. Manning and Goldberg (1997) reported the similar

results. The maximum Fe content (5.21 ppb) of surface water was recorded during summer season followed by winter (3.69 ppb) and rainy season (2.11 ppb). The maximum Fe content (6.61 ppb) of ground water was observed during summer season followed by winter (4.53 ppb) and rainy season (2.97 ppb). The overall mean value for surface and underground water was 3.67 ppb and 4.70 ppb, respectively (Table 4.65). The highest Fe content in surface water (6.67 ppb) and underground water (8.78 mg/l) was recorded during summer season at Barotiwala (Table 4.43) where as minimum Fe of surface water (0.56 ppb) and underground water (0.89 ppb) was recorded during rainy season at Chandi- Goyla (Table 4.58). The maximum iron content during summer season may be due to the higher evaporation of water during summer and minimum in rainy season may be due to dilution by precipitation and run off from catchment area during rainy season. The present findings are in confirmation with the findings of Bhatt *et al.*, (1999) who reported that high concentration of iron during summer may be due to the evaporation of water from lakes and low concentration in rainy season due to dilution by precipitation and run off from catchment area. The content of iron in water samples under different land uses were within permissible limit (300 ppb).

The maximum Mn content (2.43 ppb) of surface water was observed under urban land use followed by agriculture (1.22 ppb) and forest land use (0.68 ppb). The maximum Mn (2.91 ppb) of ground water also observed under urban land use followed by agriculture (2.05 ppb) and forest land use (1.37ppb) (Table 4.65). The overall mean value for surface and underground water was 1.44 ppb and 2.11 ppb, respectively (Table 4.65). The maximum Mn content (7.42 ppb) of surface water was recorded at Barotiwala (Table 4.44) under urban land use and minimum (0.15 ppb) at Parwanoo under forest land use (Table 4.29). The maximum Mn content (8.73 ppb) of underground water was recorded at Barotiwala (Table 4.44) under urban land use and minimum (0.40 ppb) at Dharampur under forest land use (Table 4.14). The maximum Mn content (1.79 ppb) of surface water was recorded during summer season followed by winter (1.34 ppb) and rainy season (1.20 ppb). Similarly the maximum Mn content (2.80 ppb) of ground water was observed during summer season followed by winter (1.89 ppb) and rainy season (1.63 ppb) (Table 4.66). The overall mean value for surface and underground water was 1.44 ppb and 2.11 ppb, respectively (Table 4.66). The highest Mn content (4.84 ppb) of surface water was recorded at Barotiwala (Table 4.44) during summer season and minimum (0.35 ppb) of surface water at Parwanoo during rainy season (Table 4.29). The highest Mn content (8.17 ppb) of underground water was recorded at Barotiwala (Table 4.44) during summer season and minimum (0.43 ppb) of surface water was at Chandi

Goyla during rainy season (4.59). Higher value on Mn in underground water may be due to anaerobic conditions which favour manganese is preferably reduced from its ore itself to more soluble +2 state along with iron. McKenzie (1975) reported that the higher levels of Manganese in urban land use may be due to industrial pollution. Dwivedi and Tiwary (1997) also observed higher levels of Manganese in industrial polluted water. The manganese content in water samples were below the permissible limit (100 ppb).

The overall mean value of Zn for surface and underground water was 0.38 ppt and 0.53 ppt, respectively (Table 4.65). The maximum Zn content (0.60 ppt) of surface water was observed under urban land use followed by agriculture (0.47ppt) and forest land use (0.05 ppt). The maximum Zn (0.83 ppt) of ground water was also observed under urban land use followed by agriculture (0.69 ppb) and forest land use (0.07 ppt) (Table 4.65). The highest value of Zn content in surface water (1.02 ppt) and underground water (1.08 ppt) was recorded under urban land use at Barotiwala (Table 4.45) where as minimum Zn content in surface water (0.00 ppt) and underground water (0.00 ppt) was recorded under forest land use at Chandi- Goyla (Table 4.60). The highest concentrations of Zn in urban land use may be due to the discharge of heavy metal loaded industrial waste water, land derived materials along with domestic and municipal waste water. Shah *et al.* (2005); Ananthan *et al.* (2006) reported the highest concentrations of Zn at Palta due to the discharge of heavy metal loaded industrial waste water. The maximum Zn content (0.58 ppt) of surface water was recorded during summer season followed by winter (0.33 ppt) and rainy season (0.23 ppt). The maximum Zn (0.77 ppt) of underground water was also observed during summer season followed by winter (0.48 ppt) and rainy season (0.34 ppt) (Table 4.66). The overall mean value for surface and underground water was 0.38 ppt and 0.53 ppt, respectively (Table 4.66). The highest Zn content in surface water (0.90 ppt) and underground water (1.18 ppt) was recorded during summer season at Barotiwala (Table 4.45) where as minimum Zn content of surface water (0.12 ppt) and underground water (0.17 ppt) was recorded during rainy season at Chandi- Goyla (Table 4.60). The low concentration of Zn in monsoon may be due the prevailing lower pH which renders dissolved metal carbonate complexes to release free metal ions into the water column. The present findings corroborate the findings of Ananthan *et al.* (2006) who reported that lower concentration of Zn in surface water during rainy season may be due to high phytoplankton population in monsoon. They consume more Zn leading to low concentration of Zn in the monsoon season. The zinc content in all the water samples under different land uses were below permissible limit (5ppt).

