Assessment of Change in Ground Water and Surface Water Quality in the Nearby Area Due To Solid Waste at Sisdol Sanitary Landfill Site, Nuwakot

A Dissertation
Submitted to Central Department of Environmental Science
for the partial fulfillment of the requirement for the
Master's Degree in Environmental Science

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LETTER OF RECOMMENDATION

This is to certify that works incorporated in this dissertation “**Assessment of Change In Ground Water and Surface Water Quality In The Nearby Area Due To Solid Waste At Sisdol Sanitary Landfill Site, Nuwakot”** submitted by Mr. Ujjwal Thapa Shrestha was under my supervision and guidance. He has worked with sincere interest during field work and laboratory work. This research work bears the candidate’s own work.

Therefore, I recommend this research work for approval and acceptance.

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Declaration by Student

I, Ujjwal T. Shrestha, hereby declare that the work presented herein is genuine work done originally by me and has not been published or submitted elsewhere for the requirement of a degree program. Any literature data works done by others and cited within this dissertation has been given due acknowledgement and listed in the reference section.

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LETTER OF APPROVAL

The dissertation entitled "**Assessment of Change In Ground Water and Surface Water Quality In The Nearby Area Due To Solid Waste At Sisdol Sanitary Landfill Site, Nuwakot"** submitted by Mr. Ujjwal Thapa Shrestha under the supervision of Prof. Jaya Krishna Shrestha, Central Department of Chemistry has been accepted as partial fulfillment of the requirement for the completion of Master's degree in Environmental Science.

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ABSTRACT

The Sisdol sanitary landfill site is situated at ward no. 4 of Okharpauwa VDC in Nuwakot district and is bordered by Kolpu Khola to the south from Dhading district and to the south east from Kathmandu district. It is about 18 km NW from Kathmandu City center. The present study has been carried out to determine the impact of the leachate contamination on the ground water and surface water nearby landfill Site from December, 2007 to August, 2008. Altogether nine stations were taken viz. six sites for surface water, 2 sites for groundwater and one for leachate.

It was found that leachate was severely polluted with most of the physicochemical parameters being higher than the Generic standard (2003) for industrial effluent discharged into inland surface water. Most of the parameters of surface water of Kolpu Khola showed sudden increase in values at station 2 i.e. point of discharge of leachate compared to station 1 (upstream) probably due to mixing of pollutants present in the leachate. Compared to other seasons, the water pollution was less in monsoon season probably as the pollutants were diluted in the season. The BOD and COD of stations 2 to 5 in all the four months including station 1 in February and August had value above WHO guideline (1993). However the ammoniacal nitrogen content, electrical conductivity and calcium at all sites of Kolpu Khola were within Nepal Drinking Water Quality Guidelines (2062). Similarly the surface waters of all the stations are within WHO guideline (1993) and NDWQG (2062) from pH, TDS, hardness, chloride and nitrate-nitrogen point of view.

Except site S_2 the surface water of all other five sites are safe for aquatic life from point of view of dissolved oxygen. However the surface water of only station S_1 and S_6 are suitable for fishes and other aquatic animals from the point of view of free CO_2, iron content and total chromium. Surface water of Kolpu Khola under study is excellent for irrigation from conductivity point of view and is generally safe for all plants when used for irrigation from the chloride and TDS point of view. However the surface water is not safe for agricultural uses from microbiological point of view. The river water is safe for livestock drinking from point of view of TDS, pH, alkalinity, nitrate- nitrogen and chloride.

The groundwater from GW-2 (bore hole-2) has been contaminated and was found to be more polluted compared to groundwater from private well (GW-1) from December (winter season) till March (pre-monsoon). The ground water quality of both GW-1 and GW-2 exceeded the WHO guideline (1993) with respect to alkalinity and ammoniacal nitrogen content whereas both ground water were below the WHO limit with respect to pH, hardness, nitrate-nitrogen and TDS. All the surface water, ground water and leachate were found to contain faecal coliform indicating the faecal contamination of leachate and consequently surface water and groundwater.

From the socioeconomic survey in three VDCs namely Okharpauwa, Chhatredeurali and Chauthe, around the periphery of Kolpu Khola households were found to be predominantly farmers. Households that use the river water were found to use it only for irrigation purpose. Most of the respondents know what leachate is. However majority of them don’t have any idea about suitable method for disposal of leachate and what may or should be done after closure of the landfill. Most of the respondents believe that the surface water quality of Kolpu Khola has changed or degraded extremely after operation of landfill at Sisdol. Households affected on agriculture were found to be the maximum in Chhatredeurali VDC and those affected on health were found to be the maximum in Okharpauwa VDC.

Keywords: Ground water, leachate, microbiological, physicochemical, Sisdol Sanitary landfill, solid waste

ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
APHA	American Public Health Association
ASCE	American Society of Civil Engineers
AWWA	American Water Works Association
BOD	Biochemical Oxygen Demand
BKM	Bhaktapur Municipality
CBO	Community Based Organization
CBS	Central Bureau of Statistics
CCME	Canadian Council Ministries of Environment
CEQG	Canadian Environmental Quality Guidelines
CKV	Clean Kathmandu Valley
Cl	Chloride
CO_2	Carbondioxide
CO_3^{--}	Carbonate
Cr	Chromium
CSU	Colorado State University
DO	Dissolved Oxygen
dS/m	deciSiemens per meter
EC	Electrical conductivity
EIA	Environmental Impact Assessment
ENPHO	Environment and Public Health Organization
FCEB	Fukuoka City Environmental Bureau
FDD	Fisheries Development Division
Fe	Iron
GLFS	Gokarna Landfill Site
Ha	Hectare
HMG	His Majesty’s Government
ICIMOD	International Centre for Integrated Mountain Development
IUCN	The World Conservation Union
JICA	Japan International Cooperation Agency
K	Potassium
KMC	Kathmandu Metropolitan City
KRM	Kirtipur Municipality
LSMC	Lalitpur Sub-metropolitan City
MCL	Maximum Contaminant Level
µg/L	Microgram/Liter

µS/cm	MicroSiemen/Centimeter
MOLD	Ministry of Local Development
mg/L	Milligrams/Liter
MOEST	Ministry of Environment, Science and Technology
MOPE	Ministry of Population and Environment
MPN	Most Probable Number
MTM	Madhyapur Thimi Municipality
NDWQG	Nepal drinking water quality guideline
NDWQS	Nepal drinking water quality standard
NESS	Nepal Environmental and Scientific Services
NH_3	Ammonia
NH_4-N	Ammoniacal nitrogen
NO_3^-	Nitrate
NO_3-N	Nitrate-Nitrogen
NPC	National Planning Commission
NTU	Nephelometric Turbidity Unit
OECD	Organisation for Economic Co-operation and Development
OH^-	Hydroxide
P	Phosphorus
PGR	Population Growth Rate
PO_4^{---}	Ortho-phosphate
SLFS	Sisdol Landfill Site
SPSS	Statistical Package for Social Science
SWMRMC	Solid Waste Management and Resource Mobilization Centre
TA	Total alkalinity
TDS	Total Dissolved Solid
TSS	Total Suspended Solid
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
USDA	United States Department of Agriculture
US EPA	United States Environmental Protection Agency.
VDC	Village Development Committee
WEDC	Water, Engineering and Development Centre
WEF	Water Environment Federation
WHO	World Health Organization
WVIN	World Vision International- Nepal

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CHAPTER I

1. INTRODUCTION

1.1 General Introduction

Water is integral part of the environment and is of vital importance to all socioeconomic sectors. Human and economic development is not possible without a safe, reliable water supply (Gustard et al., 2002). Water quality refers to the set of concentrations, speciation and physical partitions of inorganic and organic substances including the composition and state of aquatic biota in the water body. However, water quality assessment is defined as the overall process of evaluation of the physical, chemical and biological nature of water in relation to natural quality, human effects and intended uses, particularly uses which may affect human health and the health of aquatic system itself (UNESCO, 1996).

Though water is present in ample quantity on the Earth's surface, the supply of freshwater in the globe is limited and governed by the renewal processes associated with the global hydrological cycle. The mountains and the uplands of the world play an extremely important and distinctive role in the hydrological processes of the planet and in the regional hydrology of all continents' (Bandyopadhyay, 1995). By their interaction with the global atmospheric circulation, the mountains can extract substantial water in the form of snow and rain. In turn this precipitated water flows out as rivers, both seasonal and perennial, forming the most accessible freshwater supply to large areas in the plains below. This supply has been traditionally used by human societies in sustaining themselves as well as to irrigate the farms to ensure food security. With the expansion of human settlements and the growth of industrial activities, water proved to be the most convenient medium for the assimilation and discharge of wastes. This resource had been taken for granted and only in the past few decades increasing scarcity of this vital resource and drastic decline in the quality of water from pollution has drawn attention of environmental groups as well as policy makers. This led to concerns about where the water will be available from to meet the requirements of the next century (Bandyopadhyay, 1995).

Due to their biophysical conditions, mountain areas are characterized by high degree of fragility, marginality, limited accessibility, specific niche resources/products, diversity and specific human adaptation mechanisms. Due to their fragility (caused by slope, altitude, sensitivity to seismic activities etc.), the vulnerability of the Hindu Kush Himalayan (HK-H) mountains is easily amplified by natural forces such as mass wasting, flash floods, glacier melting, earthquakes etc (Jodha, 2005). Literature on mountains is extensive and voluminous. Yet, there is no rigorous definition of universal acceptance of what constitutes a mountain. Most discussions on mountains and their development merge the concept of Montaigne (Old French, meaning a considerable height) with the concept of the old English term hill (small mound), and these are not the same. Despite this specialness, it has never been acknowledged that the mountains enrich the lowlands with their wealth. In particular, the vast fresh-water systems of the earth flow out of the mountains and into the seas (Gurung, 1999). Mountains and highlands are often referred to as natural "water towers" since they provide the adjacent lowlands with essential freshwater for irrigation and food production, for industrial use and for rapidly growing urban populations.

The particular hydrological characteristics of mountain areas are manifested by disproportionately large discharge, typically about twice the amount that could be expected from the areal proportion of the mountainous section. Mountains account for 20–50% of total discharge in humid areas, while in semi-arid and arid areas, the contribution of mountains to total discharge are 50–90% with extremes of over 95%. Moreover, discharge from mountainous areas is highly reliable and causes a significant reduction of the coefficient of variation of total discharge (Viviroli et al, date not mentioned).

'Water pollution is any physical, chemical or biological change in water quality that has a harmful effect on living organism or makes water unsuitable for desired uses' (Miller, 2002). In Asia and the Pacific region, water supply is a serious problem. Already at least one in three Asians has no access to safe drinking water and freshwater will be the major limiting factor to producing more food in the future (UNEP, 1999). The sources of water pollution can be broadly categorized into two types: point source and non point source. Improper disposal of solid waste is one of the causes of water pollution.

Solid waste may be defined as all the discarded solid materials from municipal, agricultural, domestic and industrial activities that can neither be transported by water in to streams nor readily escape in to the atmosphere (Karki, 2004). Solid waste is useless and sometimes hazardous material with low liquid content. Solid wastes include municipal garbage, industrial and commercial waste, sewage sludge, wastes resulting from agricultural and animal husbandry operations and other connected activities, demolition wastes and mining residues (OECD, 2007). Solid waste is of two types: biodegradable and non-biodegradable.

Solid waste is an inevitable byproduct of human activities. At all levels of socioeconomic development, human beings produce solid waste. The production of solid waste is closely linked with the behaviour and attitudes. Since the beginning of civilization people have been producing waste and have been looking for safe disposal of waste produced by them. In the past, this was not a major problem as the waste generation rate at that time used to be very low and most of the wastes generated were bio degradable waste. The people had their traditional method of managing the waste in a proper and safe manner. However, the introduction of new materials and changing consumption patterns especially in urban areas have resulted in increasing volumes of waste and as a result, the breakdown of traditional systems of waste management has taken place. In Nepal as in many other developing countries, these changes have taken place rapidly over the past few decades, while the government and the people have failed to realize their serious implications and the urgent need to address them. As a result, many cities in Nepal are now suffering from the adverse impacts of unmanaged wastes.

Due to urbanization the economic and consumption pattern of the people have been changed. The rapid urbanization and migration trend from rural to urban areas also have rapidly been increased. Consequently, the piles of waste has been increased and posed environmental problems. Owing to rapid industrialization coupled with urbanization, the management of solid waste has become increasingly difficult throughout the world. Solid waste management has emerged as a major issue in the urban area of Kathmandu valley. The negative effects of unmanaged solid waste are seen increasingly nowadays. These negative environmental implications of inefficient solid waste management have resulted into the decline of quality of life of the evergrowing population and have resulted in decline in quality of environment (SWMRMC, 2004).

1.2 Methods of Solid Waste Management

The commonly adopted approaches throughout the globe for the disposal of solid waste include open dumping, sanitary landfilling, incineration, deep-well disposal and composting. Among these, sanitary landfill is the most common and is being widely used in developing countries. Since a filled landfill can be reclaimed and used for recreational purposes like parks, golf courses, athletic fields, wildlife areas, its significance is increased.

a. Open dumping

Open dumping is the most widespread form of waste disposal throughout the world. About three-quarters of the countries and territories around the world use this method of disposal. It thrives because of the mistaken belief that it is the easiest and cheapest disposal method to use in those countries with economies in difficulties or where there is insufficient political will to allocate adequate public resources to improve the prevailing disposal practices.

b. Controlled dumping

A controlled dump is usually what can evolve quickly from an open dumpsite when it is rehabilitated. The main features of a controlled dumpsite are: to reduce the working area of the site to a smaller and more manageable size; slope and cover with soil exposed waste on unneeded parts of the site; prevent new fires from being started; construct simple measures to intercept surface water; and establish some rules of on-site work with site workers, drivers and scavengers.

c. Engineered landfill

An engineered landfill is characterized as a disposal site where, through planning before construction or through modifications at an exiting site, there is a gradual and obvious adoption of engineering techniques to control and manage solid wastes.

d. Sanitary landfill

Sanitary landfill is an engineered facility for the disposal of municipal solid waste designed and operated to minimize public health and environmental impacts. The development of sanitary landfills, as recognized in high-income cities, involves the continuing refinement and increasing complexity in engineering design and construction techniques started in the engineered landfill stage. This can also involve a radical change in the operational practices at the site if the sanitary landfill is to be operated according to the flushing bioreactor or semi-aerobic concepts. Sanitary landfills typically have many additional features to those found on engineered landfills.

1.3 Scenario of solid waste generation in Nepal

Although there are different sources for the generation of solid waste, such as industrial, commercial etc, households are the main sources of solid waste in Nepal. The per capita waste generation of household waste is estimated to be 0.48 kg per day in 2001 (MOPE, 2001). In 1999, about 3 million urban residents of Nepal’s 58 municipalities generated a total of 426,486 tones of waste, of which the city of Kathmandu alone contributed 29%. Of the total waste generation in the country, solid waste made up about 83%, agricultural waste 11% and industrial waste 6% of the total (UNEP, 2001).

The dramatic change in the land use pattern of the urban centers has significantly altered the composition of waste. Thus along with organic wastes other types of wastes are also rapidly increasing their share. The composition of the urban wastes has changed remarkably, previously solid wastes consisted mainly of organic materials and it now also includes plastics, paper and glass. The percentage of plastics in urban wastes is increasing; however, two-thirds of the waste remains organic (ADB, 2004).

Solid waste is the most prominent environmental issue in the urban areas of Nepal that requires immediate attention. Although waste generation is a common phenomenon, its safe disposal has become a major problem in urban and industrial areas due to lack of sanitary landfill sites. Migration of huge number of people in urban areas results to very high population densities and parallel use of non-biodegradable materials that result in the generation of enormous wastes. The volume and composition of waste is steadily rising, however, very little space can be allocated for its disposal.

Solid waste generation rates vary depending upon living standards, livelihood practices, and consumption patterns. Studies carried out in the past suggest that the waste generation rate has changed over the years in Kathmandu's urban areas (Table 1.1). The current estimated generation rates of municipal solid waste in five municipalities of the Kathmandu Valley are given in Table 1.2.

Table 1.1: Recent Estimates of waste generation rates in five municipalities (kg/person/day)

Municipality	IDI Pvt. Ltd. 2004 (2003 survey)		Nippon Koei 2005 (2004 survey)	
	Household rate	Municipal rate	Household rate	Municipal rate
Kathmandu	0.39	0.52	0.250	0.416
Lalitpur	0.54	0.72	0.285	0.416
Bhaktapur	0.39	0.52	0.120	0.316
Madhyapur thimi	0.11	0.15	0.160	0.266
Kirtipur	0.34	0.45	0.150	0.266

Source: ICIMOD, MOPE & UNEP, 2007

Table 1.2: Waste generation in five municipalities (tons/day)

Municipality	Generation in 2004	Collection in 2004	Projected generation 2015
Kathmandu	308.4	250	547.9
Lalitpur	75.1	52	135.4
Bhaktapur	25.5	19	46.2
Madhyapur thimi	14.3	5	27.8
Kirtipur	11.6	4	18.1
Total	434.9	330	775.4

Source: Annonymous (2005)

The unit generation rate of solid waste is estimated at 0.416 kg/day-capita in KMC and Lalitpur Sub-metropolitan City (LSMC), 0.316 in Bhaktapur Municipality (BKM) and 0.266 in Madhyapur Thimi Municipality (MTM) and Kirtipur Municipality (KRM). The total generation quantity of waste in the five municipalities is estimated to be 435 ton/day. Composition of household waste shows a similarity among the five municipalities, which has a very high portion, 65 to 75 %, of organic waste, while recently increasing the proportion of plastic waste up to more than 10 % of the total (Annonymous (2005)).

The total population of Kathmandu valley is about 1.7 million and the current growth rate of Nepal is 4.6% per decade (CBS, 2003). The extremely high population growth within Kathmandu valley over the last 30 year has created problems with the quantity and quality of water supplies due to high demand and inadequate waste disposal systems. Although urbanization itself is not necessarily a problem as it promotes economic activities and alleviates pressure on land resources, but haphazard and unplanned urban growth generate many environmental problems such as public space and river bank encroachment, air and water pollution and solid waste generation. A survey of 3890 urban residents all over Nepal was carried out in 1997 regarding public opinion on environmental problems in urban areas. It indicated that 59 % of the urban residents considered solid waste to be the major problem followed by 25% sewage (UNEP, 2001) as shown in fig. 1.1.

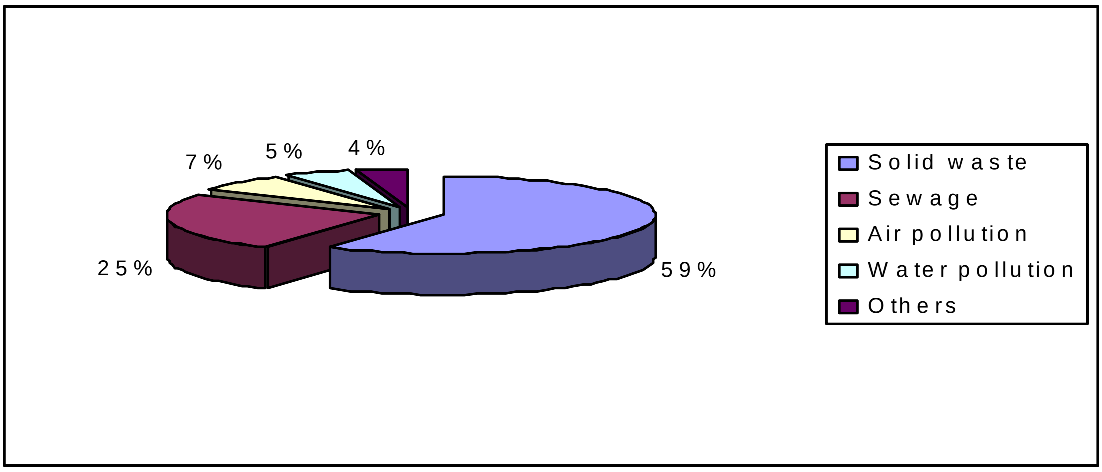

Figure 1.1: Public opinion on environmental problems in urban areas

Source: UNEP, 2001

1.4 Solid waste management in Nepal

Waste management was not a major issue in the past primarily because not much was produced in the first place and whatever was produced was recycled. According to a study done about 40 years ago, human waste generated by Kathmandu residents at that time were sold for NRs. 0.50 per tin. Furthermore, several houses used to share a ‘sagaa’ to manage their waste (‘Sa’ means compost and ‘gaa’ means pit in the Newari language). We can draw three conclusions from this: (a) waste had a value, (b) waste recycling was a standard practice, and (c) people felt it was their responsibility to took care of their waste themselves. These basic principles of waste management are relevant even today and Kathmandu's waste management system needs to be built upon these foundations. Waste should be seen as a resource that needs to be recycled to the extent possible, not dumped (Tuladhar, 2003).

The initial concept of SWM was focused on just removal of waste from the cities to keep them clean and hygienic. This traditional concept has been changed. The recent concept of SWM focuses on protection of public health and environment through sanitary and economic disposal of solid waste.

Solid waste management was virtually non-existence in the country before 1979. Only after the establishment of Solid Waste Management Board in 1979, the importance of solid waste management was realized. Subsequently Solid Waste Management and Resource Mobilization Centre were established in 1986. After that the collection and disposal of the solid waste started in some systematic way in Kathmandu valley (MOPE, 2001).

The urban population makes up about 15% of the country’s total population. However, the rapid growth of the urban population with over a 5% per annum increase in Nepal has exerted tremendous pressure on the urban environment. One consequence of this is an increasing amount of garbage, which is often seen littering city streets or dumped on riverbanks and in other public places (UNEP, 2001). Only 18 percent of the urban population is served by the municipal solid waste management service. Less than one-fifth of the urban population has access to regular garbage collection (ADB, 2004).

The disposal of solid wastes in a nearby river and open field is a general practice that is adopted in Kathmandu valley for a long time (MOPE, 2001). In KMC, LSMC and BKM, a curb-side and on-ground collection system has been widely introduced. Bell and door-to-door collection systems have also been introduced, sometimes involving private sector operators or NGOs/CBOs. Almost all waste is collected with all components mixed together, while source separated collection system is quite rarely practiced for special use like community composting. More than 70 % of waste is collected in KMC, LSMC and BKM, while the other two municipalities still collect only about 40 % (Annonymous, 2005).

Because of the relatively high composition of organic waste materials in the waste, a variety of composting activities at household and community levels as well as municipal level has been tried in the Kathmandu Valley. For example, BKM has more than 20 years experience of composting around 6 ton/day, whereas vermin-composting has been introduced at household level and home composting activities have become more popular among the people in cooperation with NGOs/CBOs (Annonymous, 2005).

The various kinds of recyclable materials are collected, such as paper, plastic and iron. A total of about 116 tones of the recyclable materials are daily exported from the Valley, excluding bottles, feathers and waste oil from automobiles. In the case of KMC, it is said that about 30 to 35 groups of waste pickers have been identified, who were operating mainly at Teku Transfer Station (TTS) and the Bagmati River dumping site with a total of more than one hundred persons (Annonymous, 2005).