The maximum water quality index (WQI) (21.10) of surface water of Dharampur block was worked out under urban land use followed by agriculture (13.40) and forest land use (9.02). Similarly the maximum WQI (15.93) of underground water was also observed under urban land use followed by agriculture (12.34) and forest land use (8.89) (Table 4.67). On the basis of WQI, the surface and underground water falls under excellent category. The water quality worked out for Dharampur block was as per rating limit (<100).

Irrespective of land use the highest WQI (16.42) of surface water was recorded during summer season followed by rainy season (19.16) and winter season (7.96) (Table 4.68), Similarly the maximum WQI (14.76) of underground water was during summer season followed by rainy season (14.42) and winter season (7.99) (Table 4.68). On the basis of water quality index rating (<100) the water quality of different seasons falls under excellent category. The higher WQI was worked out for summer season as compared with rainy and winter seasons. In the present investigations the water quality indices worked out for surface and ground water at all the locations under different land uses during different seasons were good to excellent category. However at Barotiwala slightly higher WQI was worked out which may be due to over exploitation of resources and anthropogenic activities such as discharge of effluents from industries, runoff of agricultural and domestic sewage.

The highest WQI was worked out at Barotiwala (31.32) followed by Parwanoo (18.98), Dharampur (31.32) and Chand-Goyla (9.52) (Table 4.69). The WQI was worked out as excellent at Chandi-Goyla, Dharampur and Parwanoo whereas it was good at Barotiwala. The higher values of WQI at Barotiwala may be due to anthropogenic activities, discharge of effluents from industrial, agricultural and domestic uses.

5.2 EFFECT OF LAND USES ON AQUATIC INSECTS UNDER SURFACE WATER DURING DIFFERENT SEASONS

The maximum number (59 individuals) of aquatic insects were recorded under forest land use at Dharampur, followed by Parwanoo (48 individuals), Barotiwala (36 individuals) and Chandi-Goyla (70 individuals) whereas urban land use registered minimum number of aquatic insects at all the locations (Dharampur—48 individuals, Parwanoo-31 individuals, Barotiwala -21 individuals and Chandi-Goyla -50 individuals). The most abundant family of aquatic insects was Baetidae of Ephemeroptera order. The low number of individuals under urban land use may be due to the discharge of industrial effluents and anthropogenic

activities like addition of domestic wastes, sewage and industrial discharge which may lead to reduction in species. Similar results were reported by Wahizatul *et al.* (2006). Foreman *et al.* (2008) reported that the human activities add nitrogen and phosphorus to the water, which lead to algal blooms and low dissolved oxygen in slow-moving streams which caused reduction in aquatic insects.

The maximum number of aquatic insects in surface water were recorded during winter season at all the locations (Chandi- Goyla -109 individuals, Dharampur-105 individuals, Parwanoo-62 individuals and Barotiwala-35 individuals) where as rainy season registered minimum number of individuals at all the locations (Dharampur -20 individuals, Parwanoo-22 individuals, Barotiwala-20 individuals and Chandi- Goyla- 27 individuals). The high abundance of aquatic insect during winter season may be due to relatively low velocity of water, high dissolved oxygen, low hydromedian depth and low turbidity of water. Similar to present findings Sharma *et al.* (2004) and Sharma *et al.* (2008) also reported highest number of aquatic insects during winter season at Nanda Devi Biosphere Reserve, Uttaranchal and Chandrabhaga river, respectively.

The maximum Simpson's Diversity index was equal (0.91) at Dharampur as well as at Chandi- Goyla (0.91). Lowest Simpson's Diversity index (0.88) was recorded at Barotiwala (Table 4.74). The less diversity of aquatic insects at Barotiwala may be due to intensive human activities, such as urbanisation, recreation, and agricultural activities. The substrate of the site may also be responsible for reduction in species diversity of aquatic insect communities. Wahizatul *et al.* (2006) reported that the reduction in species diversity at Sekayu Recreational Forest was associated with human activity.