Unfortunately no municipality has been able to prepare an appropriate engineered landfill site in the Kathmandu Valley since Gokarna Landfill site was stopped from accepting the waste. KMC, LSMC and KRM have started to dispose their waste along the bank of the Bagmati River since 2000. BKM is presently dumping the waste at some sites along the Hanumante River and MTM is disposing the waste on the back yards of core areas (Annonymous, 2005).

Within five municipalities of the Kathmandu Valley, it has been noted that a significant number of private organizations are involved in SWM practices, especially in primary collection of solid waste. These organizations consist of a mixed bag of private enterprises, NGOs and CBOs. As of June 2005, aside from the most recent Public Private Partnership (PPP) initiative in MTM, most private organizations are working on their own or under some kind of verbal understanding with the municipalities.

If we really want to get rid of solid waste management problem, the first thing is that the consumers need to internalize managing waste as their responsibility too and change their behavior and attitude towards solid waste and should also change the consumption pattern. They should focus on minimizing the quantity and quality of waste. Also segregating waste plays a crucial role in solving the problem in sustainable way. So waste segregating practice needs to be adopted at the household level too and the municipalities should also segregate it at transfer stations and dispose the hazardous and non- hazardous wastes separately.

1.5 Solid waste management in Kathmandu Metropolitan City

Administratively, Nepal is divided into 5 developmental regions, 14 zones, 75 districts, 58 municipalities and 3,912 Village Development Committees (VDCs) with Kathmandu as its capital. Among the 58 municipalities, Kathmandu Municipality is the largest of all and hence is called as Kathmandu Metropolitan City (KMC). KMC lies within Kathmandu valley. With the total population of 0.67 million, Kathmandu metropolis accounts for nearly one-fifth of the total solid waste generated in the cities of Kathmandu valley. In many wards of the city, there is no provision for waste container disposal service. In core urban areas, people dump wastes on roads and alleys (Thapa et al., 1999).

KMC primarily consists of 12 departments, including Environment Department, which is the largest of all. This department is divided into three sections: Solid Waste Management section, Mechanical section and Urban Environment section. Overall Environment department is responsible for managing the solid waste produced in Kathmandu.

1.5.1 Waste Generation and Waste Characteristics

Solid waste generation by urban households in Kathmandu valley in 2001 was estimated to be 900 metric ton per day. Kathmandu Metropolitan City alone produces 310 tons of garbage every day. In Kathmandu valley, single family produce, on an average, 0.8 kg of waste per day, however, 26 % of families generate only about 0.5 kg of waste. Seventy-five percent of solid waste generated is disposed off. Scavengers reduce about five percent of the solid waste that is reusable or recyclable such as metal scraps, papers, bottles, plastics etc. Domestic waste occupies 75 % of total waste generated. The production of waste in the Kathmandu valley has dramatically increased over the last 30 years. The increase is mainly attributed to rapid population growth, economic and industrial activities, and increased consumption of packaged foods and other items. The lowest income families tend to have lowest rate of waste generation ranging between 0.4 to 0.7 kg per household while economically well off families tend to produce higher amount of waste with about 2.0 kg of waste per day. The trend suggests that the greater the economic prosperity, the higher the amount of solid waste produced. The trend in waste composition has also changed during last 30 years. One study suggests that the percentage of organic material in the total solid waste of Kathmandu valley has decreased to 52.2 % in 1995 from 67.6 % in 1976. On the other hand, plastic has increased from 3 % to 5.4 % and glass from 1.3 % to 3.6 % from 1976 to 1995 (WVIN, 2002).

1.5.2 Collection of waste in Kathmandu

Most of the people dispose their domestic waste either in the streets or in the public waste containers. The municipal sweepers clean the streets and collect the waste, usually by handcarts, before it is loaded on the either tractors or trucks. In the street plastics, paper and metals are collected and when the waste reach the transfer station and the dumping sites scavengers sort out another percentage of the paper, plastic and metals. Only 306 ton waste is collected by the metropolitan daily and rest remains uncollected or disposed haphazardly near river banks or in public places (Pradhanang, date not mentioned).

1.4.3 Methods of disposal adopted in Kathmandu valley

1.5.3.1 Composting

In 1986 GTZ Solid Waste Management Project introduced a semi mechanized screening plant with windrows at Teku Transfer Station. The plant produced maximum one tones compost per day but was difficult to manage manually. The plant was maintained until 1991 when local people at Teku started to oppose the compost plant and the screening machine did not work properly.

Since the fraction of organic waste produced in Kathmandu is high, there have been plans to start a new compost plant. In addition, in Kathmandu, in different areas, Non Governmental Organization (NGO)s and Community Based Organization (CBO)s have promoted compost for households. Recycling of organic waste needs to be a top priority in managing Kathmandu's waste and the best option for this is Composting.

The total waste of Kathmandu and Lalitpur cities can be recycled by setting up a 300 ton/day organic fertilizer plant for which an India-Nepal joint venture project is already selected. By doing this, the waste disposal problem is reduced by 80% with minimal environmental impacts, and high quality fertilizer can be generated (Tuladhar, 2003).

1.5.3.2 Incineration

Incineration of waste is carried out in limited extent in Kathmandu Valley. Small incineration plants, with a capacity of 400 kg/day, have been tried out on medical waste. Public opposition for incineration of medical waste is increasing as risks of dioxin and other harmful emissions are great.

For waste minimization there is potential for composting, recycling and reuse in the future; however, controlled incineration seems unsuitable for Nepal. In addition, it demands expensive technology that is difficult to maintain in developing countries like Nepal.

1.5.3.3 Recycling and Scavenging

In Kathmandu, there is no material recovery or recycling industries though some demolition waste is sorted out and reused in the private sector. A greater part of materials is sorted out in the households, on the streets, in the industry and commercial contexts. Plastic, paper, glass and metals are sorted out by scavengers and are sold to private companies that sell it, mostly to India, where it is used to make new second grade materials.

Since there is no provision of separation, collection, handling or disposal of hazardous waste, all kinds of waste mix up and sorted out by the scavengers. Due to poor economical condition and awareness the scavengers are exposed to hazardous materials without any protection (Khanal, 2005).

1.5.3.4 Sanitary landfilling

Gokarna Landfill Site (GLFS) is the first sanitary landfill in Nepal with the whole history of the GTZ Solid Waste Management Project. GLFS was selected as the most suitable site after a comparative assessment of 12 possible landfill site (LFS)s in 1976. In Nov 9, 1986, GLFS was opened for final disposal of solid waste at Gokarna, northern part of Kathmandu city. Before construction of GLFS no proper waste management was available; the waste was simply dumped around the flood plains of Bagmati River and Bishnumati River. The site was finally closed down in January 1994 due to strong opposition from the people. Following that Shova Bhagavati along the Bishnumati River was chosen as a temporary dumping site for one and a half years, which ended in 1995 (Devkota et al, 2004b). But this was more hazardous than the wastes dumping in Gokarna as this would pollute the groundwater source of the valley. Meanwhile Government of Nepal explored number of locations for possible landfill sites in the vicinity of Kathmandu Valley. An extensive study carried out by Government of Nepal identified Banchare Danda at Okharpauwa VDC in Nuwakot as one of the possible site for the long term landfill site for the Kathmandu Valley. After then the dumping was started in Sisdol Landfill Site since June 5, 2005. The Sisdol landfill site (SLFS) has been selected for short-term operation with an objective to develop the Okharpauwa site for long-term operation. It has been in operation for the disposal of solid wastes of KMC and LSMC. Phase I of the SLFS has the capacity for 18 months. Phase II of SLFS will have capacity of another 18 months period (SWMRMC, 2007). The Sisdol Landfill Site had its capacity of sustaining about 275,000 cubic metre of garbage. KMC collects annually about 112,000 cubic metres of garbage generated from the valley. The SLFS is nearly full and currently temporary landfill site is under construction at Aletar.

Aletar Landfill Site, being constructed at Aletar-4 in Okharpauwa of Nuwakot for a short-term garbage dumping site, is likely to come into operation by mid-March this year. The site is 500 metres away from Sisdol Landfill Site. More than 75 per cent of works have been completed. Only the works related to drainage system are to be finished. Aletar site is being established within total space of 5,000 square metre and could accommodate garbage that generated from the Valley for maximum of 16 months. The Aletar landfill site has been seen as a viable option since the construction of permanent Bancharedanda might take another six to seven year (Annonymous, 2009)

The future landfill site at Okharpauwa is 28 km from Teku Transfer Station and the cost for operating the landfill will be more than four times higher than locating the lanfill at Chovar. As a result KMC rather prefers to have a compost plant and landfill at Chovar limestone quarry, located 6 km south of Kathmandu, which is now closed (Sturdy et al as cited in Tuladhar, 2003).

The overall waste management system operating in Kathmandu Metropolitan city consists of three levels namely: primary, secondary and tertiary. All these three levels are collectively working for the entire management of waste supported by the locals and active private sector participation. The three levels are briefly described below:

Primary level of Management

Primary level of management mainly incorporates activities such as door-to-door collection and transportation of solid waste from households to recycling centres or material recovery facility (MRF) or transfer station (TS). At present the wastes of Kathmandu, Lalitpur and Kirtipur municipalities are brought to Teku Transfer Station (TTS) prior to land filling. Waste brought at TTS are sorted out manually by scavengers and finally transferred to the landfill site. The way wastes are handled in primary level determines the effectiveness of secondary and tertiary level of management.

Secondary level of Management

Municipal authorities have role for the execution of secondary level management. The municipal authorities are responsible for the transportation of the collected solid wastes from transfer station, material recovery facility in transport vehicles to the landfill site. The wastes are retained in TTS for specific time.

Tertiary level of Management

The whole management for the final disposal as landfilling, incineration is carried out at this level. At present the dumping activities for the municipal waste of Kathmandu is carried out at Sisdol Sanitary landfill site (SLFs) from 2005. Although, the wastes are covered by soil layer after its disposal, there is no control system for leachate which directly terminates into the river water.

The problem of waste management in Kathmandu is technically not very complex, but the government needs to listen to technical logic and ensure that simple solutions do not go to waste (Tuladhar, 2003).

1.6 Types and structure of landfill

Landfill sites are classified into 5 types according to structure (Annonymous, 2009).

i. **Anaerobic landfill:** Solid wastes are filled; in dug area of plane field or valley. Wastes are filled with water and in anaerobic condition.

ii. **Anaerobic sanitary landfill:** Anaerobic landfill with cover like sandwich shape. Condition in solid waste is same as anaerobic landfill.

iii. **Improved anaerobic sanitary landfill** (Improved sanitary landfill): This has leachate collection system in the bottom of the landfill site. Others are same as anaerobic sanitary landfill. The conditions are still anaerobic and moisture content is much less than anaerobic sanitary landfill.

iv. **Semi-aerobic landfill:** Leachate collection duct is bigger than that of improved anaerobic sanitary landfill. The opening of the duct is surrounded by air and the duct is covered with small crushed stones. Moisture content in solid waste is small. Oxygen is supplied to solid waste from leachate collection duct.

v. **Aerobic landfill:** In addition to the leachate collection pipe, air supply pipes are attached and air is enforced to enter the solid waste of which condition becomes more aerobic than semi-aerobic landfill.

Structure of semi-aerobic landfill

As shown in Fig.1.2, the semi-aerobic landfill allows inflow of air through leachate collection pipes laid on the bottom of the landfill, which helps to enlarge aerobic parts, and to make aerobic bacteria active, and fastens the waste decomposition. Then these actions make the leachate quality better by lowering level of leachate concentration, and reduce generation of hazardous gases, all of which lead to faster stabilization of the landfill site. See Fig.1.3.

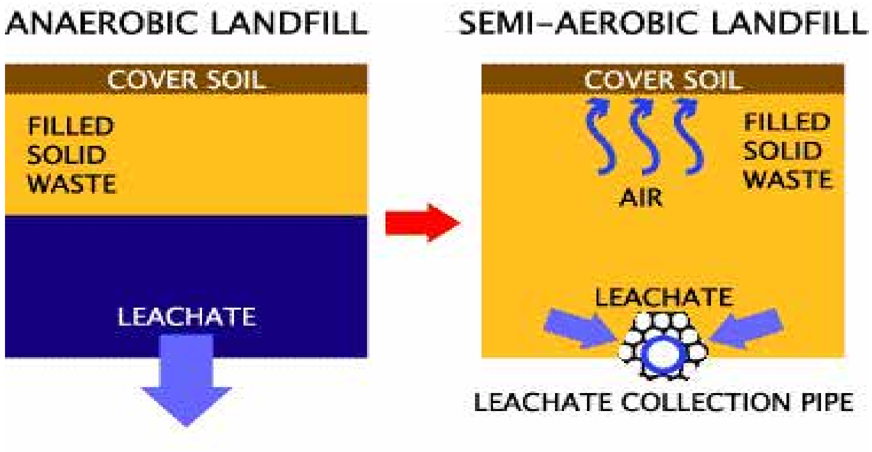

Figure 1.2: Landfill Type and Leachate Collection System

Source: Annonymous, 2009

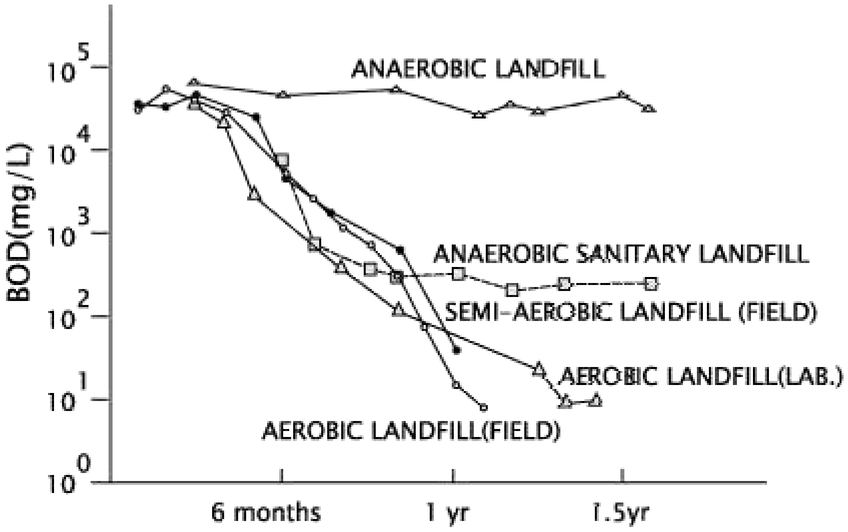

Figure 1.3: Change in the BOD concentration of Leachate by Landfill Type

Source: Annonymous, 2009

Anaerobic decomposition of organic matter produces methane and water, and the decomposition is slow and leachate content is large. On the other hand, under aerobic decomposition, organic matter decomposes into carbon dioxide and water and the decomposition is rapid. Aerobic decomposition requires a supply of oxygen to be pumped into the landfill, but this is costly system both in terms of construction and maintenance.

At the sanitary landfill, decomposition of the organic matters increases the temperature in the waste layers. Under semi-aerobic sanitary landfill system, as the main leachate collection pipes discharges the collected leachate into the leachate pond and air is sucked into the landfill through the gas removal pipes and the leachate collection pipes- consequently creating a semi-aerobic system. In a semi-aerobic system, specifically the following process is observed (SWMRMC, 2007).

- Parts of the landfill in the vicinity of the pipes are under aerobic conditions.
- The differential temperature in the landfill will create natural ventilation and the supply of air to the landfill.
- The leachate quality will improve within a quick time.

Leakage and Contamination problems in landfill Sites

Among common problems, following are the major problems that lead to groundwater and soil contamination in landfill sites in general (Panthee, 2008):

1. Compaction of drainage carpet materials at high load which may cause clogging and airing problem
2. Puncture of geo-membrane and clay lining
3. Chemical reaction between leachate and drainage material and /or clay liner

1.7 Sisdol Landfill Site

Sisdol landfill site

Sisdol Landfill site lies at about 20 km northwest from Kathmandu and is semi-aerobic landfill. In the semi-aerobic landfill, leachate is collected in a leachate collection pond through properly sized perforated pipes (main leachate pipes and branch leachate pipes) embedded in graded gravels/ boulders as filter material. As the outlet of the main leachate collection pipe is always open to air, fresh air is drawn into the layers thereby introducing an aerobic condition around the pipes. Since leachate is removed as quickly as it is formed, the internal layers have lower water content. The differential temperature in the landfill creates natural ventilation and the supply of air to the landfill. The landfill system in Sisdol landfill is an appropriate adoption of the so-called "Fukuoka Method" of semi-aerobic type. In this method the leachate collected in the pond is regularly aerated through proper aerator system, which can be regarded as biological aerobic treatment. The aerated leachate is further recirculated by means of a pump to spray the leachate over landfill cells for a simple anaerobic biological treatment. The integration of these two processes results in significant improvement in the leachate quality. This system has been successfully applied in the Asian countries like Iran and Malaysia and has been proved to be scientific, but simple and cost-effective as compared to fully aerobic type or anaerobic type with advanced technologies (JICA, 2004).

Sisdol landfill site has been planned to be operated in two phases. The first phase operation is going on. The landfill site consists of two basins, of which the first basin has 11200 square metre area, and having capacity of 166085 cubic metres. The second basin has 9501 square metre area and capacity of 108910 cubic metres (CKV 2002, as cited in Panthee, 2008). The landfill site has capacity only for two years.

Facilities in the Sisdol landfill

The landfill site is semi-aerobic type that was designed according to the design developed by Fukuoka City Environmental Bureau (FCEB), Japan. The Fukuoka method is categorized into 4 types on the basis of facilities used in the site. The Sisdol landfill site is the type-3 landfill site. The first basin (phase I) of the landfill site was constructed in the lower portion (Fig. 5). The length of the site is 120 m with gradient 4% laterally and 3% longitudinally (CKV and JICA, 2002). At the base, two clay liners are present and are overlain by gravel. A sandwich method has been operated to fill the solid waste material. Leachate-perforated collection pipes and ventilation pipes, which were constructed on the material, drain leachate and ventilate. The lower part contains leachate collection pond. Three groundwater monitoring wells were installed. The leachate which was collected in the collecting pond was acidic and that varied according to the seasons. The perforated pipes have been used for drainage collection and have been adjusted as parallel branches of trees (Panthee, 2008).

Figure 1.4: Drainage material, leachate collection pipe and gas pipe of Sisdol landfill site

Geology and geotechnical conditions of Sisdol landfill site

The Sisdol landfill site comprises a thick river deposit of black clay silt underlain by gravelly sand. The river deposit is underlain by limestone which is fractured and has three sets of discontinuities. The volumetric joint number of the limestone varies from $9/m^3$ to $15/m^3$. The black clay silt has hydraulic conductivity of 3.2×10^{-2} m/day (Panthee, 2008).

Drainage material and Clay lining

The drainage material used in the landfill site consists of 50 to 150 mm sized gravel. The modal size however is 70 mm. Gravel is subangular to subrounded. Red residual clay produced on limestone from surrounding of the landfill site has been used for clay lining and is alkaline (pH = 8.5 to 8.9). The hydraulic conductivity of the red clay (in compact condition) is 2.06×10^{-8}m/sec. The clay has been lined in two compacted layers, i.e., the first 0.25 m and the second 0.25 m. A thin sand layer has been placed in between them (Panthee, 2008).

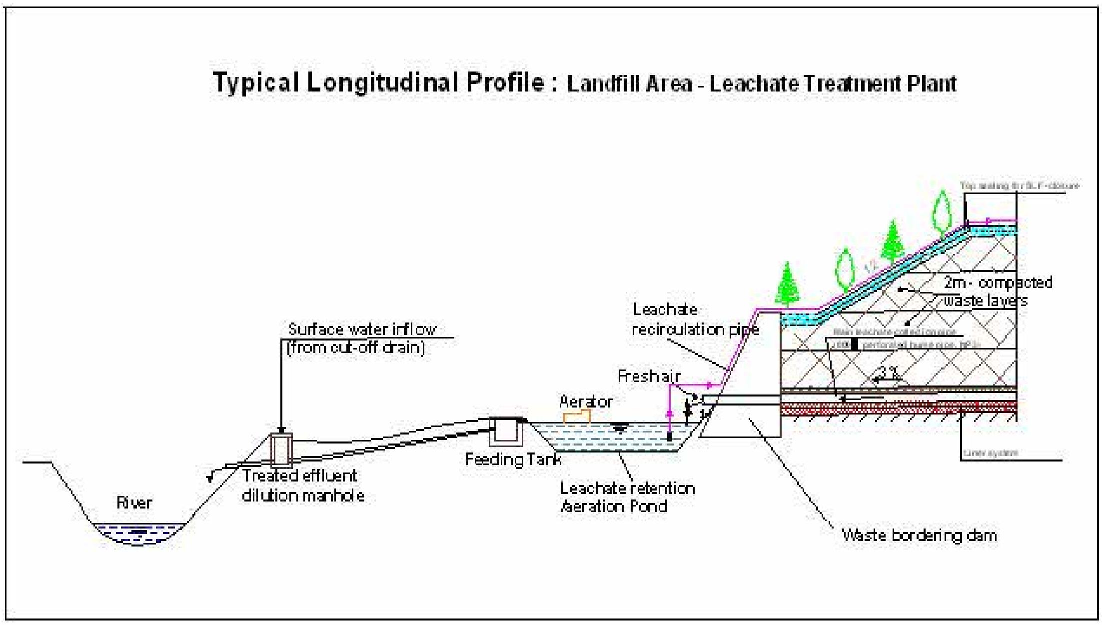

Figure 1.5: Typical Longitudinal Profile: Landfill Area – Leachate Treatment Facility

Okharpauwa is not the solution to Kathmandu's waste management problems. It is technically and environmentally not suitable and is very expensive. The Environmental Geology Project of Department of Mines and Geology conducted a geological evaluation of the site and concluded that it was not a suitable site for a landfill (Tuladhar, 2003).

1.8 Process of formation, composition and effect of leachate

When rain water percolates through a pile of solid waste, it picks up the soluble materials with it. The resulting contaminated water is called leachate. According to United States Environment Protection Agency (USEPA) ‘Leachate is any liquid including any suspended components in the liquid, that has percolated through or drained from hazardous waste’

Precipitation that infiltrates the solid wastes disposed on land mixes with the liquids already trapped in the crevices of the waste and leach compounds from the solid waste. The leachate thus formed contains dissolved inorganic and organic solutes. In course of time, the leachate formed diffuses into the soil and changes the physicochemical characteristics of water. Leachate from a solid waste disposal site is generally found to contain major elements like calcium, magnesium, potassium, nitrogen and ammonia, trace metals like iron, copper, manganese, chromium, nickel, lead and organic compounds like phenols, polyaromatic hydrocarbons, acetone, benzene, toluene, chloroform etc (Freeze and Cherry, 1979). The concentration of these in the leachate and water depends on the composition of wastes (Alker et al. 1995b as cited in Vasanthi et al, 2008). Some of the pollutants may be adsorbed on to the soil media during the flow of leachate through the soil. The leachate migrates from unsaturated zone to ground water table. When leachate mixes with ground water it forms a plume that spreads in the direction of flowing ground water contaminating the ground water of the locality. The degree of contamination in the aquifers depends on the transport rate of contaminants and depository conditions at the site as the contaminants permeate through the soil media.