The maximum Ephemeroptera, Plecoptera, Trichoptera (EPT) index (43.67) was recorded at Chandi- Goyla and lowest EPT index(27.33) was recorded at Barotiwala where as the EPT index of Dharampur and Parwanoo was 41.67 and 32.67 (Table 4.75). The EPT index (>27) indicated the "Excellent water quality". The higher EPT index at Chandi Goyla may be due to clean environment and lowest EPT index at Barotiwala may be due to high loads of organic and inorganic suspended materials, increased runoff from agriculture land and industrial and sewage disposal which lead to environmental stress. Armitage *et al.* (1983) also reported that members of EPT were sensitive to environmental stress .

The maximum Family biotic index (FBI) (2.73) was recorded at Barotiwala and lowest was recorded at Dharampur (2.31) which indicated excellent water quality of these areas where as FBI at Parwanoo and Chandi- Goyla was 2.49 and 2.45 respectively (Table 4.76).The present findings support the findings of Armitage *et al.* (1983) who reported the biological indices provided better information about the environmental conditions under which they lived than a consideration of the individual taxa alone. On overall basis the maximum diversity of aquatic insects was recorded at Chandi-goyla and minimum at Barotiwala.

Chapter-6

SUMMARY AND CONCLUSION

The present investigations, “Effect of different land uses on water quality of Dharampur Block of Solan district of Himachal Pradesh” were conducted under different land uses during different seasons and the results obtained are summarised as under:

The overall pH of surface water and underground water of Dharampur block under different land uses ranged from 7.47 to 7.75 and 7.52 to 7.96, respectively. The maximum pH of surface (7.75) and ground water (7.96) of Dharampur block was recorded under urban land use followed by agriculture and forest land use. The overall pH of surface and underground water under different land uses during different seasons was 7.61 and 7.75, respectively. Season wise the overall pH of surface and ground water varied from 7.42 to 7.89 and 7.51 to 8.08, respectively. Irrespective of land use, maximum pH of surface (7.89) and underground water (8.08) was recorded during summer season and minimum during winter season. The pH was within permissible limit (<6.5-8.5).

The overall EC value of surface and underground water from different land uses ranged from 0.29 dS/m to 0.53dS/m and 0.50 dS/m to 0.70 dS/m, respectively. The maximum EC of surface (0.53 dS/m) and ground water (0.70 dS/m) was recorded under urban land use followed by agriculture and forest land use. The overall EC of surface and underground water under different land uses during different seasons was 0.40 dS/m and 0.59 dS/m, respectively. The EC value of surface and ground water from different seasons irrespective of land uses, ranged from 0.33 dS/m to 0.46 dS/m and 0.52 dS/m to 0.65 dS/m. The maximum EC of surface (0.46 dS/m) and underground water (0.65 dS/m) was recorded during summer season and minimum during winter season.

The colour of surface and underground water under different land uses during different seasons varied from colourless to blackish and colourless to light brown, respectively. The odour of both water sources (surface and underground water) under different land uses during different seasons varied between odourless to septic. The strong odour of both water sources was recorded in rainy season followed by summer and winter season.

The overall temperature of surface water and underground water under different land uses varied between 20.51⁰C to 23.00⁰C and 19.76⁰C to 21.82⁰C, respectively. The maximum temperature of surface (23.00⁰C) and underground water (21.82⁰C) was recorded in urban land use followed by agriculture and forest land use. The overall mean value of temperature for surface and underground water under different land uses during different seasons was 21.68⁰C and 20.70⁰C. During different seasons, the temperature of surface water varied between 11.87⁰C to 28.30⁰C and 13.46⁰C to 26.20⁰C in underground water. The maximum temperature of surface (28.30⁰C) and underground water (26.20⁰C) was recorded during summer season followed by rainy and winter season.

The TDS value of surface and underground water irrespective of season, ranged from 209.01 to 343.87 mg/l and 293.93 to 488.18 mg/l, respectively. The Maximum TDS of surface (343.87 mg/l) and underground water (488.18 mg/l) was observed under urban land use followed by agriculture and urban land use. The overall mean value of TDS for surface and underground water under different land uses during different seasons was 388.41 mg/l and 277.73 mg/l. Irrespective of land uses the TDS value of surface and underground water during different seasons, ranged from 202.90 to 366.78 mg/l and 304.55 to 479.99 mg/l, respectively. The maximum TDS of surface (366.78 mg/l) and underground water (479.99 mg/l) was observed during rainy season followed by summer and winter season. The TDS was within permissible limit (500 mg/l).

The overall BOD of surface water and underground water ranged from 1.85 to 5.75 mg/l and 1.41 to 2.72 mg/l, respectively. The maximum BOD of surface (5.75 mg/l) and underground water (2.72 mg/l) was recorded under urban land use followed by agriculture and forest land use. The overall mean value of BOD for surface and underground water under different land uses during different seasons was 3.61mg/l and 1.98 mg/l. The BOD of surface water and underground water ranged from 1.10 (winter season) to 6.34 mg/l (summer season) and 0.71(winter season) to 3.46 mg/l (summer season), respectively. The BOD was within permissible limit (<5 mg/l) except surface water of urban land use (>5mg/l).