Leachate contains different chemicals that are harmful to human health. Therefore leachate represents one of the most significant environmental problems in the design and maintenance of landfills. Leachate generation is an unavoidable problem associated to landfills, and water pollution by leachate has been historically a major environmental concern (Goodall and Quigley, 1977 as cited in Durmusoglu et al., 2006). Since most of the newly constructed landfills are sealed at the bottom, leachate generation becomes an even greater problem, and must be removed for treatment (Stegmann, 1983).

The characteristics of municipal landfill leachate vary greatly within an individual landfill over space and time. Also, leachate characteristics vary considerably from one landfill to another. Many factors influence the leachate composition including the types of wastes deposited in the landfill, composition of wastes, moisture content, the particle size, the degree of compaction, the hydrology of the site, the climate, and age of the fill and other site-specific conditions including landfill design and type of liners used, if any (Leckie et al. 1979; Kouzeli-Katsiri et al., 1999). The spatial variations in leachate composition mainly reflect differences in waste composition and infiltration of water through the top cover of the landfill (Kjeldsen et al., 1993).

The storage of any waste material in a landfill poses potential problems. One problem is the possible contamination of soil, groundwater and surface water that may occur as leachate produced by water or liquid wastes moving into, through and out of the landfill, migrates into adjacent areas. This problem is important especially when industrial wastes are involved because many of these substances are resistant to biological or chemical degradation and, thus, are expected to persist in original form for many years, perhaps even for centuries (Fatta et al., 1999).

The current technology of landfilling causes the production of highly contaminated leachate and biogas for a very long time. Therefore, the main aim of modern landfill strategies is to reduce landfill emissions in terms of landfill gas and leachate such that environmental problems are not left to future generations (Cossu et al., 2003). The control of leachate quantity and quality is the basis for long-term landfill operation and leachate treatment. To secure long-term dewatering of landfills and reduce treatment costs, it is necessary to control leachate quantity and quality. Leachate recirculation is a potential solution for on-site control and treatment.

Besides economic advantages, land filling enables the organic part of the refuse to be decomposed to inert and stabilized materials under controlled conditions. The organic part of the refuse within landfills is gradually decomposed by the activity of aerobic and anaerobic bacteria. Anaerobic decomposition of solid waste in conventional landfills is a slow process; the decomposition rate depends on many factors, such as the age and composition of landfilled refuse, its moisture content, the geology of the site, the leachate level, the temperature distribution within the landfill, and the effectiveness of capping of the site (Pohland 1980; Christensen and Kjeldsen 1989; Barlaz et al., 1990)

CHAPTER II

2. LITERATURE REVIEW

2.1 Review of Literatures

Studies outside Nepal

Areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site. Such contamination of groundwater resource poses a substantial risk to local resource user and to the natural environment. The impact of landfill leachate on the surface and groundwater has given rise to a number of studies in recent years (Saarela, 2003; Abu-Rukah and Kofahi, 2001; Looser et al., 1999; Christensen et al., 1998; De Rosa et al., 1996; Flyhammar, 1995). The adverse impacts of landfill leachates on adjacent surface and groundwater have prompted a great number of studies since 1980. Many approaches have been used to assess the contamination of underground water. It can be assessed either by the experimental determination of the impurities or their estimation through mathematical modeling (Moo-Young et al., 2004; Hudak, 1998; Stoline et al., 1993; Butwa et al., 1989).

A number of incidences have been reported in the past, where leachate had contaminated the surrounding soil and polluted underlying ground water aquifer or nearby surface water (Chian and DeWalle 1976; Kelley 1976; Kumar et al., 2002). In Hong Kong, the principal concerns regarding leachate are related to the pollution potential of uncontrolled leachate migration into the local surface water, groundwater or the sea (Lo 1996). Thousands of drinking water wells across the USA have already been shutdown due to the contamination from landfills (Masters 1998).

This includes studies of the leachate intrusion in the groundwater, such as Zheng et al. (1991) investigated the impacts on groundwater of the leachate originating from the Lone Pine landfill situated in Monmouth County, New Jersey. Sanchez et al. (1993) investigated the leachates generated by two different landfills located in the municipality of Madrid. Gailey and Gorelick (1993), who developed and applied a groundwater quality management tool for the Gloucester landfill site near Ottawa in Canada (as cited in Fatta et al., 1999). The qualitative and quantitative characteristics of leachates are very important in the design and management of landfills. This was demonstrated by Tejero et al. (1993) from results obtained at the Meruelo landfill in Spain and by analysing the control measures and the treatment of liquids. It also includes studies of the constituents in leachate such as Flyhammar (1995) examined the leachate quality of several active Swedish landfills. Blight (1995) examined the pollution of the groundwater downstream of an unlined landfill in South Africa.

In India a number of incidents have been reported where leachates have contaminated the surrounding ground water and surface water. Gopal et al. (1991) investigated the extent of ground water pollution by solid wastes in Kanpur city. Landfills have been identified as one of the major threats to groundwater resources (Fatta et al., 1999). In urban areas the groundwater is contaminated due to leachate from municipal solid waste disposal site and in rural areas, leachate from fertilizers used for agricultural purposes has contaminated the groundwater (Eldho, 2001). Mor et al. (2006) has reported the effect of municipal solid waste disposal on ground water around a landfill site at Delhi.

Kumar et al. (2005) studied on evaluating leachate contamination potential of landfill sites- two active and two closed landfill sites in Hong Kong using leachate pollution index (LPI). The high value of LPI for the closed Ma Tso Lung landfill in comparison to the LPI values of Pillar Point (PP) and Shuen Wan (SW) active landfills indicate that the leachate produced from the Ma Tso Lung landfill has more contamination potential as compared to PP and SW landfills. The LPI values of the two active landfill sites are quite comparable and indicate that the leachate should be treated before allowing discharging.

Bilgili et al. (2006) studied the effect of leachate recirculation on the quantity and quality of leachate in aerobic pilot-scale landfills and found that from the viewpoint of leachate treatment, the aerobic landfill showed a sound capability for the reduction of leachate contamination. Further they reported that leachate quality did not vary significantly between the recirculated and non-recirculated landfill reactors and little improvement in leachate quality was obtained with leachate recirculation, while the main difference occurs in leachate quantity. Recirculation decreased the quantity of the leachate by 47.3%.

Vasanthi et al. (2008) studied the impact of leachate percolation on ground water quality around a municipal solid waste disposal site at Perungudi dumping site, Chennai (a major Indian city with a population of more than 6.98 million). They investigated the effects of distance of ground water source from the dumping yard and temporal variations on the contamination levels. Vasanthi et al. (2008) reported high concentration of total dissolved solids, electrical conductivity, hardness, nitrate, chloride and sulphate in ground water near landfill deteriorating the quality of water and also concluded that the principal threat to groundwater comes from inadequately controlled landfills where leachate generated from the fill is allowed to escape to the surrounding and underlying ground.

Literature on other dumping sites and landfill sites in Nepal

Sharma et., al. (1995) reported significant increased in COD, ammoniacal nitrogen, chromium, lead, nickel, cadmium, sodium and potassium concentrations in the downstream section of Bishnumati river after mixing with leachate. Their study on Bishnumati provisional landfill site also indicated high heavy metal concentration above the hazardous limit in the surface and sub surface waters.

NESS (1997) carried out the groundwater investigation at GLFS and suggested the leachate permeations from the bottom of the western side which is polluting the groundwater resources of the western side.

Shrestha (1998) concluded conspicuous increase in pollution parameters like conductivity, hardness, chloride, nitrate-nitrogen, orthophosphate concentrations in the surface water and stone tap nearby the Gokarna landfill site (GLFS).

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Dangol (2000) analyzed the water samples collected from GLFS. He reported high levels of nitrogen in ground water and concluded that the inefficient landfill activities had caused the ground water pollution of Gokarna.

MOPE (2001) studied on contamination of soil and ground water by heavy metals and mineral oils due to disposal of solid wastes. From the analysis of water samples collected from around the dumping, landfill sites the study reported that heavy metal pollution in shallow tube wells and open wells are not alarmingly high. The heavy metals in soil sample around the dumping site are also not very high. The toxic metals like Cd, Cr (VI) and Hg are virtually absent. Only lead, copper and nickel were detected in significant amount. However it is not justifiable to conclude that these metals came into soil through the contamination by the dumping of solid waste.

ENPHO (2002) reported high electrical conductivity, nitrogen, ammonia, phosphorus, and iron well exceeding WHO limit in the water samples collected from tube wells within Teku Transfer Station (TTS), close to the present landfill site. Furthermore microbiological tests showed high level of fecal coliform contamination in the water samples.

Devkota et al. (2003) studied the impact of GLFS on groundwater and reported that the groundwater quality of the periphery has not been deteriorated seriously. They also reported high concentration of most of the pollution parameters in surface water close to the landfill site. They also compared the previous works to determine the trends in change of water quality of GLFS and concluded that pollution level for few parameters on water was decreasing, however, parameters like pH, alkalinity, conductivity and phosphorus were found to increase. Based on the learning experience from GLFS, Devkota et al. (2003) emphasized to take counter and mitigative measures to threats of solid waste management and recommended environmental monitoring system to be integral components of any solid waste landfill site.

Christina and Veronica (2004) applied the Vaxjo Risk Assessment Model as the checklist for risk assessment of the terminated GLFS to investigate the possibilities of using the model in future environmental risk assessments of old landfills in developing countries. She concluded that further investigations are needed to clear if the site constitutes a concrete environmental conflict and proposed the proper closure with possibly cover and treatment as the most reasonable alternative.

Karki (2004) studied the Sanitary landfill along the banks of Bagmati river in Kathmandu and its impact on the environment and reported that the surface water pollution in Bagmati river along the landfill site is extremely high. Further She reported that the soil test had confirmed that the marked increase in pollution in the surface water is primarily due to uncontrolled and unregulated seepage of the leachate from the adjacent waste dumps.

Khanal (2005) studied post project environmental monitoring and impact assessment-a case study of Gokarna Landfill Site after operation and closure and found that the construction and operation of the GLFS was not undertaken studying the various environmental factors of the site; nor public were involved when the locality was selected for the purpose of landfilling. He reported that inventory of environmental factors at GLFS after final operation and closure indicated that GLFS may constitute a concrete environmental conflict. He found that adjoining groundwater are within the WHO guidelines of drinking water; however more concentration of pollution parameters downstream and since the area that could be affected is not well defined, future risk of landfill to groundwater cannot be excluded.

Prasai (2007) assessed the leachate contamination in the groundwater quality of Gokarna Landfill Site and found the leachate to be most polluted with all the physicochemical parameters being higher than the permissible limit. The study found that the groundwater sample close to the leachate drain has higher values of the chemical parameters and in addition, all the samples contained more than 20 coliform bacteria per 100 ml of water sample. Prasai (2007) emphasized that though the permeability of the soil at Gokarna is moderate, the leachate pollution in the natural groundwater is significant.

Literature on Sisdol Landfill Site (SLFS)

Only few literatures were found regarding solid waste management at Sisdol landfill site and its impact on groundwater and surface water. The previous studies were mainly based on one time sampling and frequent sampling has been rarely carried out.

SWMRMC, (Date not mentioned) conducted Environmental Impact Assessment for Solid Waste Treatment Plant and Development of Sanitary Landfill Site at Sisdol-ko-gairo and reported that (technically speaking) small site like Sisdol-ko-gairo is not ideal site for landfill operation. They also reported that Kolpu Khola water was very turbid and was flowing with appreciable amount of suspended solids due to the disposal of clay produced in excess during the process of agricultural terrace construction in the upstream catchment areas.

NESS (2007) assessed the water quality of leachate and Kolpu Khola. They analyzed the leachate samples from the surface and bottom of leachate tank and also analyzed the surface water samples of Kolpu Khola from downstream to Nagdol and Kolpu confluence (S-1) up to Chausephant (S-17). The study reported that the leachate from the landfill site bears very high pollution load and are highly enriched with organic matters and also associated with high levels of toxic metals especially lead, chromium and nickel. Leachates from the landfill site were also found associated with high levels of suspended and dissolved solids as well.

Pradhanang (Date not mentioned) studied Solid Waste Management Laws and Practices- A Case Study of Kathmandu Metropolitan. Based on the interviews with the locals of Sisdol she reported that in case of Sisdol landfill the leachate filtration devices fail to filter the leachate in a proper manner. As a result it has polluted the river water, caused negative effects to health, causing skin problems and has degraded the soil quality of agrigable land. It has also caused serious effects to the environment as the waste has increased the number of houseflies, bad smell.

ENPHO (2007) performed surface water, groundwater and leachate quality monitoring at Sisdol Semi-aerobic Landfill Site and found that some of the parameters were found higher at downstream of the landfill compared to upstream. However the concentrations were not at dangerous level. The study also indicated that the groundwater in the landfill site has been contaminated and the quality of leachate was very poor. The study also found that the quality of groundwater from the borehole 1 during early spring of that year was quite low compared to that in the early spring of previous year. During that interval they found increased contamination level of the leachate. For example, concentration of indicator parameters such as BOD, COD and NH_4-N was more than doubled in that year.

Panthee (2008) studied possible methods of preventing groundwater contamination at landfill sites in Nepal and found that all the three landfill sites-Pokhara municipal sanitary landfiil site, Gokarna landfill site and Sisdol landfill site possessed drawbacks in terms of material used, and of landfill design and operation technique. This has caused contamination of groundwater and soil by leachate in Gokarna landfill site, and possible contamination in Sisdol and Pokhara landfill sites in future. Great vulnerability of collapse of basement exists in Pokhara municipal sanitary landfill site due to the reaction of leachate and basement soil. He also pointed out that thickness of the clay liner is not sufficient and the gradient of the base is also very low. Therefore, thickness and gradient of the clay liner should be increased.

Annonymous (2008) performed the water and leachate quality test at Sisdol Landfill Site in June, 2008 and found that the water qualities of upstream (100 m upstream) and downstream (25 m downstream from the leachate collection pond) of the Kolpu Khola were within WHO guidelines for drinking water (WHO, 2006) except turbidity and E. Coli. The study reported that except pH, E. coli and turbidity the other parameters of the groundwater of the monitoring well were within the range of WHO guideline value. The study also found that except BOD, COD, lead and cadmium other parameters like turbidity, TSS, chloride, phosphorus, oil and grease have decreased compared to previous year data. Annonymous (2008) reported that TSS, BOD, COD, lead mercury, hydrogen sulfide, oil and grease has exceeded the value of generic standard.

2.2 Statement of Problem:

Waste generation is a natural phenomenon on account of resource utilisation. However, its negligence and mismanagement obviously invites undesirable and suffocating environment. With rapid urbanization and migration from rural to urban area, significant increase in both volume and composition of the waste is distinctly noticeable. However, very little space and resource can be allocated for its disposal. Thus, solid waste management has become a major environmental concern for all especially in urban areas.

Municipal solid waste (MSW) is one of the most pressing forms of pollution that society has created. The most prevalent form of disposal of solid waste is by dumping the waste into a sanitary landfill. Unfortunately, sanitary landfills are not an ideal solution to the disposal problem of solid waste. Water, which infiltrates into the landfill through the top cover, saturates the waste and becomes laden with high levels of soluble contaminants, which are released during the waste decomposition process. The resulting contaminated water is called leachate. Leachate from a solid waste disposal site is generally found to contain major elements like calcium, magnesium, potassium, nitrogen and ammonia, trace metals like iron, copper, manganese, chromium, nickel, lead and organic compounds like phenols, polyaromatic hydrocarbons, acetone, benzene, toluene, chloroform etc (Freeze and Cherry, 1979). The concentration of these in the leachate and water depends on the composition of wastes (Alker et al., 1995b as cited in Vasanthi et al, 2008).

The leachate can contaminate groundwater resources in the immediate vicinity of the landfill by diffusive transport or direct infiltration through the landfill liner, and/or by failure of the engineered leachate collection system. Threats to groundwater from the unlined and uncontrolled landfills exist in many parts of the world, particularly in the underdeveloped and developing countries where hazardous industrial waste is also co-disposed with municipal waste and no provision of separate landfills for hazardous waste exist. The dumping of solid waste in uncontrolled landfills can cause significant impacts on the environment and human health.

Analysis of solid wastes generated in the municipality and their systematic disposal by classifying the nature of the waste is yet to come into practice. All types of hazardous wastes, biodegradable and non-biodegradable wastes are dumped at one place. Since there is no provision of separation, collection, handling or disposal of hazardous waste, all kinds of waste mix up and sorted out by the scavengers. Except segregation of organic matter at households and other reusable or recyclable materials like plastics, paper and metal scraps by scavengers nearly all types of wastes are dumped at Sisdol landfill without proper segregation of municipal, industrial, hospital and other hazardous wastes. Dumping of hazardous wastes like heavy metals originated from battery and battery industry along with other wastes cause severe environmental problems in long run in soil, ground water and surface water.

2.3 Rationale of the Study:

Leachate generation is an unavoidable problem associated to landfills. Leachate contains different chemicals that are harmful to human health. Therefore leachate represents one of the most significant environmental problems in the design and maintenance of landfills.

Most of the literature available so far has only highlighted the management approach and weakness of solid waste management in Nepal. Only few reports are available describing the adverse effects of waste dumping on land, water and air. Moreover, there exists virtually none on solid waste dumping along the riverbanks. Although most people believe that a landfill activity along the riverbanks is not an environmentally sound technique, there is hardly any record of data to justify it. Thus, through the present research, the existing social and environmental impacts of landfill activities are evaluated so that it will be helpful for the concerned authorities to select proper landfill site in future.

The guidelines of sanitary landfill have not been followed in Sisdol landfill. The current practice shows that it is not landfilling of wastes, rather its practically just dumping the wastes as scientific landfilling methods have not been adopted (Pradhanang, date not mentioned). Although, the wastes are covered by soil layer after its disposal, there is no control system for leachate which directly terminates into the river water.

The leachate generated from the Sisdol landfill site due to dumping activities can contaminate surface, groundwater sources and peripheral land through infiltration. Furthermore, the preliminary field survey of the Sisdol landfill site indicated that it lacked leachate treatment and there was leakage of leachate from the landfill into Kolpu Khola. Thus, the leached substances from the wastes are contaminating the surface water of the River. Therefore, it is very likely to have severe impacts on the health of nearby residents, domesticated animals, agricultural land and overall environment of the dumping area. Periodic monitoring of nearby water sources hence seems urgent. Hence this study might help to find out the suitability of the surface water of Kolpu Khola and the groundwater nearby the landfill for different uses by the people and will also address the probable solutions to the problems.

2.4 Hypotheses

The hypotheses, null hypothesis (H_o) and alternative hypothesis (H_1) of the present study are as follows:

i. H_o: The monthly variation of physicochemical parameters of the Kolpu Khola in the investigation period is not significant.

   H_1: The monthly variation of physicochemical parameters of the Kolpu Khola in the investigation period is significant.

ii. H_o: The spatial (site wise) variation of physicochemical parameters of the Kolpu Khola in the investigation period is not significant.

   H_1: The spatial (site wise) variation of physicochemical parameters of the Kolpu Khola in the investigation period is significant.

The significance level (α) of a test is a probability such that the probability of making a decision to reject the null hypothesis when the null hypothesis is actually true is no more than the stated probability. Typical values for α are 0.1, 0.05, and 0.01. In statistics, a result is called statistically significant if it is unlikely to have occurred by chance. "A statistically significant difference" simply means there is statistical evidence that there is a difference; it does not mean the difference is necessarily large, important, or significant in the common meaning of the word. Confidence level is the statistical measure of the number of times out of 100 that test results can be expected to be within a specified range. For example, a confidence level of 95% means that the result of an action will probably meet expectations 95% of the time. The 95% confidence level means we can be 95% certain; the 99% confidence level means we can be 99% certain. Most researchers use the 95% confidence level. If a result is statistically significant at significance level 0.01 then we are 99 % confident that the result is significant.

2.5 Objectives of the study

General Objectives:

1. To analyze the physicochemical and microbial parameters of leachate, surface water and ground water nearby Sisdol sanitary landfill site
2. To determine the monthly as well as seasonal variation in the physicochemical and microbial parameters of leachate, groundwater and surface water of Kolpu Khola.
3. To study the socioeconomic condition of the residents nearby the Sisdol landfill and the Kolpu Khola and their perception on impact of the river pollution on their socioeconomic life.

2.6 Limitations of the study

i. The groundwater of monitoring well (bore hole-2) couldn’t be analyzed in August (monsoon season) because of the blockage of the well by mud.

ii. Different organic and inorganic compounds including heavy metals like cadmium, lead, mercury etc that may possibly be present in the leachate, groundwater and surface water could not be studied due to the time and resource constraints.

iii. Groundwater samples could not be taken at different distances from the landfill due to unavailability of monitoring wells and also due to burial of pre-existed well.

iv. The water samples could not be taken and checked frequently due to financial and time constraint

CHAPTER III

3. STUDY AREA

3.1 Location and Accessibility of the Study Area

Nuwakot district lies to the north-west corner of Kathmandu. It is situated between latitude 27º 45’ N to 28º 20’ N and longitude 85º 0’ E to 85º 45’ E. Altitude from the sea level varies from 457 m to 5144 m and covers an area of 1121 sq. km (HMG/NPCS, 2005). The district is connected with Rasuwa to the north, Kathmandu and Dhading to the south, Sindhupalchowk to the east and Dhading to the west. Dhading district is situated between latitude 27º 40’ N to 28º 17’ N and longitude 84º 35’E to 80º 17’E (HMG/NPCS, 2006).

The Sisdol sanitary landfill site is situated between latitude 27° 46’ 00" to 27° 46’ 30" N and longitude 85° 14’ 30" to 85° 15’ 30" E in Nuwakot district and is bordered by Kolpu Khola to the south from Dhading district and to the southeast from Kathmandu district. The SLFS is about 18 km NW from Kathmandu City center (SWMRMC, 2005). It is about 28 km from Teku Transfer Station.

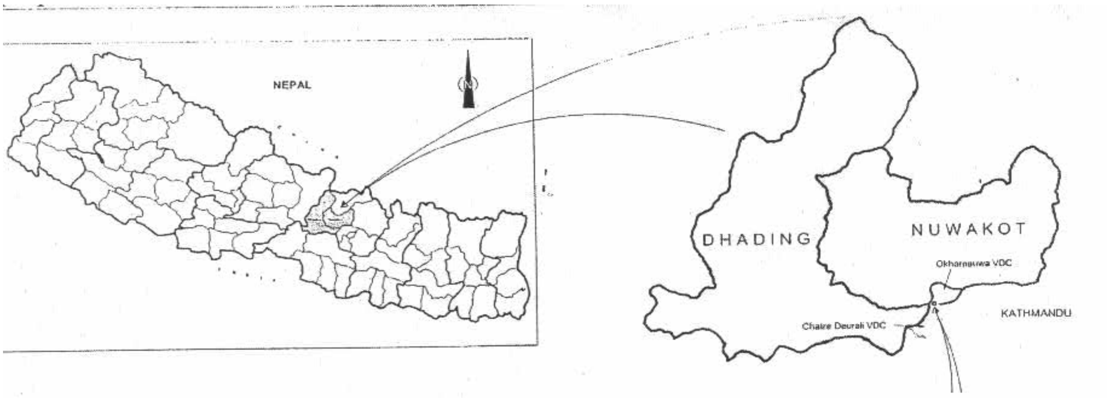

Figure 3.1: Map showing Okharpauwa VDC of Nuwakot district and Chhatredeurali VDC of Dhading district.

The SLF site itself lies to the south of Nepaltar village at Sisdol-ko-gairo on the right bank of Kolpu Khola, whereas other affiliated waste management sites lies to the west of the SLF on the river terrace to the north of Kolpu Khola at ward no. 4 of Okharpauwa VDC. The altitude at landfill site is about 1150 m above mean sea level and about 350m below Tinpiple, the point of diversion of the existing road to Trishuli from the newly constructed access road to Okharpauwa. The Sisdol landfill site has been selected for short-term operation with an objective to develop the Okharpauwa site for long-term operation. The site at Sisdol-ko-Gairo, together with a waste processing plant (at Aletar), covers a total area of about 20 ha.

3.2 Topography

The SLF is situated in a small well-protected valley with a very limited catchment. Geomorphologically speaking it forms the abandoned course of the Kolpu Khola and is protected on all sides by elevated ridge spurs. The Kolpu Khola originates at surrounding hills. Number of springs and natural drainage systems join and make the flow in the river. The Kolpu Khola emerges from the west slope of a mountain 2200 m high and situated at the north-eastern edge of Kathmandu valley.

Owing to the topographically protected nature of SLF, except for potential for water pollution the SLF site at Sisdol-ko-gairo is safe from other consideration of landfill management and operation (SWMRMC, 2005).

3.3 Geology

The dominant lithological types are the migmatities with xenoliths of different types of mica schist. A major fault, the Kolpu Khola fault passes close to the landfill site. The landfill site is bounded on all sides by the moderately to deeply weathered migmatites. Hard rock exposures are seen to the south, north and western hill flank of the landfill. Geologically due to hard rock composition of the SLF site, it offers a better proposition compared to the other sandy and gravely areas. Dominant soil type at the SLF can mainly be considered as residual and alluvium soils. Residual soils mainly present in uphill slope of the SLF whereas valley slope is occupied by alluvium deposit. Residual forms of soil are developed from deep weathering of migmatite (SWMRMC, 2005).

3.4 Climate

Nuwakot district has diverse form of climate due to its geophysical structures. The average maximum temperature reaches up to 19.75ºC in summer and the average minimum temperature in winter reaches up to 10.02ºC. The maximum rainfall (691.7 mm) occurs in July and the amount of rainfall decreases considerably in winter. The average annual rainfall reaches up to 184.64 mm (HMG/ NPCS, 2005).

Table 3.1: Average maximum, minimum temperatures and rainfall in Nuwakot

Month	Average maximum temperature (ºC)	Average minimum temperature(ºC)	Average rainfall (mm)
January	13.8	3.2	30.0
February	14.4	3.8	65.0
March	18.2	7.1	68.0
April	23.5	12.0	45.0
May	23.6	12.0	19.2
June	22.8	14.9	210.2
July	22.5	15.1	691.7
August	22.8	15.4	612.7
September	22.5	13.9	454.9
October	21.2	10.7	13.0
November	18.2	7.0	0.0
December	13.5	5.1	6.0

Source: Statistical Information of Nepalese Agriculture 2003/04, Ministry of Agriculture and Co-operation. (As cited from HMG/ NPCS, 2005)

The SLF has warm subtropical climate. The climate is characterized by heavy monsoon rainfall, which occurs between June to September and delivers a total annual average rainfall of 2990 mm (1990). This figure is based on Kakani rainfall station, which may vary with rainfall at the bottom of the hill, at Kolpu Khola basin (SWMRMC, 2005).

There is no meteorological station in the vicinity of SLF; however there are three meteorological stations in the surroundings of the area namely-Kakani, Dhunibesi and Kathmandu (Panipokhari).

Table 3.2: Rainfall Data Interpolation for the Okharpauwa Site (mm)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
17.0	18.0	29.0	53.0	88.0	319.0	478.0	493.0	262.0	72.0	8.0	10.0	1847

Source: Solid Waste Management in Nepal 1996: Fact finding Mission prepared on behalf of the GTZ, May 1996 (as cited in SWMRMC, 2005)

The annual average temperature at the top of the hills, Kakani varies from 8°C to 19.7°C. At Okharpauwa, the bottom of depression of the hills, average temperature is 21°C with a maximum and minimum temperature 41°C and 4°C respectively (SWMRMC, 2005).

3.5 Drainage and Hydrology

Both surface and groundwater hydrology are important factors in determining the potential water pollution due to landfill because pollution in the form of leachate is transported by means of surface and groundwater. The Kolpu Khola flows through the eastern and southern side of the SLF. Mean monthly discharge of Kolpu Khola is depicted in the following table (table 4.2). The Kolpu Khola has an enormous discharge volume during the high floods, which is estimated to be as high as 6m^3/sec.

Table 3.3: Mean monthly discharge of Kolpu Khola

Month	Discharge (m^3/sec)	Month	Discharge (m^3/sec)
January	0.45	July	4.71
February	0.38	August	5.79
March	0.33	September	4.49
April	0.32	October	1.98
May	0.31	November	0.87
June	1.52	December	0.58

Source: Shrestha et al., 1995: Preliminary Design and Environmental Studies of Proposed SLF at Okharpauwa, Project Report, July 1995 Kathmandu (as cited in SWMRMC, 2005)

3.6 Socioeconomic condition

Socioeconomic pattern of the study area is predominantly rural and is guided by Hindu traditional value systems. The society is cohesive in nature and very co-operative.

3.6.1 Demography

According to census 2058 (2001 AD), total population of Nuwakot district is 288478, out of which 142731 is males and 145747 is number of females (CBS, 2001). Population density is 257.34 per sq. km. Urban density is 633.00 per sq. km and the rural population density is 245.77 per sq. km. The annual rate of population growth from 1991 to 2001 for the district is 1.62 %.

Table 3.4: Population and population density of Nuwakot and Dhading districts

	District	
	Nuwakot	Dhading
Population	288,478	338,658
Population density (Person/sq. km)	274	175.5
No. of males	142,731	1,65,864
No. of females	145,747	1,72,794
No. of households	53,169	62,759
Average household size	5.79	5.4
Annual population growth rate (%)	1.59	1.97

Source: CBS, 2001

The total population of Okharpauwa VDC is estimated to be 8087 of which 49.62 percent is female. Balami community dominates the Okharpauwa VDC. Kshetri, Brahmin, Tamang and Balami are the dominant classes of people in the entire area of Okharpauwa VDC. They live in a combined family. Often the family comprise of three to four generation members. The SLF is located in ward no. 4 of Okharpauwa VDC and the population of the ward is 655 (SWMRMC, 2005). The Kolpu Khola is the political and administrative boundary between two districts, namely Nuwakot to the east, Dhading to the west.

Table 3.5: Composition of population and PGR of two VDCs of Nuwakot district

Name of VDC	No. of male	No. of female	Total	PGR (2048- 2058) %
Chauthe	2011	1948	3959	2.89
Okharpauwa	4074	4013	8087	2.67

3.6.2 Occupation and Employment

Most of the people are farmers. 198764 people (68.90%) are involved in agricultural sector in Nuwakot district. About 97 % households are related with agriculture in one way or another. The occupation of about 69 % economically active population is agriculture. The main occupation of 66.4 % males and 77.9 % females, as a whole 71.6 % of population is agriculture and forestry. They thrive in sustainable agriculture. But most of the people have little land to keep them busy in the agricultural activity round the year. Besides, the traditional agricultural practices do not require their input round the year. Livestock raising is the other subsidiary economic activity.

Most of the populations of the area are agriculturally employed people in disguise. They have works for about 3 to 4 months in a year in the agricultural farm. For rest of the other period, they have not much to do except for the daily household chores. Some deprived population utilizes this time as labour force in various economic activities in the Kathmandu city.

3.6.3 Public Health and Education

The environmental sanitation condition in the SLF and its surrounding area is poor. Personal and household level hygiene and sanitary condition of the people does not seem to be good. People awareness level regarding health and hygiene is very low. The existing health service is poor. Skin diseases and respiratory diseases, diarrhea, worms, gastritis, anemia, ear infections, eye diseases and diseases related to nutrition are the main diseases in the Nuwakot district (CBS, 2001).

Table 3.6: VDC wise literacy rate in Nuwakot district

Name of VDC	**Literacy rate**		
	Total	Male	Female
Chauthe	52.0	65.5	38.0
Okharpauwa	31.4	40.0	22.5
District as a whole	51.4	62.4	40.7

Table 3.7: Education status of people of 6 years or above in Dhading district

Education status	**%**
1. Uneducated	56.5
2. Informal education or other	3.2
3. Primary level	25.1
4. Lower secondary and secondary	11.8
5. SLC and above	3.3

Source: CBS, 2001

3.6.4 Water and Sanitation

About 73% populations from more than 85% of the total households have an access to drinking water provided by governmental and non-governmental sectors in Nuwakot district. Similarly about 85 % households have an access to tap water for drinking. Apart from Trishuli and Tadi watersheds the district has about 36 sub-watersheds as sources of water.

Table 3.8: Number of households having access to drinking water in VDCs of Nuwakot

Name of VDC	No. of HHs	Population	% population
Chauthe	592	3440	91.78
Okharpauwa	560	3260	41.31

Table 3.9: Number of households based on source of drinking water in Nuwakot district

Source of drinking water	No. of households	% of household
1. Tap water	45179	84.97
2. Well	2987	5.62
3. Tube well	0	0.00
4. Spring	3974	7.47
5. River/ Stream	388	0.73
6. Others	47	0.09
7. Not mentioned	594	1.12
Total	100	100

Table 3.10: Number of households based on source of drinking water in Dhading district

Source of drinking water	No. of households	% of household
1. Tap water	49731	79.24
2. Well, tube well	5516	8.79
3. Springs (Kuwa)	6602	10.52
4. Rivers and others	909	1.45
Total		

3.7 Vegetation

The surrounding vegetated area of SLF is intensively grazed and degraded land. Some of the major types of vegetation are *Alnus nepalensis* (Uttis), *Schima wallichii*(Chilaune), *Woodfordia fruticosa* (Dhaero), *Cyperus* (Mothe), *Eupatorium* (Banmara), *Rubus ellipticus* (Aiselu), *Urtica dioca* (Sisau), *Artemisia vulgaris* (Titepati). In the slopes of the SLF surrounding area, there are some trees with shrubs and grasses. The woodland on the site appears to be planted or re-vegetated recently and does not denote conservation interest (SWMRMC, 2005). Together with 253 community forests the government forests, religious forest, private forests of the district has 35991 hectares of forests and shrubs that covers more than 55 % of the total area of the Nuwakot district. Parts of areas of Langtang national park and Shivapuri national park cover 237.8 hectares of land of the district. In Okharpauwa VDC there are 4 community forests that covers 5 wards namely 3, 4, 5, 7 and 8 that occupying 231.41 hectares.

3.8 Landuse

Based on the appropriateness most of the land area is being used for agricultural production. Terrace farming is common. In the hills with greater than 30° slopes grasslands and woodlands are in existence (SWMRMC, 2005).

Table 3.9: Landuse pattern of Nuwakot and Dhading district

	Nuwakot		**Dhading**	
	Area (ha)	%	Area (ha)	%
Agricultural land (ha)	45242	40.36	73346	38.10
Forest land (ha)	40516	36.14	92854	48.24
Grazing land(ha)	15950	14.23	15941	8.28
Others (ha)	10392	9.27	10346	5.37
Total area (ha)	112100		192487	

Source: SWMRMC, 2007

CHAPTER IV

4. MATERIALS AND METHODS

4.1 Data Collection Method

Data was collected using different methods and sources. Both primary and secondary data has been used in the study. Data collected by field visit in socioeconomic survey and those obtained by analysis of physicochemical parameters in the laboratory are primary. Journals, abstracts, published and unpublished reports are the sources of secondary data.

4.2 Details of Procedure for analyses of water and Questionnaire Survey

Methods of sample collection, preservation and analysis

4.2.1.1 Physicochemical Parameters

4.2.1.1.1 Water sample collection and preservation

The type of sample taken was grab sample. From each sampling site, water sample was collected in a clean sampling bottle (plastic bottle). Prior to the collection, the sample bottle was rinsed thoroughly with the sample water even if it was precleaned. Most of the physicochemical parameters such as secchi disc transparency, velocity, pH, conductivity, chloride, dissolved oxygen, free carbon dioxide, alkalinity, calcium hardness and total hardness were measured in the sampling site. Water samples were collected and preserved for the analysis of BOD_5, PO_4-P, NO_3-N, NH_4-N. Water sample for analysis of NH_4-N was preserved by adding conc. H_2SO_4 to pH less than 2 whereas water samples for the analysis of chromium (heavy metal) were preserved by adding conc. HNO_3 to pH less than 2. All samples were brought to laboratory as early as possible and refrigerated (4^oC but above freezing).

4.2.1.1.2 Methods of Analysis of Physicochemical Parameter

Table 4.1: Methods and instruments used for analyzing physicochemical parameters

S.N.	Parameters	Methods	Instruments
	Physical Parameters		
1	Transparency	Secchi disc method	Secchi disc
2	Total solids (TS), TDS, TSS	Dried method	Porcelain basin, funnel, Whatman filters paper
3	Electrical conductivity (EC; µS/cm)	Potentiometric method	Conductivity meter
4	Temperature		Mercury thermometer
5	Velocity	Floatation method	
	Chemical Parameters		
1.	pH	Potentiometric method	pH meter
2.	Ammoniacal nitrogen	Phenate method	Spectrophotometer, Conical flask, beaker
3.	DO	Winklers Iodometric method	BOD bottle, pipette, burette.
4.	BOD_5	Titrimetric method	BOD bottle, burette, incubator
5.	COD	Titrimetric method	COD reflux assembly
6.	Chloride	Argentometric method	Burette, pipette, conical flask
7.	Alkalinity	Titrimetric method	Burette, pipette, Conical flask.
8.	Hardness	EDTA method	Burette, pipette, Conical flask.
9.	Calcium	EDTA method	Burette, pipette, Conical flask.
10.	Calcium hardness	EDTA method	Burette, pipette, Conical flask.
11.	Magnesium	EDTA method	Burette, pipette, Conical flask.
12.	Free CO_2	Titrimetric method	Burette, pipette, Conical flask.
13.	Orthophosphate (PO_4 - P)	Ammonium molybdate method.	Spectrophotometer (690 nm)
14.	Nitrate-nitrogen (NO_3-N)	Phenol disulfonic method	Spectrophotometer (410 nm)
15.	Total iron	Phenanthroline method	Spectrophotometer (510 nm)
16.	Potassium	Flame photometric method	Flame photometer (768 nm)
17.	Total chromium	Colorimetric method	Spectrophotometer (540 nm)

Physicochemical Parameters of Surface water and groundwater

1. Temperature

The water temperature was measured by using a mercury-filled Celsius thermometer. For determination of surface temperature, the surface water was collected in a beaker.

Soon after the collection of the water sample, the thermometer was dipped into the water sample keeping the thermometer away from direct sunlight and noted the reading. While taking the reading, the scale of the thermometer was immersed in the water upto the level of mercury in the capillary column (Trivedy and Goel, 1986).

2. pH

For the determination of pH of water, water sample was taken in a clean beaker and electrode (rinsed with distilled water, dried with a soft tissue paper) of pH meter was dipped into the water sample. Equilibrium between electrode and water sample was established by stirring water sample to ensure homogeneity. Then the reading of pH meter was noted (APHA, 1995).

3. Conductivity

For measuring the conductivity of water, the electrode was rinsed with distilled water and dipped in the beaker containing the water sample. The reading was noted after the reading stabilized at a certain point.

Electrical conductance is the ability of a substance to conduct the electric current in water. In water, it is the property caused by the presence of various ionic species. It is generally measured with the help of a conductivity meter having a conductance cell containing electrodes of platinum coated with platinum black or carbon. These electrodes are mounted rigidly and placed parallely at a fixed distance. Conductance, when measured between the electrodes having a surface area of 1 cm^2 and placed at a distance of 1 cm, is called electrical conductivity and is the property of the water sample, rather than the measuring system. As the ionization of the solutes depends on the temperature, conventionally the results are reported at 25 °C.

Conductivity at 25°C = Observed conductance × Cell constant × Temperature factor

4 Transparency (Light penetration)

Transparency of a body of water was measured by immersing Secchi disc and observing its visuality. Secchi disc of 20 cm diameter was lowered in the water until it just disappeared. The depth was noted by marking on the rod. Then the Secchi disc was uplifted and noted the depth at which it reappeared again. The Secchi disc transparency was calculated by the following equation (Trivedy and Goel, 1986).

Calculation

$$\text{Secchi disc light penetration} = \frac{A+B}{2}$$

Where, A = Depth at which Secchi disc disappears

B = Depth at which Secchi disc reappears.

5. Velocity

For the measurement of stream velocity, a float (thermocole) was thrown on the water surface. The time't' required for a float to travel a known distance 'd' was taken and the average velocity was obtained by using the following equation (Trivedy and Goel, 1986)

Average velocity, $v = d/1.2t$

The factor 1.2 accounts for the fact that surface velocities are normally about 1.2 times higher.

6. Alkalinity

The alkalinities are determined by titrating the water sample with a strong acid like HCl,. H_2SO_4 etc by using the indicators- phenolphthalein at first and methyl orange at the second time. The volume of acid used with phenolphthalein indicator corresponds to phenolphthalein alkalinity and the whole of the acid used with both indicators corresponds to the total alkalinity.

For the determination of alkalinity, 100 ml of sample was taken in a conical flask and 2 drops of phenolphthalein was added. When the solution remains colorless phenolphthalein alkalinity is zero. When the color changed to pink after addition of phenolphthalein, the solution was titrated with 0.1 N HCl until the color disappeared. This gives phenolphthalein alkalinity. Then 2-3 drops of methyl orange was added to the same sample and titrated further until the yellow color changed to pink at end point. This gives total alkalinity (TA) (APHA, 1995, Trivedy and Goel, 1986)

Calculation

$$\text{PA as } CaCO_3\text{, mg/L} = \frac{A \times N \times 1000 \times 50}{\text{Volume of sample (ml)}}$$

$$\text{TA as } CaCO_3\text{, mg/L} = \frac{B \times N \times 1000 \times 50}{\text{Volume of sample (ml)}}$$

Where,

PA= Phenolphthalein alkalinity

TA= Total alkalinity

N= Normality of HCl

A= Volume of HCl used with phenolphthalein.

B=Total volume of HCl used with phenolphthalein and methyl orange.

Concentration of hydroxyl ions carbonates and bicarbonates can be determined from the table 5.2 using the values of PA and TA.

Table 5.2: Values of hydroxyl ions, carbonates and bicarbonates from the values of phenolphthalein and total alkalinities**.**

Result of titration	OH alkalinity as $CaCO_3$	CO_3 alkalinity as $CaCO_3$	HCO_3 alkalinity as $CaCO_3$
P= 0	0	0	T
P<1/2 T	0	2P	T-2P
P= ½ T	0	2P	0
P> ½ T	2P-T	2(T-P)	0
P= T	T	0	0

Source: APHA, 1995; Trivedy and Goel, 1986

Where,

P= Phenolphthalein alkalinity

T = Total alkalinity

7. Dissolved Oxygen

The dissolved oxygen was determined by Winkler’s Iodometric method. The sample water was filled in BOD bottle of known volume (e.g. 300ml) carefully avoiding any air bubbling and trapping of air bubbles in the bottle after placing the stopper. With the help of two separate pipettes 2 ml of manganous sulphate and 2 ml of alkaline potassium iodide was added into the bottle, well below the surface from the wall. A brown precipitate appeared which indicated the presence of oxygen in the sample. The stopper was placed and the content was shaken well by inverting the bottle repeatedly. The bottle was kept for sometime to settle down the precipitate. Then 1-2 ml of conc. H_2SO_4 was added to dissolve the precipitate. The bottle was again stoppered and shaken well. 50 ml of the content was taken in a conical flask for titration. Bubbling was prevented to avoid further mixing of oxygen. The content was titrated against 0.025 N sodium thiosulphate using starch as indicator. The starch was added when the colour of the content became pale. At the end point the initial dark blue colour changed to colourless. The above steps were repeated till the concurrent reading obtained (APHA, 1995, Trivedy and Goel, 1986). The dissolved oxygen is calculated by the following equation.

Calculation

$$\text{Dissolved Oxygen (mg/L)} = \frac{\text{(Vol.} \times \text{N) of titrant} \times 8 \times 1000}{V_2\,(V_1 - V)/V_1}$$

Where,

N = Normality of titrant ($Na_2\,S_2\,O_3$) in ml.

V_1 = Volume of BOD bottle

V_2 = Volume of part of content used for titration.

V = Volume of $MnSO_4$ and alkaline KI added.

8. Chloride

Chloride content of water was determined by “Argentometric method” in which water sample is titrated with $AgNO_3$ using $K_2\,Cr\,O_4$ as indicator. 50 ml of water sample was taken in a conical flask and 2 ml of Potassium chromate ($K_2\,Cr\,O_4$) was added to it and stirred well. The content in the flask was titrated against $AgNO_3$ solution until persistent red tinge appeared. The chloride is calculated by the following equation. (Trivedy and Goel, 1986)

Calculation

$$\text{Chloride content, mg/L} = \frac{\text{Titrant's volume} \times \text{Normality of } AgNO_3 \times 35.5 \times 1000}{\text{Volume of sample}}$$

9. Hardness

For the determination of hardness, 50 ml of water sample was taken in a conical flask. Then 1 ml of buffer solution was added. If the water sample is having higher amounts of heavy metals, 1 ml of Na_2S should be added. Then 100- 200 mg of Erichrome Black T was added and the solution turned into wine red. The content was titrated against EDTA solution. At the end point colour changed from wine red to blue. The hardness is calculated by the following equation. (APHA, 1995, Trivedy and Goel, 1986).