The COD value of surface and underground water irrespective of season, ranged from 9.25 to 28.68 mg/l and 8.03 to 14.33mg/l, respectively under different land uses. The maximum COD of surface (28.68 mg/l) and underground water (14.33 mg/l) was recorded under urban land use followed by agriculture and forest land use. The overall mean value of

COD for surface and underground water under different land uses during different seasons was 17.01 mg/l and 0.94 mg/l, respectively. The overall COD value of surface and underground water irrespective of land uses, ranged from 13.37 to 20.77 mg/l and 9.71 to 12.00 mg/l, respectively. The maximum COD of surface (20.77 mg/l) and underground water (12.00 mg/l) was observed during rainy season followed by summer and winter season. The COD was within permissible limit (<20 mg/l) except surface water of urban land use (>20mg/l)..

The overall Ca content of surface water and underground water under different land uses ranged from 69.44 to 97.15 mg/l and 92.99 to 107.61 mg/l, respectively. The highest Ca content of surface (97.15 mg/l) and underground water (107.61 mg/l) was observed under urban land use followed by agriculture and forest land use. The overall mean value of Ca content for surface and underground water under different land uses during different seasons was 81.99 mg/l and 100.35 mg/l. Season wise, the overall Ca content of surface water and underground water ranged from 73.03 to 88.71 mg/l and 94.06 to 104.72 mg/l, respectively. The highest Ca content of surface (88.71 mg/l) and underground water (104.72 mg/l) was recorded during summer season followed by winter and rainy season. The Ca content of both water sources was above the permissible limit (>75 mg/l).

The overall Mg content of surface and underground water under different land uses varied between 5.68 to 10.34 mg/l and 9.66 to 14.76 mg/l, respectively. The maximum Mg content of surface (10.34 mg/l) and underground water (14.76 mg/l) was recorded under urban land use followed by agriculture and forest land use. The overall mean value of Mg content for surface and underground water under different land uses during different seasons was 8.04 mg/l and 12.36 mg/l. The overall Mg content of surface and underground water at Dharampur block during different seasons varied between 7.05 to 9.58mg/l and 10.25 to 14.54 mg/l, respectively. The highest value of Mg content of surface (9.58 mg/l) and underground water (14.54 mg/l) was recorded during summer season followed by winter and rainy season. The Mg content of both water sources was within permissible limit (<30 mg/l).

The overall NO₃ content of surface water and underground water ranged from 1.07 to 2.04 mg/l and 1.65 to 4.51 mg/l , respectively. The maximum NO₃ of surface (2.04 mg/l) and ground water (4.51 mg/l) was observed under urban land use followed by agriculture and urban land use. The overall mean value of NO₃ content for surface and underground water under different land uses during different seasons was 1.64 mg/l and 3.10 mg/l. Season wise,

the overall NO₃ content of surface and ground water varied from 1.08 to 2.34 and 2.67 to 3.63, respectively. Irrespective of land uses, the maximum value of NO₃ content in surface (2.34 mg/l) and underground water (3.63 mg/l) were recorded during rainy season followed by summer season and winter season. The NO₃ content in both water sources was within permissible limit (<45 mg/l).

The overall Cl content of surface water and underground water under different land uses ranged from 21.74 to 34.58 mg/l and 13.56 to 24.82 mg/l, respectively. The maximum Cl content of surface (34.58 mg/l) and underground (24.82 mg/l) water was observed under urban land use followed by agriculture and forest land use. The overall mean value of Cl content for surface and underground water under different land uses during different seasons was 28.36 mg/l and 18.67. Season wise, the overall Cl content of surface water and underground water varied from 24.97 to 31.75 mg/l and 13.81 to 22.73 mg/l, respectively. Irrespective of land uses, the maximum Cl content of surface (31.76 mg/l) and underground water (22.73 mg/l) was during summer season followed by winter and rainy season. The Cl content of both water sources under different land uses during different season was within permissible limit (<250 mg/l).

The overall Fe content of surface water and underground water ranged from 1.97 to 5.30 ppb and 7.42 to 7.88 ppb, respectively. The maximum Fe content of surface water (5.30 ppb) and underground water (7.88 ppb) was observed under urban land use followed by agriculture and forest land use. The overall mean value of Fe content for surface and underground water under different land uses during different season was 3.67 ppb and 7.61 ppb, respectively. Season wise, the overall Fe content of surface and ground water varied from 2.11 to 5.21 ppb and 2.97 to 6.61 ppb, respectively. Irrespective of land uses, the Fe content of surface (5.21 ppb) and underground water (6.61 ppb) was maximum during summer season followed by winter and rainy season. The Fe content of both water sources was within permissible limit (<300ppb).