Calculation

$$\text{Hardness as mg/L } CaCO_3 = \frac{\text{Volume of EDTA used} \times B \times 1000}{\text{Volume of sample in ml}}$$

$$= \frac{\text{Volume of EDTA used} \times 1000}{\text{Volume of sample in ml}}$$

Where, B= mg $CaCO_3$ equivalent to 1.00 ml of 0.01 M EDTA = 1

10. Calcium and Calcium hardness

For the determination of calcium, 50 ml of water sample was taken in a conical flask (If the sample contains higher alkalinity, smaller volumes could be taken and diluted to 50 ml). 2 ml of NaOH was added to the sample. Then 100-200 mg of murexide was added and the solution turned into pink. The content was titrated against EDTA solution until the pink colour changed to purple. Calcium and calcium hardness are calculated by the following equation (APHA, 1995)

Calculation

$$\text{Calcium, mg/L} = \frac{\text{Volume of EDTA used} \times B \times 400.8}{\text{Volume of sample in ml}}$$

$$= \frac{\text{Volume of EDTA used} \times 400.8}{\text{Volume of sample in ml}}$$

$$\text{Calcium hardness as mg/L } CaCO_3 = \frac{\text{Volume of EDTA used} \times B \times 1000}{\text{Volume of sample in ml}}$$

$$= \frac{\text{Volume of EDTA used} \times 1000}{\text{Volume of sample in ml}}$$

$$= \text{Calcium (in mg/L)} \times 2.497$$

Where, B= mg $CaCO_3$ equivalent to 1.00 ml of 0.01 M EDTA = 1

11. Magnesium

Magnesium can be estimated as the difference between hardness and calcium as $CaCO_3$, if interfering metals are present in non interfering concentrations in the calcium titration. It is calculated by the following equation (APHA, 1995).

$$\text{Mg (mg/L)} = \text{Hardness (as mg/L } CaCO_3) – \text{Calcium hardness (as mg/L } CaCO_3) \times 0.244$$

12. Free CO_2

For the determination of free carbondioxide content of water sample, 100 ml of water sample was taken in a conical flask and a few drops of phenolphthalein indicator were added to it. If the colour turns pink, free CO_2 is absent. If the sample remained colourless, it was titrated against standard NaOH solution (0.05N). At the end point the colour of solution changed into pink.

Calculation

$$\text{Free } CO_2\text{, mg/L} = \frac{\text{Titrant's value} \times \text{Strength of NaOH} \times 44 \times 1000}{\text{Volume of sample}}$$

13. Biochemical Oxygen Demand (BOD)

For the determination of BOD, dilution water (aerated water) was prepared in a container by aerating with air in distilled water for about 30 minutes. 1 ml each of phosphate buffer, magnesium sulphate, calcium chloride and ferric chloride were added in a liter of volumetric flask. Then aerated water was added upto the mark of volumetric flask and the mixture was shaken thoroughly. The dilutions of water sample were prepared according to the expected BOD range. 20 ml of dilution water was taken out of the volumetric flask and 20 ml of sample water was added to the flask and shaken well so that the sample water is 50 times diluted.

Two set of BOD bottles were taken. The diluted sample in the volumetric flask was filled in both the bottles. One of the bottles was wrapped with black cloth and stoppered. It was then kept in incubator at 20^0C for 5 days. The DO content in the water sample of second BOD bottle was determined by Winkler's Iodometric method. After 5 days of incubation, the final DO (D_5) was measured by Winkler's Iodometric method.

Calculation:

$$\text{Dissolved Oxygen (mg/L)} = \frac{(\text{Vol.} \times \text{N}) \text{ of titrant} \times 8 \times 1000}{V_2 (V_1 - V)/V_1}$$

Where,

N = Normality of titrant ($Na_2 S_2 O_3$) in ml.

V_1 = Volume of BOD bottle

V_2 = Volume of part of content used for titration.

V = Volume of $MnSO_4$ and alkaline KI added.

BOD (mg/L) = $(D_O - D_5)$ ×Dilution factor

Where,

D_0 = Initial DO in the sample

D_5 = DO after 5 days incubation at 20^0C.

14. Chemical Oxygen Demand (COD)

Chemical Oxygen Demand was determined by open reflux method (APHA, 1995). 20 ml sample was taken in a 500 ml COD flask. Then 10 ml of 0.25 N potassium dichromate solution, a pinch of Ag_2SO_4 and $HgSO_4$ were added to the flask. 20 ml of conc. H_2SO_4 was added. The content of the flask was refluxed at least for 2 hrs on a water bath. The flask was removed, cooled under tap water and distilled water was added to make the final volume to about 140 ml. 2-3 drops of ferroin indicator was added to the flask and shaken well. The content of the flask was titrated against 0.1N ferrous ammonium sulphate (FAS). The above process was repeated for distilled water (blank solution).

Calculation

$$\text{COD mg/L} = \frac{(b-a) \times \text{Strength of F.A.S.} \times 8 \times 1000}{\text{Volume of sample}}$$

Where,

a =Volume of titrant used with sample

b = Volume of titrant used with blank.

15. Orthophosphate (PO_4^- P)

For the determination of orthophosphate, 100 ml of filtered clear sample was taken in a volumetric flask. 2 ml of ammonium molybdate followed by 5 drops of stannous chloride solution was added to the flask. Blue colour appeared after sometime. The reading was taken at 690 nm on a spectrophotometer using a distilled water blank with the same amount of chemicals. The reading was taken after 5 minutes but before 12 minutes of the addition of the last reagent i.e. $SnCl_2$. Finally the phosphate concentration of the sample was determined with the help of standard calibration curve.

Preparation of standard curve

The standard calibration curve containing concentration and absorbance was prepared as follows. 10 ppm (mg/L) of standard phosphate (K_2HPO_4) solution was taken. Standard solution of 0.5 mg/L was prepared by diluting 5.0 ml of standard phosphate solution to 100 ml. Then various dilutions at the interval of 0.1 mg/L were made from the standard phosphate solution. Two ml of ammonium molybdate followed by 5 drops of stannous chloride solution was added to the flask. The reading was taken at 690 nm on a spectrophotometer and a standard curve was made by plotting a graph of absorbance against concentration.

16. Iron

The iron contained in water is usually determined by Phenanthroline method. 50 ml of water sample was taken in a conical flask. 2 ml of conc. HCl and 1 ml of Hydroxylamine hydrochloride solution was added to the sample. Some glass beads were added in the flask and heated. The content was boiled to half of the volume for dissolution of all the iron. 10 ml of Ammonium acetate buffer and 4 ml of Phenanthroline were added. An orange red colour appeared. The volume was made 100 ml by adding distilled water and the flask was shaken well. The solution was kept for 10 minutes for maximum colour development. The reading was taken for the absorbance at 510 nm on a spectrophotometer. The concentration of Fe was directly determined from the standard curve.

Preparation of standard curve

Standard solution of 0.5 ppm (0.5 mg/L) was prepared by adding 2 ml conc. HCl, 1 ml Hydroxylamine hydrochloride, 10 ml Ammonium acetate buffer and 4 ml Phenanthroline to 5 ml standard solution of iron in a volumetric flask and then diluting the solution to 100 ml. Similarly 1.0 ppm, 2.0 ppm, 3.0 ppm, 4.0 ppm standard solution were prepared by adding 10 ml, 20 ml, 30 ml, 40 ml standard iron solution respectively to the same quantities of all other constituents mentioned above and diluting these to 100 ml. The absorbance of all the standard solutions were measured using spectrophotometer and a standard curve was prepared.

17. Nitrate-nitrogen (NO_3 - N)

Nitrate-Nitrogen is determined by Phenoldisulfonic acid method. 50 ml of filtered sample or an aliquot containing not more than 1 mg/L of NO_3^- N was taken in a conical flask. An equivalent amount of silver sulphate solution was added in the aliquot to remove chlorides (1mg/L Cl = 1 ml Ag_2 SO_4 solution). The content was heated slightly and filtered to remove the precipitate of AgCl. The filtrate was evaporated in a porcelain basin to dryness and cooled. 2 ml of phenoldisulfonic acid was added to dissolve the residue and the contents was diluted to 50 ml. 6 ml of liquid ammonia was added to develop a yellow colour. The reading was taken at 410 nm. The concentration of NO_3^- N was calculated from the standard curve.

The standard curve was prepared between concentration and absorbance 0.0 mg N/l to 1.0 mg N/l at the interval of 0.1. The absorbance of the standard solution was found using the same procedure described for the sample except the removal of the chlorides as in steps 2-3.

18. Total Solids

Total solids are determined as the residue left after evaporation of the unfiltered sample. Total solids include total suspended solids and total dissolved solids. An evaporating dish made up of porcelain of 100 ml capacity was taken and ignited in burner flame for 15 minutes and cooled in a desiccator and weighed. 100 ml of unfiltered sample poured into the dish and evaporated. The residue left after evaporation was heated in an oven at 103-105ºC for one hour and the final weight was taken after cooling in a desiccator.

Calculation

$$\text{Total solids, mg/L} = \frac{(A - B) \times 1000 \times 1000}{V}$$

Where, A = Final weight of dish in gm.

B = Initial weight of dish in gm.

V = Volume of sample taken in ml.

19. Total Dissolved Solids

Total dissolved solids are determined as the residue left after evaporation of filtered sample. An evaporating dish made up of porcelain of 100 ml capacity was taken and ignited in burner flame for 15 minutes and cooled in a desiccator and weighed. The sample was filtered through whatman's filter paper. 100 ml of the filtered sample was evaporated in pre-weighed evaporating dish on a water bath. The residue left after evaporation was dried at 103-105ºC in an oven for an hour and the final weight was taken after cooling in a desiccator.

Calculation

$$\text{Total dissolved solids, mg/L} = \frac{(A- B) \times 1000\times 1000}{V}$$

Where,

A = Final weight of dish in gm.

B = Initial weight of dish in gm.

V = Volume of sample taken in ml.

20. Total Suspended Solids (TSS)

Total suspended solids are that portion of solid present in water which are not dissolved and can be held upon a filter paper of 2.0 µm (or smaller) pore size under specific condition. It also includes the settleable solids. They give the water a muddy or dirty appearance reducing the visibility for aquatic animals and retard light penetration. They make the water unfit for drinking and other domestic needs.

Total suspended solids are determined as the difference between the total solids and total dissolved solids.

TSS = TS – TDS

21. Total chromium

For the determination of total chromium, 50 ml of sample (containing 10-100 µg Cr) was taken in a conical flask and a few drops of methyl orange were added. Conc. NH_4OH was added until the solution just became basic. This was indicated by the change of colour of methyl orange from red to yellow. H_2SO_4 (1+1) was added dropwisely until the solution was just acidic and further 1 ml of the acid was added in excess. The solution was boiled for 2 minutes. 1ml sodium azide (NaN_3) solution was added and boiling continued. If the red colour did not disappear within 1⁄2 min. further 1ml NaN_3 was added. Boiling was continued for 1min. more after fading of the colour. The contents were cooled and 5 drops of H_3PO_4 was added.

The contents were diluted to 100 ml in a volumetric flask. 2 ml diphenylcarbazide solution was added to develop the colour. The contents was mixed and kept for 5 to 10 min. to develop the full colour (red-violet). The intensity of the color was measured at 540 nm. The standard curve in the range of 1 to 10µg Cr was prepared.

22. Potassium

In order to determine only the dissolved potassium the sample was filtered through a filter paper to remove any suspended matter which otherwise may clog the capillary of the flame photometer. Then the concentration of potassium was determined using flame photometer. Calibration curves for potassium in the ranges of 0 to 1, 0 to 10 and 0 to 100 mg/L was made by using various standard solutions of sodium. The potassium concentration was determined by using curve of suitable range depending upon the initial concentration of potassium in the sample. The samples having more potassium were diluted to come in the range of determination.

Calculation

K (mg/L) = (mg/L K in diluted aliquot)* Dilution factor

4.2.1.2 Microbiological water quality

4.2.1.2.1 Multiple tube fermentation technique

Water samples for microbiological examination were collected in bottles (glass) that had been cleansed and sterilized by keeping more than 60 minutes at a temperature of 170ºC in an oven. When sample was collected, ample air space (at least 2.5 cm) was left in the bottle to facilitate mixing by shaking, before examination. They were packed in ice box and brought to the laboratory as soon as possible and fecal coliforms were studied by MPN method. For this, glasswares including sample bottles, test tubes, pipettes, containers for culture medium, culture plates (petri plates) were sterilized.

Two techniques are available for the estimation of most probable number of coliforms in a water sample- the multiple tube fermentation technique and the membrane filter (MF) technique. Both the techniques are in use. The membrane filter technique involves inoculating the sample and/or its several dilutions in a suitable liquid medium. After the expiry of the incubation period, the tubes are examined for gas production by the coliform organisms. This test is known as the presumptive test. Since this reaction may also be produced by the organisms other than the coliforms, the positive tubes from the presumptive test are subjected to a confirmatory test. For a very definite presence of coliform bacteria, the completed test is carried out. The density of bacteria is calculated on the basis of positive and negative combination of the tubes using MPN tables. This density however, is only a most probable number of the bacteria and is not actual bacterial density. Thus multiple tube fermentation technique involves 3 sequential stages: Presumptive, Confirmed and Completed tests.

a. Presumptive Test:

Procedure

Dilutions were selected according to the expected bacterial count. 5 tubes of 10 ml double strength medium with 10 ml sample, 5 tubes of 10 single strength medium with 1 ml sample and 5 tubes of 10 ml single strength medium with 0.1 ml sample were taken and labeled as D.S., S.S (1 ml) and S.S.(0.1 ml). D.S., S.S (1 ml) and S.S. (0.1 ml) tubes were aseptically inoculated with 10 ml, 1.0 ml and 0.1 ml of water sample respectively using sterile pipette. All the water samples were vigorously shaken immediately before removing sample aliquots to inoculate the series of test tubes. One Durham’s tube was inverted in each test tube and all the inoculated tubes were incubated at 35-37ºC for 48 hours. After 48 hours of incubation, all the tubes were examined for gas production. Those showing gas in the Durham’s tube were recorded as positive (+). The tubes showing positive test are subjected to confirmatory test, as gas production is not the only criterion for a positive test.

b. Confirmed Test

Procedure

The fermentation tubes with positive results in the presumptive test were inoculated into Brilliant Green Lactose Broth (BGLB) tubes (containing 10 ml BGLB medium). For this one loopful of medium was transferred to BGLB broth. Inoculated tubes were incubated at 35-37ºC for 48± 2 hours. After 48 hours of incubation, all the tubes were examined for gas production. Those showing the gas production were recorded as positive.

c. Completed Test

Procedure

The inoculum from the BGLB tubes was streaked on the Eosin Methylene Blue (EMB) agar petri plates in such a way that the colonies after separation have a distance of 0.5 cm. These plates were incubated at 35-37ºC for 24 hours. The plates were examined for bacterial growth and colony appearance after 24 hours. An isolated coliform colony from each EMB agar plate was inoculated into the tubes of McConkey's broth and nutrient agar slant. Broth tubes and agar slants were incubated at 35-37ºC for 24 hours. Broth tubes were observed for the gas production. The colonies from the agar slants were subjected to the gram staining.

4.2.2 Household Information Collection

The household survey was conducted by direct interview with household member using structured questionnaire with some close ended and some open ended questions. Three members research team (classmates) were mobilized for survey to bring the same level of required information. Before conducting the formal survey, discussions among research members on subject matter was done to obtain the similar and equal understanding for filling the questionnaire. Interview was made with the family head member as far as possible, in absence of family head interview was made with knowledgeable member of the household. Questionnaire was developed focusing on five main parts (Appendix XXVI) including household information. Altogether 85 households (10 % of the total households) were taken in the selected area. General information about SLFS and perception of local people towards its impact on different aspects of their socioeconomic life was collected.

4.3 Data Processing and Analysis

Primary data collected from field survey, water quality analysis and questionnaire survey were analyzed and compared with secondary data. For data processing, Microsoft Excel was used as main tool. Data collected by group discussion, unstructured interviews and observations were referred for the analysis of the collected data.

Statistical analysis

4.3.1 Analysis of Variance (ANOVA)

One way ANOVA was applied to test the significance of temporal/monthly/seasonal and spatial (upstream to downstream of the river) variation of physicochemical parameters of surface water of Kolpu Khola. The statistical software SPSS 11.5 was used for the analysis.

4.4 Selection of sampling sites

The sampling stations of Kolpu Khola were selected on the basis of reconnaissance survey throughout the River from confluence of Thulo Khola and Kolpu Khola up to Jyamire Kholso. The sampling stations in the Kolpu Khola were fixed by the confluence of rivers and rivulets joining into the River. A reference station at upstream of the River for surface water and a private well for groundwater were taken for facilitating the comparative study of the water quality obtained during the study. Other stations in the River were either in the immediate downstream, upstream of the confluence of the river or leachate discharge.

4.5 Sites of Study

Figure 4.1: Map showing different stations for surface water and groundwater sampling and the adjoining VDCs of the River

All together 9 samples were collected for analysis of water quality- 1 sample from leachate tank, 1 from monitoring well, 1 from private well (well dug for drinking purpose) for ground water analysis and remaining 6 samples from the Kolpu Khola at various distances from the landfill. These stations are described below.

Station 1: Okharpauwa

The sampling station 1 is located behind the bridge at about a distance of 300 metre upstream from the point of confluence of Thulo Khola and Kolpu Khola. It is the upstream part of Kolpu Khola. There is agricultural field on the right side of the river. The substrate consists of mainly boulders, cobbles, gravels and sand. Sewerage discharge into the river was absent.

Station 2: Sisdol, Okharpauwa

The sampling station 2 is located about 30 meters downstream from the confluence of Thulo Khola and Kolpu Khola. At this point leachate that comes from leakage from the landfill gets mixed into the Kolpu Khola. The Sisdol landfill site lies on the right side of this station. Simkhada gaun is situated on the uphill side on the left bank of the river. Its substrate consists of mainly boulders, cobbles, gravels and sand. There is agricultural field on the left side of the river.

Station 3:

The sampling station 3 is located on the way to Banchare Danda at a distance of about 1 kilometer from the confluence of Thulo Khola and Kolpu Khola. It lies in the upstream part of the river from the bridge which lies on the way to Banchare Danda from Aletar. There is agricultural field on the left side of the river.

Station 4: Chilaune gaun (Upstream to Bachhbichhe confluence)

The sampling station 4 is located just before the confluence of Kolpu Khola and Bachhbichhe Khola. It lies at a distance of approximately 4.4 kilometers from the confluence of Thulo Khola and Kolpu Khola.

Station 5: Soti

The sampling station 5 is located at a distance of about 5.3 kilometers from the confluence of Thulo Khola and Kolpu Khola. This site is just before the confluence of

Khole Khola and Kolpu Khola. The flood plain on the left side of the River is used for agricultural activities. There is sparse settlement on the right uphill side of the river.

Station 6: Bhadarthumka

The sampling station 6 is located at a distance of about 6.32 kilometers from the confluence of Thulo Khola and Kolpu Khola. It lies just upstream of the confluence of Jyamire Khola (rivulet) and Kolpu Khola. Bhadarthumka lies to the north and Jyamire gaon lies to the south of the station.

Station 7: Bore hole-2.

The sampling station 7 belongs to monitoring well made for periodic monitoring of groundwater quality. It lies on the right side of Kolpu Khola. It is closer to the leachate pond made for valley 2. Station 7 is designated as GW-2.

Station 8: Private well

The sampling station 8 belongs to private well which is located about 150 meters away from the Sisdol landfill Site (SLFS) on the northeastern part. It lies on the right side of Kolpu Khola. There is a patch of agricultural land between the well and the Kolpu Khola. Station 8 is designated as GW-1.

Station 9:

The sampling station 9 belongs to leachate pond made for valley 2 of Sisdol landfill Site.

4.6 Sampling frequency

The physicochemical parameters (except potassium and total chromium) of leachate, groundwater and surface water were analyzed from December, 2007 to August, 2008 for 4 months. However the microbiological parameter viz. fecal coliform, potassium and total chromium were studied seasonwise for 3 seasons from winter to monsoon season. The groundwater of private well was analyzed for four months i.e. three seasons. However the groundwater of bore hole-2 (GW-2) was analyzed only for three months because the groundwater could not be taken due to blockage of the pipe by mud on August.

CHAPTER V

5. RESULTS

5.1.1 Physicochemical Parameters of surface water

5.1.1.1 Temperature

The monthly variation of water temperature of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.1. The surface water temperature of 16.0°C, 20.0°C, 17.0°C, 16.0°C, 17.0°C and 16.5ºC respectively at stations 1, 2, 3, 4, 5 and 6 of Kolpu Khola of December decreased and reached the minimum level of 12.0°C at station 1, 10.5°C at station 2, 13.0°C at station 3, 13.5°C at station 4, 14.5°C at station 5 and 13ºC at station 6 in February. After these minima, the surface water temperature increased and reached maximum level in August at all stations i.e. 22.0°C; 26.0°C; 23.5°C ; 24.5°C ; 25.0°C and 26.0ºC respectively at stations 1, 2, 3, 4, 5 and 6.

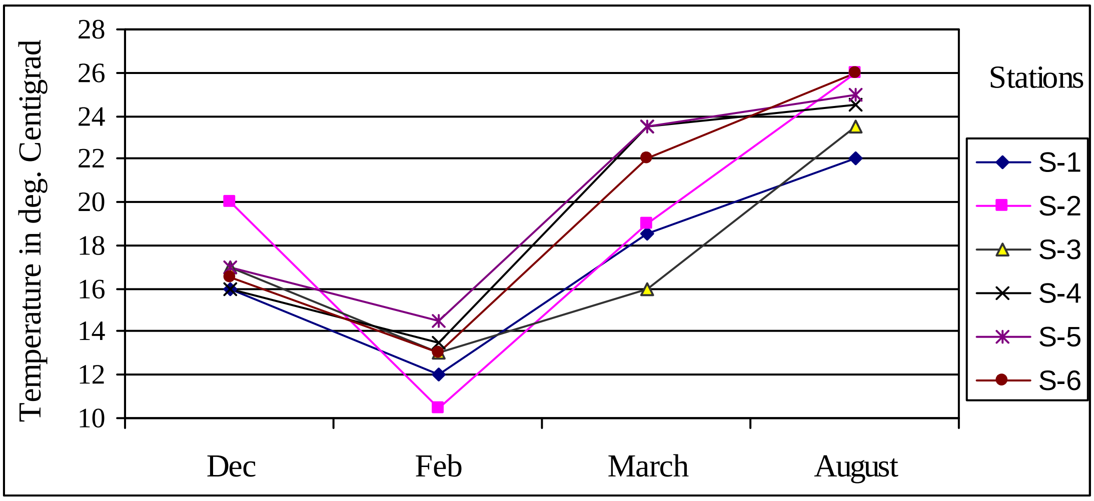

Figure 5.1: Monthly variation of water temperature of Kolpu Khola

On the average, surface water temperature recorded were 15.5 ± 3.3°C at station 1, 16.5 ± 5.2 °C at station 2, 15.3 ± 2.1°C at station 3, 17.7 ± 5.2°C at station 4; 18.3 ± 4.6°C at station 5 and 17.2 ± 4.5ºC over the four months of the investigation period. The average value given in the results is the average value of four samples taken during four months of study period and the value after '±' indicates the standard deviation of the values obtained in four different months. In general, the surface water temperature increased from station 1 to 2, decreased at station 3, again increased to station 5 from where it again decreased to station 6.