The overall Mn value of surface water and underground water from different land uses ranged from 0.68 to 2.43 ppb and 1.37 to 2.91ppb, respectively. The maximum Mn content of surface (2.43 ppb) and underground water (2.91 ppb) was observed under urban land use followed by agriculture and forest land use. The overall mean value for surface and underground water under different land uses during different seasons was 1.44 ppb and 2.11 ppb, respectively. The overall Mn value of surface and underground water for different

seasons irrespective of land uses, ranged from 1.20 to 1.79 ppb and 1.63 to 2.80 ppb, respectively. The maximum Mn content of surface and ground water was observed under urban land use followed by agriculture and forest land use. The overall mean value for surface and underground water was 1.44 ppb and 2.11 ppb, respectively. The maximum Mn of surface (1.79 ppb) and ground water (2.80 ppb) was recorded during summer season followed by winter and rainy season. The Mn content were within permissible limit (100 ppb) .

The overall Zn content of surface water and underground water under different land uses ranged from 0.05 to 0.60 ppt and 0.07 to 0.83 ppt, respectively. The maximum Zn content of surface (0.60 ppt) and ground water (0.83 ppt) was observed under urban land use followed by agriculture and forest land use. The overall mean value for surface and underground water under different land uses during different seasons was 0.38 ppt and 0.53 ppt, respectively. Season wise the overall Zn content of surface and ground water varied from 0.23 to 0.58 ppt and 0.34 to 0.77 ppt, respectively. Irrespective of land uses, the Zn content of surface (0.58 ppt) and underground water (0.77 ppt) was maximum during summer season followed by winter and rainy season. The Zn content was within permissible limit (<5ppt).

The overall water quality index (WQI) of surface water and underground water ranged from 9.02 to 21.10 and 8.89 to 15.9, respectively. The maximum WQI of surface (21.10) and underground water (15.93) was observed under urban land use followed by agriculture and forest land use. Season wise, the overall WQI of surface and ground water varied from 7.96 to 19.16 and 7.99 to 14.76, respectively. Irrespective of land uses, the WQI of surface (19.16) and underground water (14.76) during different seasons was maximum during rainy season followed by summer and winter season. Irrespective of land uses and seasons the WQI at different location ranged from 9.52 to 31.32. Maximum WQI (31.32) was recorded at Barotiwala and minimum (9.52) at Chandi – Goyla. The WQI of Dharampur block was within permissible limit (<100).

The number of aquatic insects collected from surface water of Dharampur block under different land uses during different seasons ranged from 21 to 70 individuals. The maximum count of aquatic insects (70 individuals) for surface water was observed under forest land use followed by agriculture and urban land use. The most abundant individuals were of Batidae family (Ephemeroptera) and least were of Cordullidae family (Odonata) . The number of aquatic insects during different seasons ranged from 20 to 109 individuals. The maximum

aquatic insects of surface water were recorded during winter season followed by summer and rainy season.

The Simpson's diversity index ranged from 0.88 to 0.91. The maximum Simpson's diversity index (0.91) of surface water was observed at Chandi- Goyla and Dharampur followed by Parwanoo (0.90) and Barotiwala (0.88).

The EPT index ranged from 27.33 to 43.67. The EPT index of different locations was as per rating limit (>27). The family biotic index of aquatic insects ranged from 2.31 to 2.73. The FBI of different locations were as per rating limit (<3.51).

Thus it can be concluded that all the quality parameters and contents of magnesium, nitrate, chloride and heavy metals in surface and underground water except Ca under different land uses were within prescribed permissible limits. Water quality index (WQI) of both the water sources under different land uses were also within the rating limits. Simpson diversity index indicated high diversity of aquatic insects in surface water. The EPT index as well as family biotic index were within rating limits. The quality of water of both the water sources under different land uses during different seasons were within range of good to excellent and variations in water quality were seasonal and linked to land use practices.

Chapter-7

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Title of Thesis : “Effect of different land uses on water quality of Dharampur block of Solan district of Himachal Pradesh”
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ABSTRACT

The present investigations entitled “Effect of different land uses on water quality of Dharampur block of Solan district of Himachal Pradesh” was conducted during 2011-2012 in Dharampur block of Solan district of Himachal Pradesh under different land uses (agriculture, forest and urban/ suburban) during different seasons (rainy, winter and summer) at four locations. The water samples were collected from surface as well as underground water from agriculture, forest and urban / suburban land uses where as aquatic insects were collected from surface water under these land uses. The overall mean value of pH, EC, Temperature, TDS, BOD, COD, Ca, Mg, Cl, NO₃ in surface and underground water under different land uses during different seasons were 7.61, 0.40 dS/m, 21.68 °C, 277.73mg/l, 3.61mg/l , 17.01 mg/l , 81.99 mg/l , 8.04 mg/l , 1.64 mg/l , 28.36 mg/l and 7.75, 0.59 dS/m, 20.70 °C, 388.41 mg/l , 1.98 mg/l , 10.94 mg/l , 100.35 mg/l , 12.36 mg/l , 3.10 mg/l , 18.67 mg/l , respectively. The contents of calcium under surface (81.99 mg/l) as well as underground water (100.35 mg/l) were above permissible limit (>75 mg/l). The colour of surface and underground water under different land uses during different seasons varied from colourless to blackish and colourless to light brown, respectively. The odour of both water sources (surface and underground water) under different land uses during different seasons varied between odourless to septic. The overall mean value of Fe, Mn, Zn in surface and underground water under different land uses during different seasons were 3.67 ppb, 1.44 ppb, 0.38 ppt and 7.61 ppb, 2.11ppb, 0.53 ppt, respectively. The maximum water quality index (WQI) of surface water (21.10) and underground water (15.93) was registered under urban land use and minimum under forest land use. The maximum WQI (31.32) was recorded at Barotiwala and minimum (9.52) at Chandi – Goyla. The Simpson’s Diversity index (D) and EPT index of Dharampur block ranged from 0.88 to 0.91 and 27.33 to 43.67, respectively. Both indices (Simpson’s Diversity index and EPT) were highest at Chandi- Goyla and minimum at Barotibala. The FBI (Family biotic index) of aquatic insects of Dharampur block ranged from 2.31 to 2.73. Overall water quality of Dharampur block was good to excellent category.

Signature of Major Advisor

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APPENDIX-I

ANOVA table for surface and underground water parameters at Dharampur

Source of variation	Degree of freedom	Mean sum of square							
		pH		EC		TDS		BOD	
		Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Replication	2.00	0.02	0.06	0.01	0.00	31262.70	4257.33	0.04	0.05
Treatment	8.00	0.06	0.19	0.04	0.01	13826.37	10602.08	0.62	0.34
Land Use (L)	2.00	0.10	0.51	0.13	0.03	20629.59	25240.44	0.76	0.19
Season (S)	2.00	0.12	0.25	0.04	0.02	31172.26	16070.11	1.53	1.10
L*S	4.00	0.00	0.01	0.00	0.00	1751.81	548.89	0.10	0.03
Error	16.00	0.01	0.01	0.00	0.00	9398.25	7362.33	0.04	0.03

ANOVA table for surface and underground water parameters at Dharampur

Source of variation	Degree of freedom	Mean sum of square							
		COD		Ca		Mg		NO ₃	
		Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Replication	2.00	1.41	0.22	157.91	413.80	0.96	1.39	29.36	0.59
Treatment	8.00	4.46	1.25	172.87	34.81	0.70	4.29	10.15	1.20
Land Use (L)	2.00	15.15	2.80	617.61	17.12	1.42	4.58	32.98	1.63
Season (S)	2.00	2.54	1.98	60.34	120.62	1.20	11.00	6.68	2.64
L*S	4.00	0.08	0.10	6.76	0.76	0.08	0.79	0.47	0.26
Error	16.00	0.14	0.05	64.27	182.13	0.45	3.41	10.83	0.08

ANOVA table for surface and underground water parameters at Dharampur

Source of variation	Degree of freedom	Mean sum of square							
		Cl		Fe		Mn		Zn	
		Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Replication	2.00	85.32	268.26	5.33	4.93	0.03	0.09	0.99	1.03
Treatment	8.00	123.84	167.89	17.67	20.20	0.34	0.90	0.16	0.36
Land Use (L)	2.00	398.91	404.95	32.11	29.37	0.09	0.79	0.44	0.96
Season (S)	2.00	44.54	230.09	38.11	47.81	0.40	0.73	0.14	0.32
L*S	4.00	25.96	18.26	0.22	1.81	0.44	1.03	0.02	0.07
Error	16.00	161.77	80.79	0.17	5.18	0.46	0.69	0.08	0.08

APPENDIX-II

ANOVA table for surface and underground water parameters at Parwanoo

Source of variation	Degree of freedom	Mean sum of square							
		pH		EC		TDS		BOD	
		Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Replication	2.00	0.02	0.02	0.00	0.03	58888.93	3661.00	0.80	0.00
Treatment	8.00	0.33	0.51	0.08	0.09	50158.15	102216.00	5.16	0.85
Land Use (L)	2.00	0.09	0.28	0.22	0.19	80784.93	164884.00	4.87	0.72
Season (S)	2.00	1.20	1.73	0.08	0.15	102718.37	207376.78	13.12	2.62
L*S	4.00	0.01	0.01	0.01	0.01	8564.65	18301.61	1.33	0.03
Error	16.00	0.12	0.07	0.01	0.05	27630.18	10558.79	0.54	0.05