5.1.1.2 pH

The monthly variation of pH of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.2. At stations 2, 5 and 6 the pH increased from December (7.2 at station 2, 7.10 at station 5 and 7.1 at station 6) till February and then decreased till March (7.0 at station 2, 7.4 at station 5 and 7.1 at station 6). At stations 1 and 4 the pH increased gradually from December (7.0 at station 1 and 7.3 at station 4) till March (7.2 at station 1 and 7.5 at station 4). At station 3, pH decreased from 7.2 in December to 6.7 in March. From March pH at the stations 1, 4 and 5 decreased till August (7.1 at station 1, 7.1 at station 4 and 7.2 at station 5) whereas the pH at stations 2 and 3 increased till August (7.2 at station 2 and 7.0 at station 3).

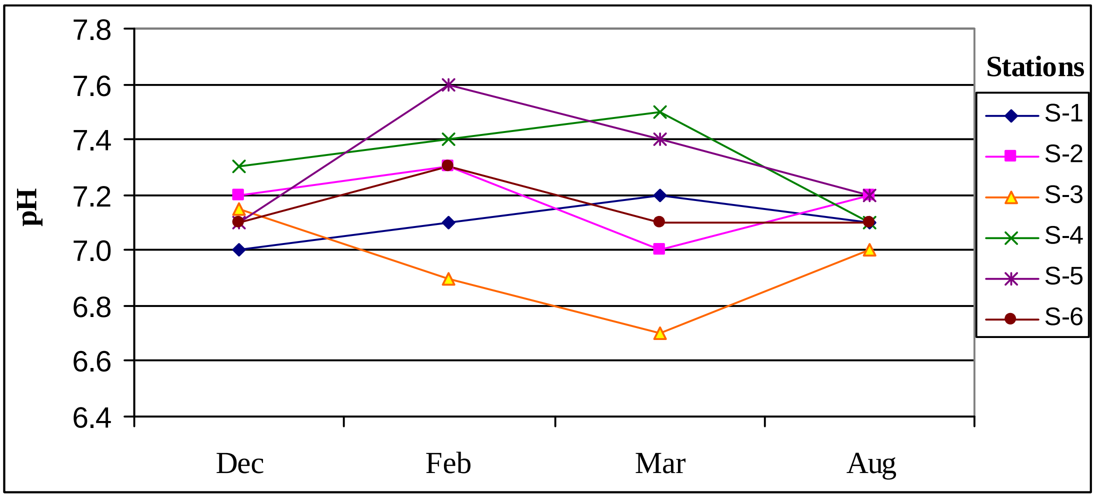

Figure 5.2: Monthly variation of pH of Kolpu Khola

On the average, the pH of surface water of the river recorded were 7.1 ± 0.1, 7.2 ± 0.1, 6.9 ± 0.2, 7.3 ± 0.2, 7.3 ± 0.2 and 7.2 ± 0.1 at stations 1, 2, 3, 4, 5 and 6 respectively during the investigation period. In general pH increased from station 1 to 2, decreased from station 2 to 3, again increased from station 3 to 4 and then decreased from station 5 to 6 throughout the investigation period.

5.1.1.3 Electrical conductivity

The monthly variation of electrical conductivity of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.3. The electrical conductivity of 57µS/cm, 113µS/cm, 135µS/cm and 127µS/cm at stations 1, 2, 5 and 6 of December increased in February while the electrical conductivity of 142µS/cm at station 3 and 161µS/cm at station 4 of December decreased till February. Then after electrical conductivity at station 1, 4, 5 and 6 increased in March but it decreased from February to March at station 2 and 3. From March the conductivity at all sites of Kolpu Khola decreased till August (49µS/cm, 94µS/cm, 75µS/cm, 89µS/cm, 63µS/cm and 51µS/cm at stations S_1, S_2, S_3, S_4, S_5 and S_6 respectively).

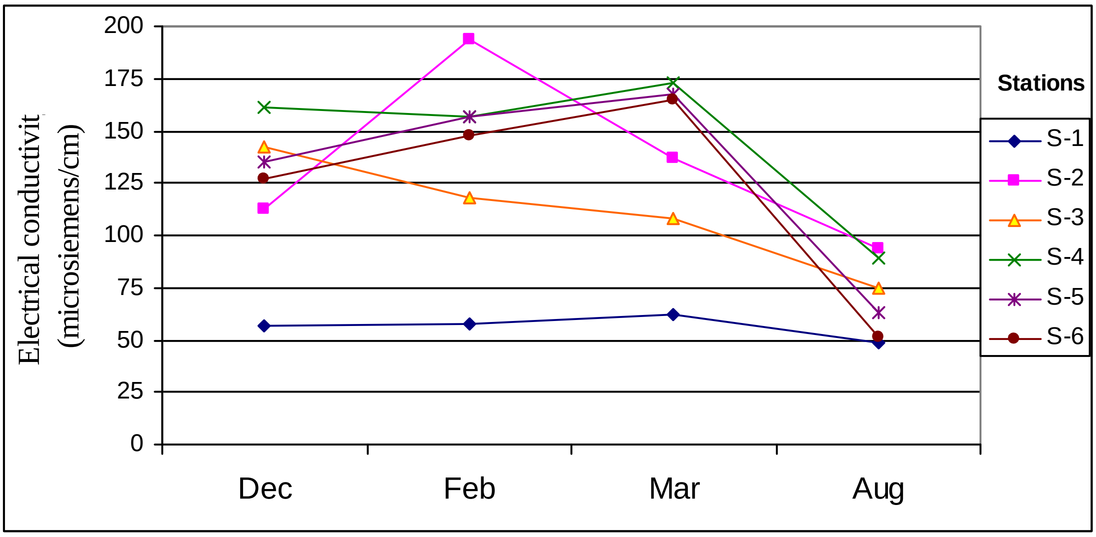

Figure 5.3: Monthly variation of Electrical conductivity of Kolpu Khola

On the average, the electrical conductivity of surface water of the river recorded were 57 ± 5µS/cm, 134 ± 43µS/cm, 111 ± 28µS/cm, 145 ± 38µS/cm, 131 ± 47µS/cm and 123 ± 50µS/cm at stations 1, 2, 3, 4, 5 and 6 respectively during the investigation period. In March and August the electrical conductivity of surface water of the river fluctuated from station 1 to 4 and then decreased from 4 to 6. The average electrical conductivity of surface water of the river fluctuated from stations 1 to 4 and then decreased up to station 6 along the river. Among all the stations during the entire investigation period, lowest electrical conductivity of 49µS/cm was recorded at station 1 in August and the highest electrical conductivity of 194µS/cm was recorded at station 2 in February.

5.1.1.4. Transparency

The secchi disc transparency at station S_1 (20 cm) and S_2 (11 cm) increased from December till March (25 cm at S_1 and 20 cm at S_2) and then decreased to August. At stations 3, 4, 5 and 6 secchi disc transparency fluctuated from December till August. The minimum level of secchi disc transparency was observed in February at three stations 4, 5 and 6. During the study period the maximum secchi disc transparency of 35 cm was observed at station 6 in March

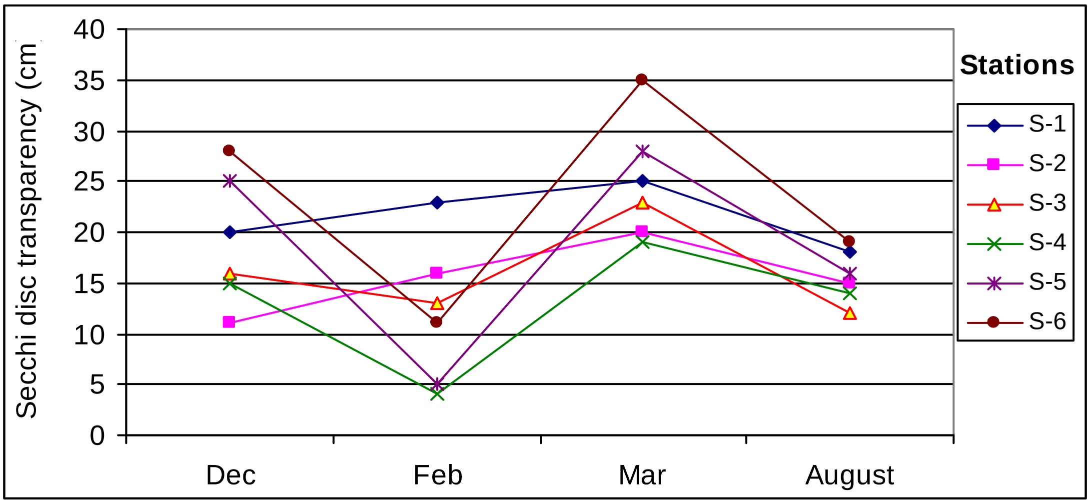

Figure 5.4: Monthly variation of secchi disc transparency of Kolpu Khola

5.1.1.5 Velocity

The monthly variation of velocity of Kolpu Khola over the period of four months (2007/2008) is shown in the figure 5.5. The velocity of water so obtained corresponds to the velocity of water at surface. The velocity of river water decreased from December (0.46 m/s at station 1; 0.69 m/s at station 2; 0.66 m/s at station 3; 0.71 m/s at station 4; 0.75 m/s at station 5 and 0.70 m/s at station 6) to February (winter) and then increased till August i.e. monsoon (1.05 m/s at station 1; 0.86 m/s at station 2; 0.85 m/s at station 3; 0.93 m/s at station 4; 0.88 m/s at station 5 and 0.82 m/s at station 6).

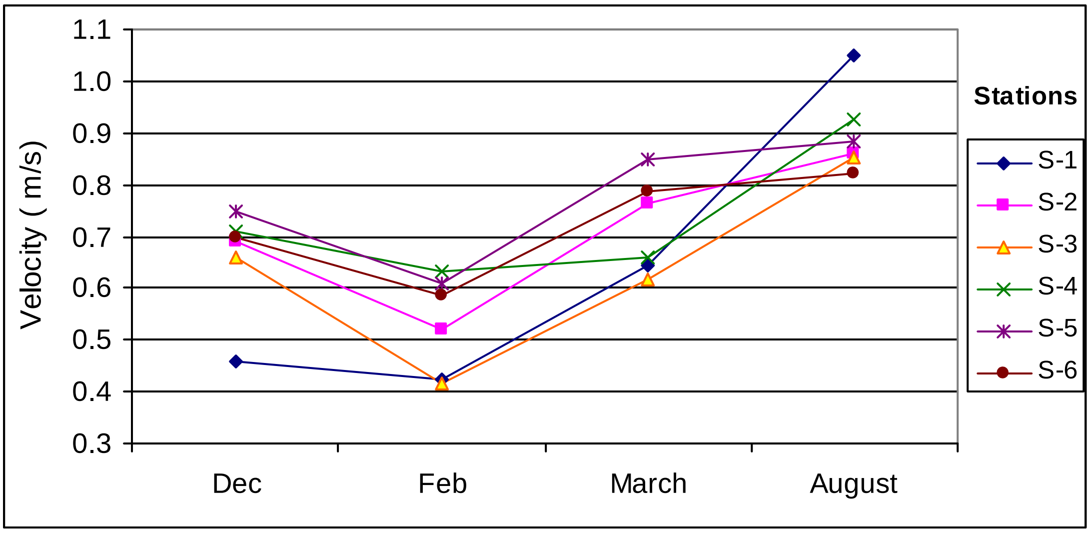

Figure 5.5: Monthly variation of velocity of Kolpu Khola

On the average, the velocities of the river water recorded were 0.64 ± 0.28 m/s at station 1, 0.71 ± 0.14 m/s at station 2, 0.64 ± 0.18 m/s at station 3, 0.73 ± 0.13 m/s at station 4, 0.77 ± 0.12 m/s at station 5 and 0.72 ± 0.10 m/s at station 6 during the investigation period. The velocity was higher at station 2 compared to station 3. Among all the stations during the entire investigation period, the lowest velocity of 0.42 m/s was recorded at station 3 in February (winter) and the highest velocity of 1.05 m/s was recorded at station 1 in August (monsoon).

5.1.1.6 Alkalinity

The alkalinity was found only due to the bicarbonate (HCO_3^-) ions in the surface water of the river because carbonate (CO_3^{--}) alkalinity and hydroxide (OH^-) alkalinity never appeared in the samples collected at all stations during the entire investigation period. Therefore, total alkalinity is equal to bicarbonate alkalinity.

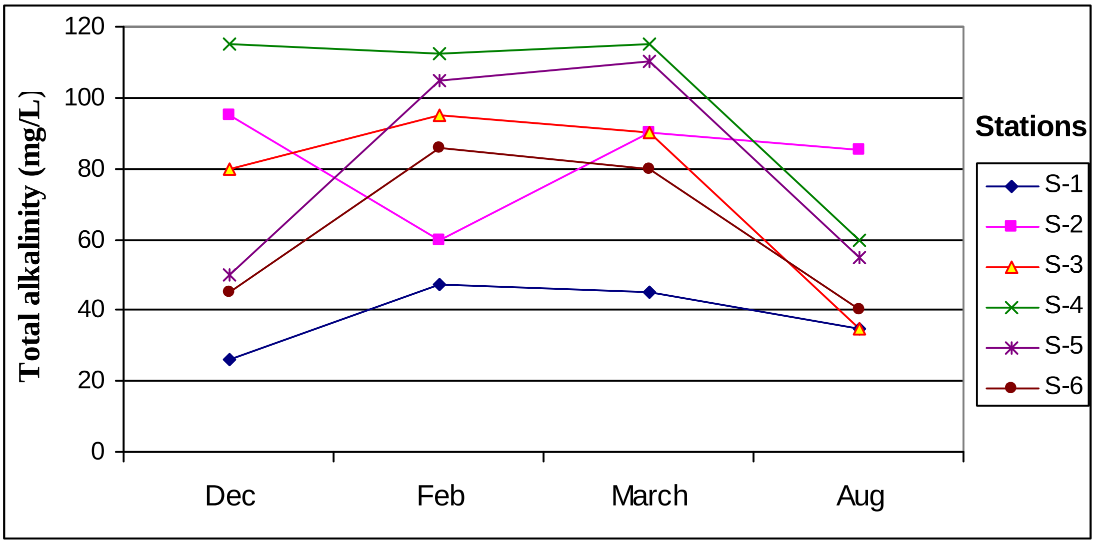

Figure 5.6: Monthly variation of total alkalinity of Kolpu Khola

The monthly variation of total alkalinity of surface water of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.6. At stations 2 and 4 the total alkalinity fluctuated from December till August. The trend of fluctuation was similar in these two sites. At stations 1, 3, 5 and 6 the total alkalinity increased from December (26 mg/L at station 1, 80 mg/L at station 3, 50 mg/L at station 5 and 45 mg/L at station 6) till February. From February, the total alkalinity at site 1, 3 and 6 decreased till August (35 mg/L at station 1; 85 mg/L at station 3 and 40 mg/L at station 6). The total alkalinity at site 5 gradually increased from December (50 mg/L) till March (110 mg/L) and finally decreased to August (55 mg/L).

On the average, the total alkalinity or bicarbonate alkalinity recorded were 38 ± 10 mg/L, 82 ± 16 mg/L, 75 ± 27 mg/L, 100 ± 27 mg/L, 80 ± 32 and 62 ± 24 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively during the investigation period. In February, the total alkalinity increased from site 1 (47.5 mg/L) to site 4 and then decreased to site 6 (86 mg/L). The total alkalinity decreased from site 5 to 6 in all the four months of investigation period.

5.1.1.7 Dissolved Oxygen

The monthly variation of dissolved oxygen of Kolpu Khola over the period of four months (2007/2008) is shown in the figure 5.7. The monthly variation of dissolved oxygen showed that oxygen content of 6.08 mg/L at station 1, 5.68 mg/L at station 2; 5.88 mg/L at station 3; 6.49 mg/L at station 4, 7.30 mg/L at station 5 and 7.50 mg/L at station 6 in December increased to February and then decreased to March. From March the DO content at station 1, 2 and 5 decreased till August (6.49 mg/L at site 1; 4.86 mg/L at site 2 and 6.89 mg/L at site 5) whereas the DO content at site 3, 4 and 6 increased till August (6.49 mg/L at site 3; 6.69 mg/L at site 4 and 7.90 mg/L at site 6).

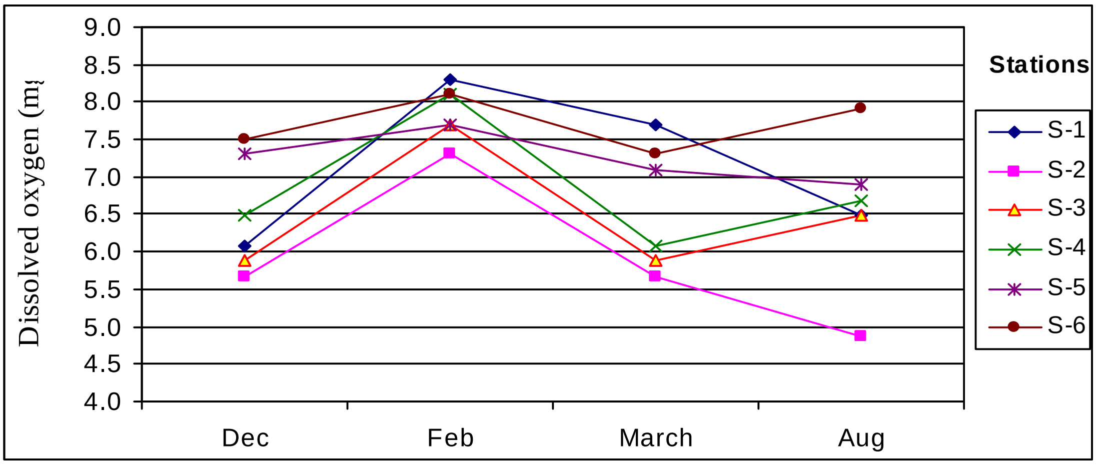

Figure 5.7: Monthly variation of Dissolved Oxygen of Kolpu Khola

On the average, the dissolved oxygen content of the water of the Kolpu Khola recorded were 8.82 ± 1.04 mg/L at station 1, 6.22 ± 1.02 mg/L at station 2, 6.49 ± 0.86 mg/L at station 3, 6.89 ± 0.88 mg/L at station 4, 7.36 ± 0.34 mg/L at station 5 and 7.64 ± 0.37 mg/L at station 6. In general, the dissolved oxygen content of the river water increased from station 2 to 6. The dissolved oxygen at station 2 was less than that at station 1. The highest dissolved oxygen content of surface water of the river was recorded at station 1 during the investigation period except in December and August and the lowest dissolved oxygen was always recorded at station 2 during the entire investigation period. During the entire investigation period, the highest dissolved oxygen content recorded was 8.31 mg/L at station 1 in February whereas the lowest dissolved oxygen content was 4.86 mg/L at station 2 in August.

5.1.1.8 Chloride

The monthly variation of chloride content of Kolpu Khola over the period of four months (2007/2008) is shown in the figure 5.8.

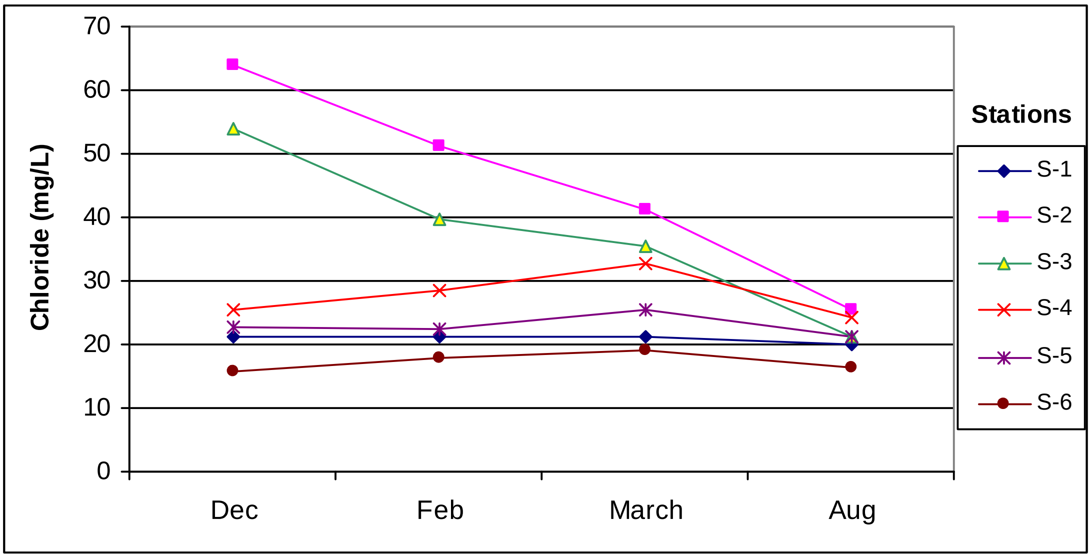

Figure 5.8: Monthly variation of chloride content of Kolpu Khola

At site 1, chloride content remains constant from December to March. At sites 2 and 3, chloride content gradually decreased from December (63.9 mg/L at site 2 and 53.96 mg/L at site 3) till August. At site 4 and 6 chloride content gradually increased from December (25.56 mg/L at station 4 and 15.62 mg/L at station 6) till March. At site 5, chloride content decreased from December (22.72 mg/L) till February and then increased to March (32.66 mg/L). The chloride content at all sites decreased from March (pre-monsoon) till August (monsoon). Throughout the investigation period, chloride content was minimum at site 6 and maximum at site 2. The maximum and the minimum chloride content were recorded at station 2 (63.9 mg/L) and at station 6 (15.62 mg/L) respectively in December.

On the average, the chloride content of surface water of the Kolpu Khola recorded were 20.95 ± 0.71 mg/L, 45.44 ± 16.19 mg/L, 37.63 ± 13.44 mg/L, 27.69 ± 3.75, 23.00 ± 1.81 mg/L and 17.22 ± 1.57 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively during the investigation period. In general, chloride content increased from site 1 to 2 and then decreased from site 2 to 6.

5.1.1.9 Free CO_2

The monthly variation of free carbon dioxide content of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.9. At site 1, free CO_2 content remained same in December and February (6.60 mg/L) which then increased till August (13.20 mg/L). At site 2, free CO_2 content increased from December (37.40 mg/L), reached maximum level in February (52.80 mg/L) and then decreased till August (15.40 mg/L). At sites 4, 5 and 6, free CO_2 content decreased from December (6.60 mg/L at site 4, 26.40 mg/L at site 5 and 5.50 mg/L at site 6) to February and then increased till August (28.60 mg/L at site 4, 37.40 mg/L at site 5 and 18.30 mg/L at station 6).