ANOVA table for surface and underground water parameters at Parwanoo

Source of variation	Degree of freedom	Mean sum of square							
		COD		Ca		Mg		NO ₃	
		Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Replication	2.00	7.86	3.00	95.95	6.13	3.59	2.25	1.01	0.50
Treatment	8.00	28.01	10.19	1497.99	419.01	29.53	68.06	11.75	2.35
Land Use (L)	2.00	88.72	30.50	4894.09	842.97	21.16	50.42	44.68	3.96
Season (S)	2.00	19.95	8.14	497.82	174.06	86.44	202.23	1.06	4.29
L*S	4.00	1.68	1.06	300.03	329.50	5.26	9.80	0.62	0.57
Error	16.00	0.99	0.45	430.93	675.48	5.91	1.51	1.58	0.62

ANOVA table for surface and underground water parameters at Parwanoo

Source of variation	Degree of freedom	Mean sum of square							
		Cl		Fe		Mn		Zn	
		Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Replication	2.00	0.95	3.62	7.26	5.15	0.12	0.01	1.60	1.30
Treatment	8.00	145.44	87.62	21.79	20.40	0.27	0.28	0.35	0.62
Land Use (L)	2.00	354.19	236.32	40.15	27.81	0.83	0.48	0.84	1.84
Season (S)	2.00	205.25	91.47	46.70	49.93	0.04	0.24	0.45	0.56
L*S	4.00	11.15	11.34	0.15	1.93	0.11	0.19	0.05	0.05
Error	16.00	7.54	6.64	0.34	5.69	0.07	0.17	0.11	0.09

APPENDIX-III

ANOVA table for surface and underground water parameters at Barotiwala

Source of variation	Degree of freedom	Mean sum of square							
		pH		EC		TDS		BOD	
		Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Replication	2.00	0.03	0.04	0.06	0.01	64944.15	43289.04	33.85	1.80
Treatment	8.00	0.28	0.58	0.06	0.07	73175.45	70166.48	324.98	56.12
Land Use (L)	2.00	0.18	0.62	0.20	0.20	101436.59	126765.48	393.26	38.91
Season (S)	2.00	0.93	1.63	0.02	0.04	150644.93	114683.59	660.27	168.82
L*S	4.00	0.01	0.03	0.01	0.01	20310.15	19608.43	123.20	8.38
Error	16.00	0.03	0.04	0.02	0.01	5824.61	27395.16	31.98	1.43

ANOVA table for surface and underground water parameters at Barotiwala

Source of variation	Degree of freedom	Mean sum of square							
		COD		Ca		Mg		NO ₃	
		Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Replication	2.00	2795.98	39.30	182.68	112.15	116.66	693.87	1.06	19.75
Treatment	8.00	3665.00	232.13	1522.12	755.12	102.34	92.27	4.94	7.74
Land Use (L)	2.00	11972.47	818.43	2697.36	1651.26	385.41	331.82	6.44	26.65
Season (S)	2.00	1336.10	56.90	3159.24	988.44	16.39	37.14	12.49	2.09
L*S	4.00	675.70	26.59	115.93	190.39	3.79	0.05	0.41	1.11
Error	16.00	806.02	11.74	62.84	46.66	50.69	119.26	0.79	3.26

ANOVA table for surface and underground water parameters at Barotiwala

Source of variation	Degree of freedom	Mean sum of square							
		Cl		Fe		Mn		Zn	
		Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Replication	2.00	50.53	31.87	17.34	4.11	11.82	1.03	2.23	2.03
Treatment	8.00	240.83	212.96	12.22	15.54	27.36	27.58	0.71	1.05
Land Use (L)	2.00	387.39	415.36	26.91	19.61	83.08	48.24	1.88	3.20
Season (S)	2.00	224.27	367.29	13.27	32.75	4.38	24.32	0.87	0.84
L*S	4.00	175.82	34.59	4.35	4.89	10.99	18.88	0.06	0.07
Error	16.00	9.71	25.72	6.34	12.29	7.42	17.32	0.12	0.09

APPENDIX-IV

ANOVA table for surface and underground water parameters at Chandi- Goyla

Source of variation	Degree of freedom	Mean sum of square							
		pH		EC		TDS		BOD	
		Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Replication	2.00	0.01	0.01	0.00	0.00	1801.41	3389.45	0.08	0.02
Treatment	8.00	0.23	0.19	0.02	0.01	4845.93	23052.19	0.63	0.43
Land Use (L)	2.00	0.56	0.46	0.05	0.03	4186.11	69028.57	0.75	0.42
Season (S)	2.00	0.29	0.22	0.04	0.01	13991.76	20240.74	1.70	1.26
L*S	4.00	0.04	0.03	0.00	0.00	602.93	1469.73	0.04	0.02
Error	16.00	0.01	0.02	0.01	0.01	2190.96	9836.69	0.05	0.02

ANOVA table for surface and underground water parameters at Chandi- Goyla

Source of variation	Degree of freedom	Mean sum of square							
		COD		Ca		Mg		NO ₃	
		Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Replication	2.00	0.03	0.64	25.51	49.78	1.01	8.33	0.98	0.97
Treatment	8.00	2.62	3.10	156.40	118.75	3.41	4.72	1.83	0.38
Land Use (L)	2.00	6.12	7.68	479.33	281.21	8.77	11.19	6.51	1.11
Season (S)	2.00	3.87	4.33	137.25	182.69	4.72	7.09	0.76	0.43
L*S	4.00	0.25	0.20	4.51	5.54	0.07	0.30	0.03	0.00
Error	16.00	0.22	0.09	10.20	22.46	0.18	0.50	0.11	0.07

ANOVA table for surface and underground water parameters at Chandi- Goyla

Source of variation	Degree of freedom	Mean sum of square							
		Cl		Fe		Mn		Zn	
		Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Replication	2.00	31.01	7.06	0.03	2.33	0.09	0.13	0.69	0.66
Treatment	8.00	127.21	98.07	3.68	6.08	0.47	1.00	0.08	0.21
Land Use (L)	2.00	381.67	206.53	7.76	14.78	0.24	0.80	0.24	0.52
Season (S)	2.00	70.89	163.74	4.68	5.44	0.69	1.49	0.03	0.21
L*S	4.00	28.14	11.00	1.15	2.06	0.48	0.85	0.01	0.07
Error	16.00	55.75	22.07	2.05	1.79	0.62	0.71	0.07	0.06

APPENDIX-V

ANOVA table for physico- chemical parameters of surface water in Dhrampur block under different land uses

Source of variation	Degree of freedom	Mean sum of square								
		pH	EC	TDS	BOD	COD	Ca	Mg	NO ₃	Cl
Replication	11	0.38	0.01	22614.33	77.93	509.22	686.86	13.80	1.54	62.95
Treatment	2	0.25	0.16	54626.94	46.80	1270.09	2365.95	65.18	3.10	496.34
Error	22	0.01	0.00	3200.59	15.41	291.73	74.08	7.26	0.19	15.61

ANOVA table for physico- chemical parameters of underground water in Dhrampur block under different land uses

Source of variation	Degree of freedom	Mean sum of square								
		pH	EC	TDS	BOD	COD	Ca	Mg	NO ₃	Cl
Replication	11	0.50	0.02	27132.49	19.39	45.96	727.74	56.85	1.47	61.90
Treatment	2	0.60	0.12	113443.54	5.43	121.24	659.45	78.69	24.66	390.74
Error	22	0.01	0.00	3801.32	1.24	16.72	56.56	5.57	1.25	7.32

ANOVA table for physico- chemical parameters of surface water in Dhrampur block during different seasons

Source of variation	Degree of freedom	Mean sum of square								
		pH	EC	TDS	BOD	COD	Ca	Mg	NO ₃	Cl
Replication	11	0.38	0.04	17069.69	61.15	1158.91	686.86	32.46	1.14	122.16
Treatment	2	0.25	0.05	82388.45	82.90	164.63	2365.95	21.73	4.94	136.73
Error	22	0.01	0.00	3449.14	20.51	67.38	74.08	1.88	0.23	18.70

ANOVA table for physico- chemical parameters of underground water of Dhrampur block during different seasons

Source of variation	Degree of freedom	Mean sum of square								
		pH	EC	TDS	BOD	COD	Ca	Mg	NO ₃	Cl
Replication	11	0.38	0.04	28801.52	11.29	93.73	808.12	65.38	7.55	86.83
Treatment	2	1.05	0.05	92872.00	23.12	15.93	374.08	55.20	2.81	244.28
Error	22	0.03	0.00	4836.95	3.68	2.41	42.32	3.45	0.20	8.17

ANOVA table for heavy metals of surface and underground water in Dhrampur block under different land uses

Source of variation	Degree of freedom	Mean sum of square					
		Surface			Underground		
		Fe	Mn	Zn	Fe	Mn	Zn
Replication	11	14.76	7.99	0.19	0.28	20.30	0.28
Treatment	2	33.19	9.70	0.99	0.71	7.16	1.94
Error	22	0.58	2.40	0.02	0.02	2.14	0.04

ANOVA table for heavy metals of surface and underground water of Dhrampur block during different seasons

Source of variation	Degree of freedom	Mean sum of square					
		Surface			Underground		
		Fe	Mn	Zn	Fe	Mn	Zn
Replication	11	15.00	12.75	0.30	17.77	21.73	0.56
Treatment	2	28.87	1.15	0.39	40.15	4.48	0.59
Error	22	0.85	0.79	0.02	1.12	1.67	0.02

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