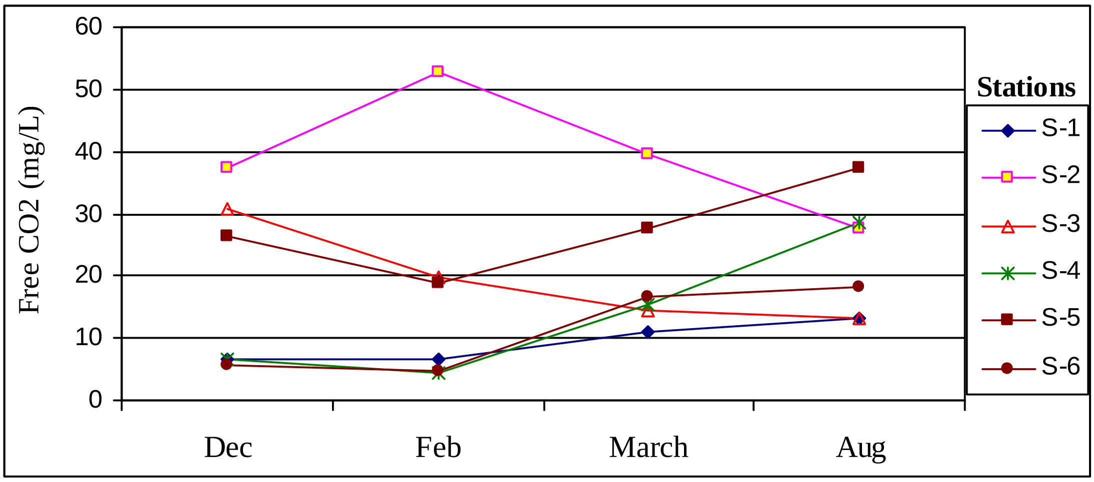

Figure 5.9: Monthly variation of free carbon dioxide content of Kolpu Khola

On the average, the free CO_2 content of water of the Kolpu Khola was recorded as 9.35 ± 3.30 mg/L, 39.33 ± 10.41 mg/L, 19.53 ± 8.05 mg/L, 13.75 ± 10.98 mg/L, 27.56 ± 7.59 mg/L and 11.29 ± 7.10 mg/L at sites 1, 2, 3, 4, 5 and 6 respectively during the investigation period.

5.1.1.10 Hardness

The monthly variation of hardness of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.10. At stations 1, 2, 4, 5 and 6, the hardness increased from December (16 mg/L as $CaCO_3$ at station 1, 60 mg/L as $CaCO_3$ at station 2, 70 mg/L as $CaCO_3$ at station 4, 64 mg/L as $CaCO_3$ at station 5 and 56 mg/L as $CaCO_3$ at station 6) till February. The hardness at station 3 remained same during December and February. From February the hardness at stations 2, 3, 4, 5 and 6 decreased till August (38 mg/L as $CaCO_3$ at station 2, 34 mg/L as $CaCO_3$ at station 3, 32 mg/L as $CaCO_3$ at station 4, 36 mg/L as $CaCO_3$ at station 5 and 24 mg/L as $CaCO_3$ at station 6) but the hardness at station 1 increased from February (20 mg/L as $CaCO_3$) to March and then decreased till August (10 mg/L).

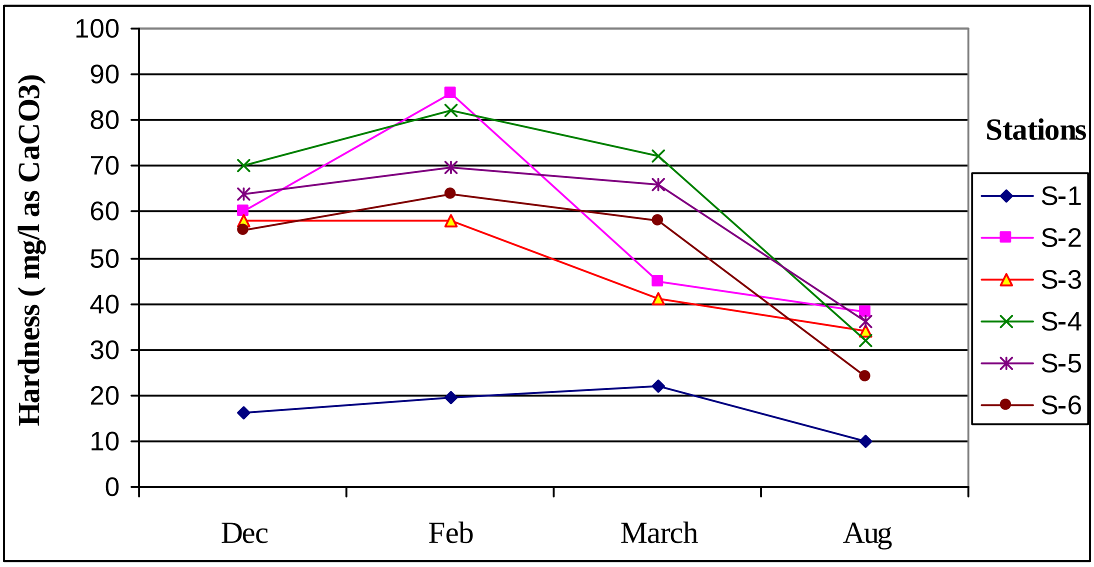

Figure 5.10: Monthly variation of hardness of Kolpu Khola

On the average, the hardness recorded were 17 ± 5 mg/L; 57 ± 21 mg/L; 48 ± 12 mg/L; 64 ± 22 mg/L, 59 ± 15 mg/L and 50 ± 18 mg/L as $CaCO_3$ respectively at stations 1, 2, 3, 4, 5 and 6 in the river during the investigation period. The hardness fluctuated from stations 1 to 5 and then decreased to station 6 in December, February and March. During the entire investigation period, the minimum hardness of 10 mg/L as $CaCO_3$ was observed at station 1 in December and the maximum hardness of 86 mg/L as $CaCO_3$ was observed at station 2 in February.

5.1.1.11 Calcium and calcium hardness

Figures 5.11 and 5.12 show the monthly variation of calcium and calcium hardness of Kolpu Khola over the period of four months (2007/2008). The pattern of variation of calcium is similar to that of calcium hardness because calcium hardness is due to the presence of calcium and they have linear relationship.

Calcium and calcium hardness increased from December (3.21 mg/L of calcium content and 8 mg/L as $CaCO_3$ of calcium hardness at station 1; 15.23 mg/L of calcium content and 38 mg/L as $CaCO_3$ of calcium hardness at station 2, 13.62 mg/L of calcium content and 34 mg/L as $CaCO_3$ of calcium hardness at station 3, 23.25 mg/L of calcium content and 58 mg/L as $CaCO_3$ of calcium hardness at station 4, 20.84 mg/L of calcium content and 52 mg/L as $CaCO_3$ of calcium hardness at station 5; 16.83 mg/L of calcium content and 42 mg/L as $CaCO_3$ of calcium hardness at station 6) till February. From then both calcium and calcium hardness decreased till August (2.40 mg/L of calcium content and 6 mg/L as $CaCO_3$ of calcium hardness at station 1, 8.82 mg/L of calcium content and 22 mg/L as $CaCO_3$ of calcium hardness at station 2, 6.41 mg/L of calcium content and 16 mg/L as $CaCO_3$ of calcium hardness at station 3, 9.62 mg/L of calcium content and 24 mg/L as $CaCO_3$ of calcium hardness at station 4 and 6.41 mg/L of calcium content and 16 mg/L as $CaCO_3$ of calcium hardness at station 5; 4.81 mg/L of calcium content and 12 mg/L as $CaCO_3$ of calcium hardness at station 6).

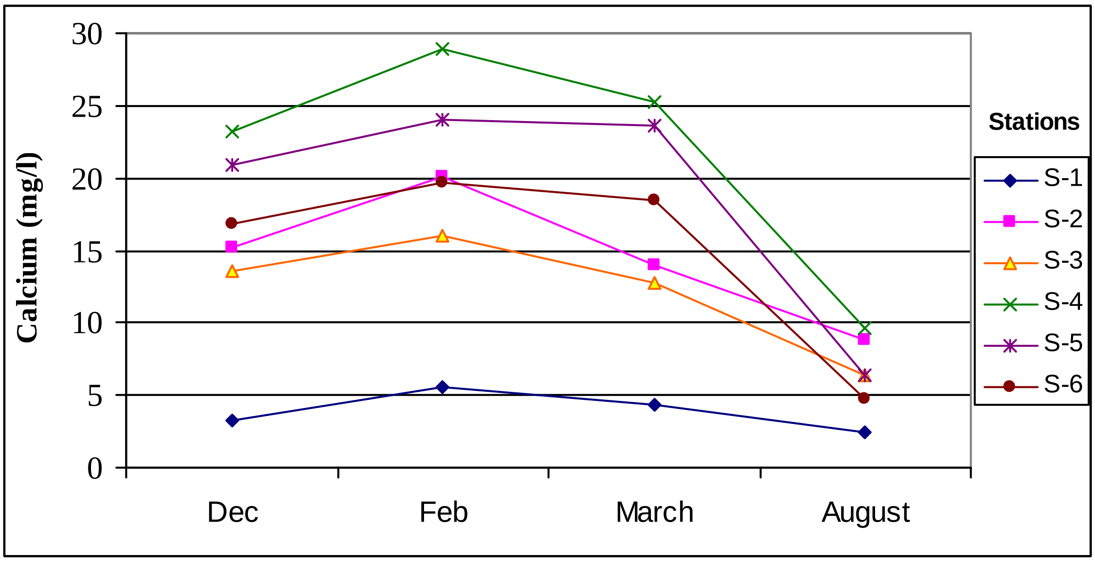

Figure 5.11: Monthly variation of calcium content of Kolpu Khola

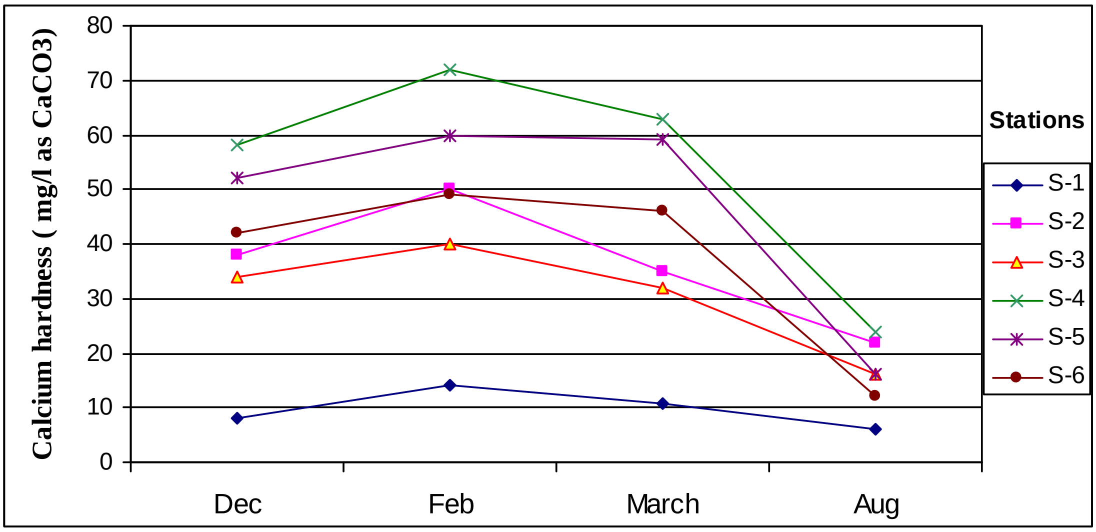

Figure 5.12: Monthly variation of calcium hardness of Kolpu Khola

The average calcium contents obtained were 3.90 ± 1.40 mg/L, 14.53 ± 4.61 mg/L, 12.22 ± 4.11 mg/L, 21.74 ± 8.41 mg/L, 18.74 ± 8.34 mg/L and 14.93 ± 6.84 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively in the river during the study period. Similarly, the average calcium hardness found were 10 ± 3, 36 ± 11, 30 ± 10, 54 ± 21, 47 ± 21 mg/L and 37 ± 17 at mg/L as $CaCO_3$ at stations 1, 2, 3, 4, 5 and 6 respectively in the river during the study period. The calcium and calcium hardness fluctuated from station 1 to 5 and then decreased from station 5 to 6 during all the four months of study period. Throughout the study period, the minimum calcium content of 2.40 mg/L and calcium hardness of 6 mg/L as $CaCO_3$ were recorded at station 1 in August and maximum calcium content of 28.86 mg/L and calcium hardness of 72 mg/L as $CaCO_3$ were recorded at station 4 in February.

5.1.1.12 Magnesium

The monthly variation of magnesium content of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.13. At sites 3, 4 and 5, the magnesium content decreased from December (5.86 mg/L at site 3, 2.93 mg/L at site 4 and 2.93 mg/L at site 5) till March (2.20 mg/L at site 3, 2.20 mg/L at site 4 and 1.71 mg/L at site 5). At site 1, 2 and 6 the magnesium content fluctuated from December (1.95 mg/L at station 1; 5.86 mg/L at station 2 and 3.42 mg/L at station 6) till August (0.98 mg/L at station 1; 3.90 mg/L at station 2 and 3.42 mg/L at station 6) but the pattern of fluctuation at site 2 and 6 is just opposite to that at site 1. The magnesium content increased from station 1 to 2 except in March. The magnesium content fluctuated from station 2 to 6 in August.

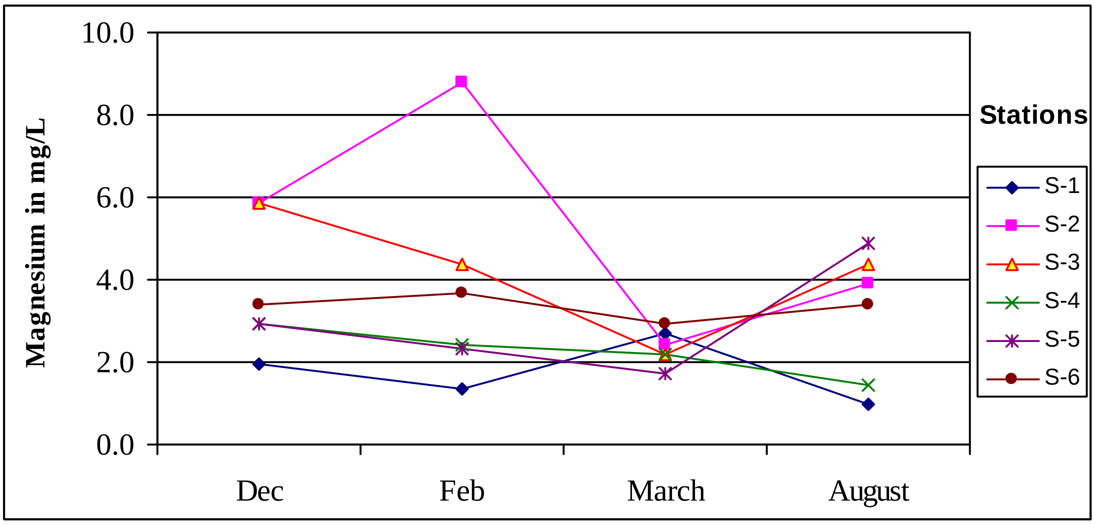

Figure 5.13: Monthly variation of magnesium content of Kolpu Khola

The average magnesium content found were 1.75 ± 0.75 mg/L, 5.25 ± 2.74 mg/L, 4.21 ± 1.50 mg/L, 2.26 ± 0.61 mg/L, 2.96 ± 1.37 mg/L and 3.36 ± 0.30 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively in the study period. The minimum magnesium content of 0.98 mg/L was found at site 1 in August and the maximum magnesium content of 8.78 mg/L was found at site 2 in February.

5.1.1.13 Biochemical oxygen demand

The monthly variation of BOD of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.14. The BOD at all sites increased from December (12.16 mg/L at site 1, 87.62 mg/L at site 2, 52.70 mg/L at site 3, 36.49 mg/L at site 4 , 22.3 mg/L at site 5 and 12.162 mg/L at site 6) till February and then decreased to March (11.91 mg/L at site 1, 79.56 mg/L at site 3, 62.55 mg/L at site 4, 21.43 mg/L at site 5 and 11.35 mg/L at site 6) except site 2 where it increased from February to March (128.43 mg/L). From March the BOD at site 1, 5 and 6 increased till August (19.26 mg/L at site 1, 24.73 mg/L at site 5 and 11.23 mg/L at site 6) whereas the BOD at site 2, 3 and 4 decreased from March till August (121.62 mg/L at site 2, 68.92 mg/L at site 3 and 45.54 mg/L at site 4).

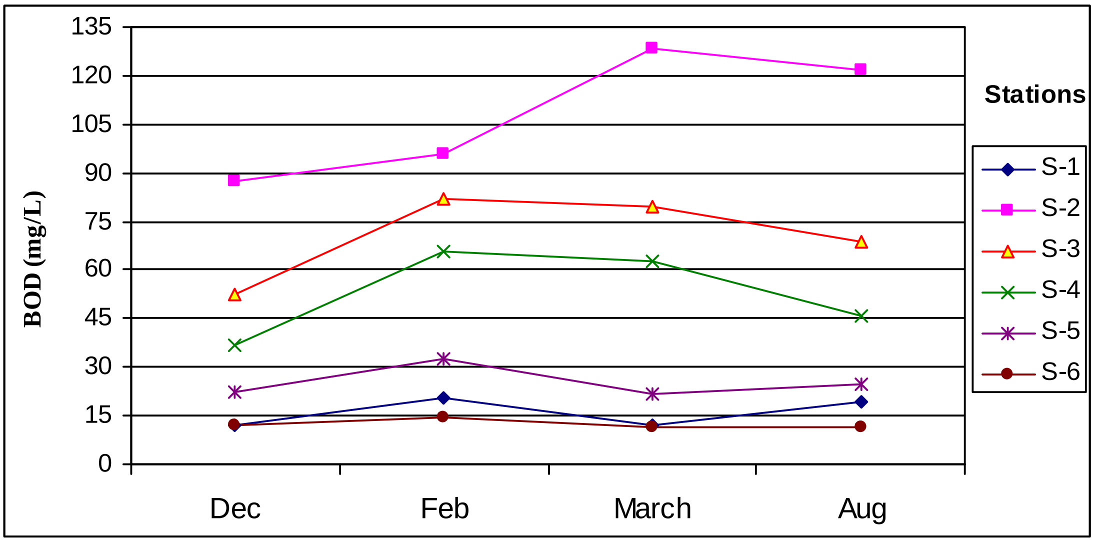

Figure 5.14: Monthly variation of Biochemical oxygen demand content of Kolpu Khola

The average BOD values obtained were 15.90 ± 4.48 mg/L, 108.43 ± 19.67 mg/L, 70.74 ± 13.27 mg/L, 52.50 ± 13.82 mg/L, 25.20 ± 4.97 mg/L and 12.33 ± 1.56 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively during the study period. BOD increased from station 1 to 2 and then gradually decreased to site 6 in all the four months of study period. During the entire investigation period, the lowest BOD of 11.35 mg/L was found at station 6 in March and the highest BOD of 128.43 mg/L was found at station 2 in March.

5.1.1.14 Chemical oxygen demand

The monthly variation of COD of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.15. The COD at all sites increased from December (24.00 mg/L at site 1, 176.00 mg/L at site 2, 124.00 mg/L at site 3, 84.00 mg/L at site 4 , 36.00 mg/L at site 5 and 27.80 mg/L at site 6) till February and then decreased to March (18.90 mg/L at site 1, 132.00 mg/L at site 3, 106.00 mg/L at site 4, 44.00 mg/L at site 5 and 23.43 mg/L at site 6) except site 2 where it increased from February to March (227.00 mg/L). From March the COD at all sites decreased till August (178.00 mg/L at station 2, 81.40 mg/L at station 3; 64.00 mg/L at station 4; 40.80 mg/L at station 5 and 15.20 mg/L at station 6) except station 1 where it increased to 20.00 mg/L.

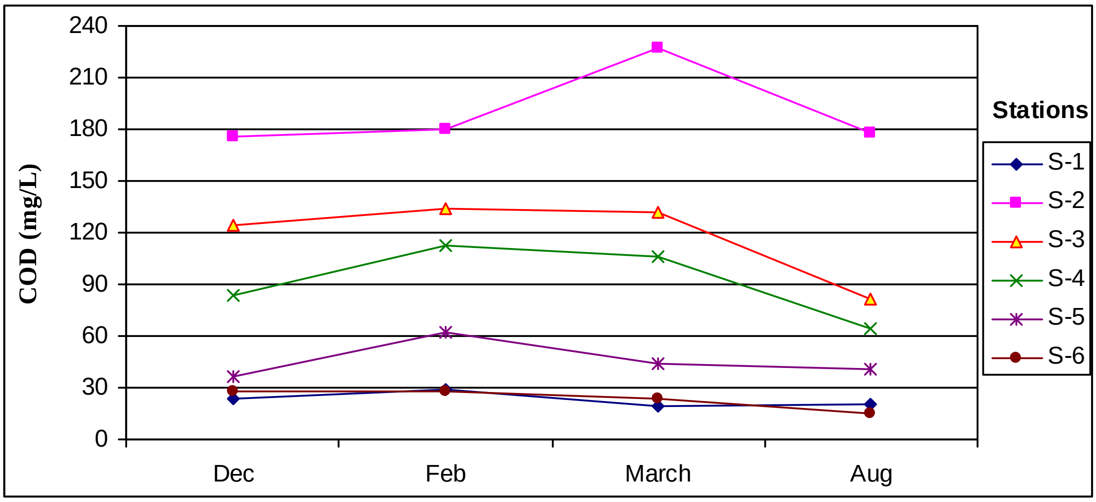

Figure 5.15: Monthly variation of Chemical oxygen demand content of Kolpu Khola

The average COD values obtained were 22.83 ± 4.33 mg/L, 190.25 ± 24.55 mg/L, 117.80 ± 24.64 mg/L, 91.50 ± 21.93 mg/L, 45.79 ± 11.52 mg/L and 23.64 ± 6.02 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively during the study period. COD increased from station 1 to 2 and then gradually decreased to site 6 in all the four months of study period except on August where COD increased from site 3 (31.40 mg/L) to site 4 (64.00 mg/L). During the entire investigation period, the lowest COD of 15.20 mg/L was found at station 6 in August and the highest COD of 227.00 mg/L was found at station 2 in March.

5.1.1.15 Orthophosphate (PO_4-P)

The monthly variation of orthophosphate content of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.16. At stations 1 and 2 orthophosphate content decreased from December (0.326 mg/L at station 1 and 0.203 mg/L at station 2) to February. From February the orthophosphate content increased gradually till August (0.281 mg/L at station 1 and 0.435 mg/L at station 2). At stations 4, 5 and 6, orthophosphate content fluctuated from December (0.131 mg/L at station 4; 0.063 mg/L at station 5 and 0.042 mg/L at station 6) till August (0.243 mg/L at station 4; 0.203 mg/L at station 5 and 0.146 mg/L at station 6). At station 3 the orthophosphate content increased from December (0.112 mg/L) till March (0.211 mg/L) and then decreased till August (0.120 mg/L).

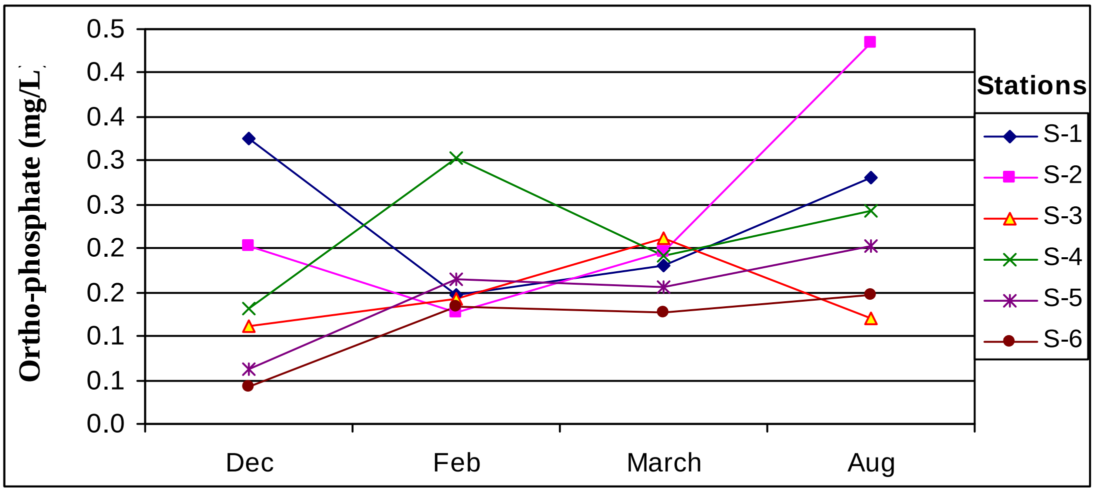

Figure 5.16: Monthly variation of orthophosphate content of Kolpu Khola

5.1.1.16 Nitrate- Nitrogen (NO_3- N)

The monthly variation of nitrate- nitrogen content of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.17. The nitrate- nitrogen content of surface water decreased from December (1.080 mg/L at station 1, 1.285 mg/L at station 2, 1.682 mg/L at station 3; 1.545 mg/L at station 4, 1.042 mg/L at station 5 and 0.411 mg/L at station 6) to February. From February, the nitrate- nitrogen content at all sites increased to March and then decreased till August (0.705 mg/L at station 1; 0.891 mg/L at station 2; 0.915 mg/L at station 3; 0.713 mg/L at station 4; 0.801 mg/L at station 5 and 0.661 mg/L at station 6).

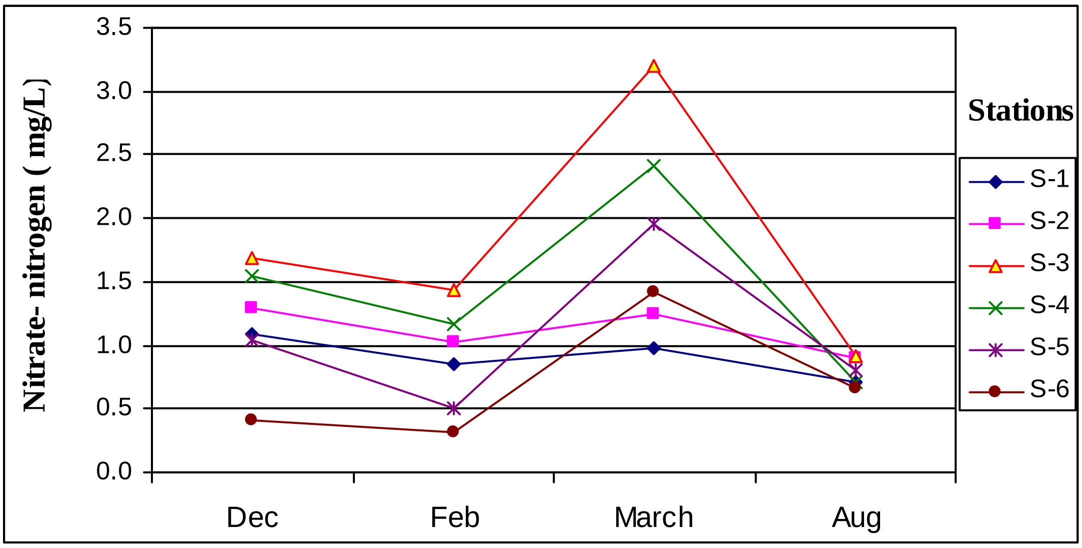

Figure 5.17: Monthly variation of nitrate- nitrogen content of Kolpu Khola

On the average, the concentration of nitrate- nitrogen obtained were 0.903 ± 0.161 mg/L, 1.111 ± 0.188 mg/L, 1.805 ± 0.981 mg/L, 1.461 ± 0.720 mg/L, 1.074 ± 0.627 mg/L and 0.704 ± 0.501 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively in the surface water during the study period. The concentration of nitrate- nitrogen increased from station 1 to 3 and then it decreased to station 6 except from station 4 to 5 in August. Throughout the study period among all the stations, the minimum nitrate- nitrogen concentration of 0.320 mg/L was found at station 6 in February and maximum nitrate-nitrogen concentration of 3.197 mg/L was found at station 3 in March.

5.1.1.17 Ammoniacal nitrogen (NH_4- N)

The monthly variation of ammoniacal nitrogen content of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.18. At stations 1, 2, 5 and 6, the ammoniacal nitrogen content of surface water decreased from December (0.33 mg/L at station 1, 0.48 mg/L at station 2, 0.41 mg/L at station 5 and 0.27 mg/L at station 6) till February. After then it remained nearly constant at stations 2 and 5 but the ammoniacal nitrogen content at station 1 and 6 decreased to March (0.16 mg/L at station 1 and 0.22 mg/L at station 6). At stations 3 and 4, the ammoniacal nitrogen content increased from December (0.44 mg/L at station 3 and 0.36 mg/L at station 4) till March (1.10 mg/L at station 3 and 0.85 mg/L at station 4). From March the NH_4-N at all stations decreased till August (0.12 mg/L at station 1; 0.62 mg/L at station 2; 0.56 mg/L at station 3; 0.49 mg/L at station 4; 0.22 mg/L at station 5 and 0.03 mg/L at station 6).

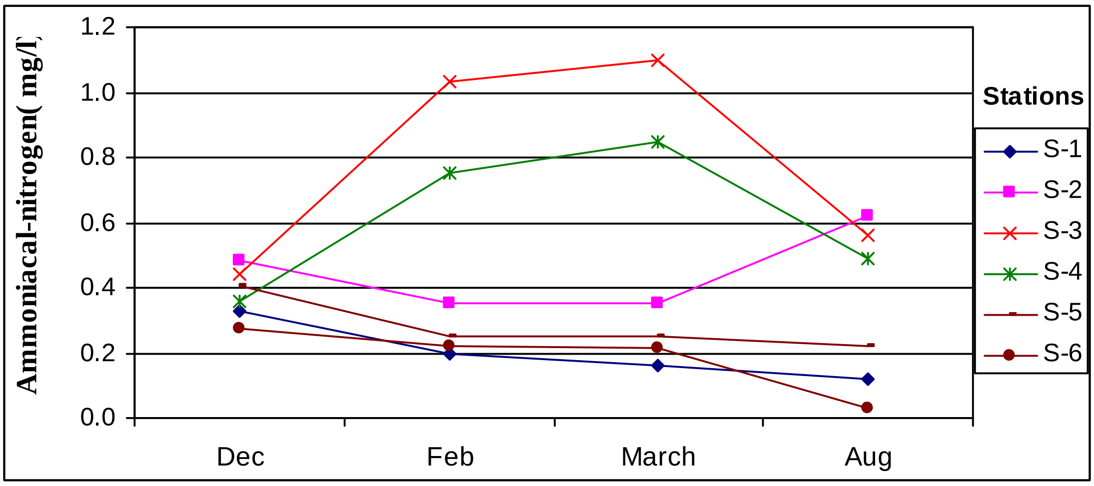

Figure 5.18: Monthly variation of ammoniacal nitrogen content of Kolpu Khola

On the average, the concentration of ammoniacal nitrogen obtained were 0.20 ± 0.09 mg/L, 0.45 ± 0.13 mg/L , 0.78 ± 0.33 mg/L , 0.61 ± 0.23 mg/L , 0.28 ± 0.08 mg/L and 0.19 ± 0.11 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively in the surface water during the study period. The average ammoniacal nitrogen content increased from station 1 to 3 and then it decreased up to site 6. The ammoniacal nitrogen content increased from station 1 to 2 in all the months of study period. Then after the ammoniacal nitrogen decreased from site 2 to 4 in December and up to site 6 in August. On February and March the NH_4- N decreased from site 3 to 6. Throughout the study period the minimum ammoniacal nitrogen content was found at station 6 in August (0.03 mg/L) and maximum ammoniacal nitrogen content was found at station 3 in March (1.10 mg/L).

5.1.1.18 Iron

The monthly variation of iron content of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.19. At all sites, the iron content of surface water increased from December (0.39 mg/L at station 1, 0.45 mg/L at station 2, 0.15 mg/L at station 3, 2.97 mg/L at station 4, 1.03 mg/L at station 5 and 0.51 mg/L at station 6) till February. After then, the iron contents at stations 2, 4, 5 and 6 decreased to March (0.47 mg/L at station 2, 0.56 mg/L at station 4, 0.63 mg/L at station 5 and 0.36 mg/L at station 6) but those at stations 1 and 3 increased to March (0.55 mg/L at station 1 and 0.70 mg/L at station 3). From March the iron content at all sites increased till August (0.63 mg/L at site 1; 4.05 mg/L at site 2; 1.48 mg/L at site 3; 1.86 mg/L at site 4; 1.05 mg/L at site 5 and 0.64 mg/L at site 6).

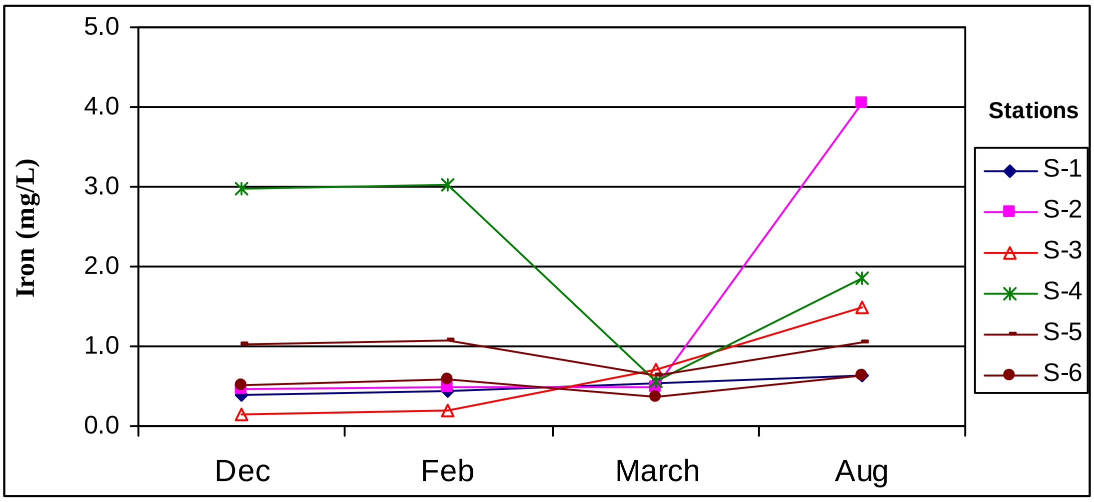

Figure 5.19: Monthly variation of iron content of Kolpu Khola

The average iron content found were 0.50 ± 0.11 mg/L, 1.37 ± 1.79 mg/L, 0.63 ± 0.62 mg/L, 2.10 ± 1.16 mg/L, 0.94 ± 0.21 mg/L and 0.52 ± 0.12 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively in the surface water during the study period. The iron content increased from station 1 to 2, decreased from station 2 to 3, again increased from station 3 to 4 and finally decreased from station 4 to 6 in winter (December and February) and monsoon (August) but the spatial (upstream to downstream) variation of iron content from station 1 to 5 in pre-monsoon season (March)) was found just opposite to that in winter and monsoon. Throughout the study period the minimum iron content was found at site 3 (0.15 mg/L) in December and the maximum iron content was found at site 2 (4.05 mg/L) in August.

5.1.1.19 Total dissolved solids (TDS)

The monthly variation of total dissolved solids of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.20. At stations 1, 2, 5 and 6, the TDS increased from December (31.35 mg/L at station 1, 73.45 mg/L at station 2, 74.25 mg/L at station 5 and 69.85mg/L at station 6) till March except from February to March at station 2. At stations 3 and 4, the TDS decreased from December (85.20 mg/L at station 3 and 88.55 mg/L at station 4) till March except from February to March at station 4. From March the TDS at all six stations decreased till August (26.95 mg/L at station 1, 61.10 mg/L at station 2, 45.00 mg/L at station 3, 48.95 mg/L at station 4, 34.65 mg/L at station 5 and 28.05mg/L at station 6).

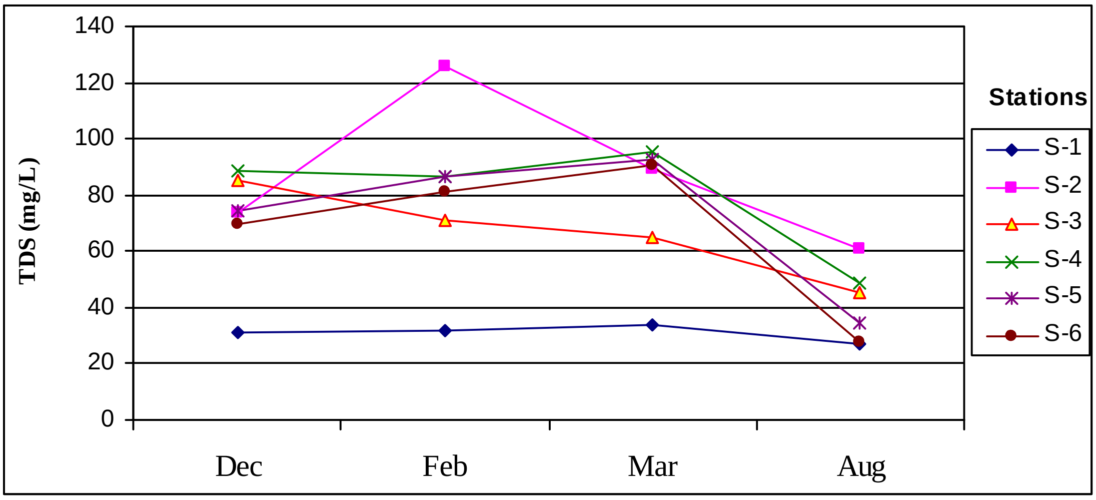

Figure 5.20: Monthly variation of total dissolved solids of Kolpu Khola

The average TDS of surface water along the river were recorded as 31.08 ± 3.00 mg/L, 87.43 ± 28.20 mg/L, 66.45 ± 16.66 mg/L, 79.45 ± 20.87 mg/L, 71.91 ± 25.96 mg/L and 67.51 ± 27.66 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively during the study period. The TDS fluctuated from station 1 to 5 in February, March and August except from station 4 to 5 in February. Then after the TDS decreased from station 5 to 6 in all the four months. The TDS at stations 4 and 5 were found equal (86.35 mg/L) in February. In December, the TDS increased from station 1 to 4 and then decreased to station 6 (69.85 mg/L). Throughout the study period, the lowest TDS of 26.95 mg/L was recorded at station 1 in August and the highest TDS of 126.10 mg/L was recorded at station 2 in February.

5.1.1.20 Total suspended solids (TSS)

The monthly variation of total suspended solids of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.21. From December, the TSS at stations 1, 2, 3, 5 and 6 decreased till February and from then it increased till August (2573.05 mg/L at station 1, 3138.90 mg/L at station 2, 2355.00 mg/L at station 3 and 1313.95 mg/L at station 6) except station S_5. The TSS at site S_4 fluctuated from December (2660.45 mg/L) till August (3151.05 mg/L).

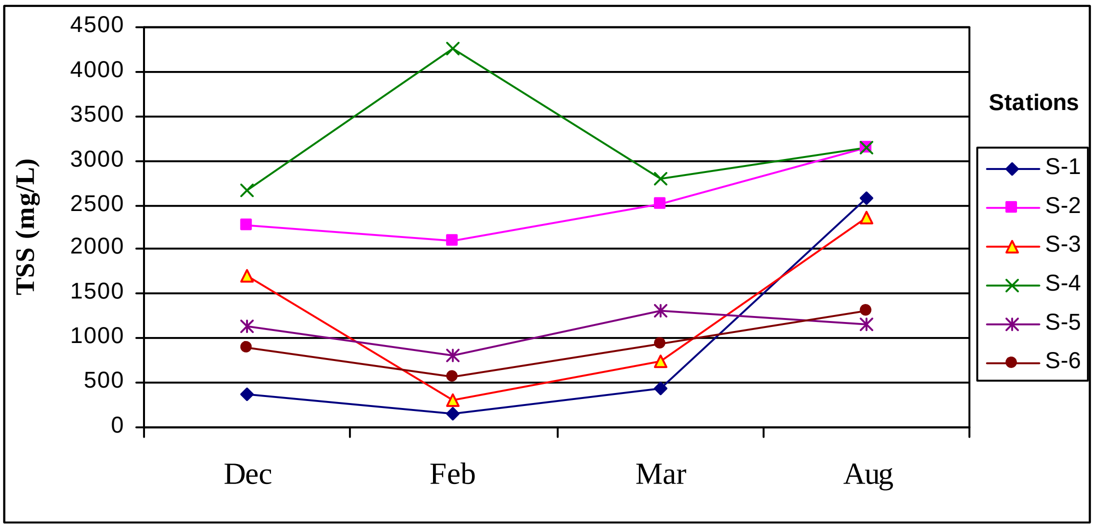

Figure 5.21: Monthly variation of total suspended solids of Kolpu Khola

The average TSS of surface water along the river were recorded as 884.18 mg/L, 2505.38 mg/L, 1276.25 mg/L, 3216.59 mg/L, 1099.68 mg/L and 930.49 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively during the study period. The TSS fluctuated from site 1 to 5 i.e. upstream to downstream in all the four months under investigation. Throughout the study period, the lowest TSS of 150.00 mg/L was recorded at station 1 in February and the highest TSS of 4250.00 mg/L was recorded at station 4 in February.

5.1.1.21 Total solids (TS)

The monthly variation of total solids of Kolpu Khola over the period of four months (2007/2008) is shown in figure 5.22. From December, the TS at stations 1, 2, 3, 5 and 6 decreased till February and from then it increased to March (479.10 mg/L at station 1, 2600.00 mg/L at station 2, 800.00 mg/L at station 3, 1400.00 mg/L at station 5 and 1038.20 mg/L at station 6) at all these five sites. At site 4 the TS in December (2749.00 mg/L) increased till February and from then it decreased to March (2900.00 mg/L). From March the TS at all the sites increased till August (2600.00 mg/L at station 1; 3200.00 mg/L at station 2; 2400.00 mg/L at station 3; 3200.00 mg/L at station 4; 1200.00 mg/L at station 5 and 1342.00 mg/L at station 6).

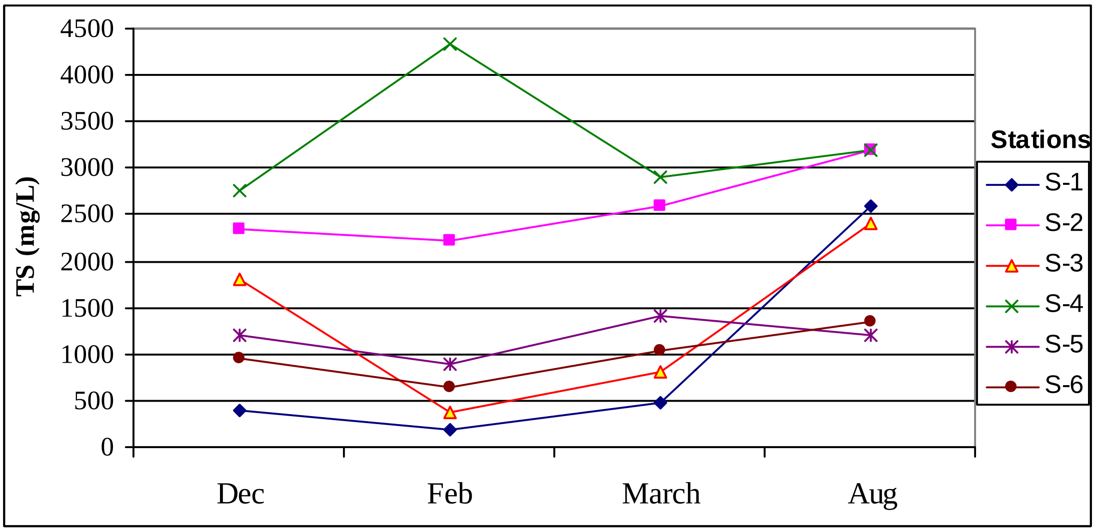

Figure 5.22: Monthly variation of total solids of Kolpu Khola

The average TS of surface water along the river were recorded as 915.25 mg/L, 2592.80 mg/L, 1342.72 mg/L, 3296.34 mg/L, 1171.59 mg/L and 998.00 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively during the study period. The TS fluctuated from site 1 to 5 i.e. upstream to downstream in all the four months under investigation. Throughout the study period, the lowest TS of 181.90 mg/L was recorded at station 1 in February and the highest TSS of 4336.35 mg/L was recorded at station 4 in February.

5.1.1.22 Total chromium

The seasonal variation of total chromium of Kolpu Khola over the period of three months viz. three seasons (2007/2008) is shown in figure 5.23. From December (winter) the total chromium at station 2, 3, 5 and 6 decreased till March i.e. pre-monsoon (0.078 mg/L at station 2, 0.069 mg/L at station 3, 0.011 mg/L at station 5 and 0.004 mg/L at station 6) whereas total chromium at station 1 and 4 increased from December (0.005 mg/L at station 1 and 0.020 mg/L at station 4) till March. From March the total chromium at all sites decreased till August (0.002 mg/L at site 1; 0.007 mg/L at site 2; 0.005 mg/L at site 3; 0.004 mg/L at site 4; 0.004 mg/L at site 5 and 0.003 mg/L at site 6).

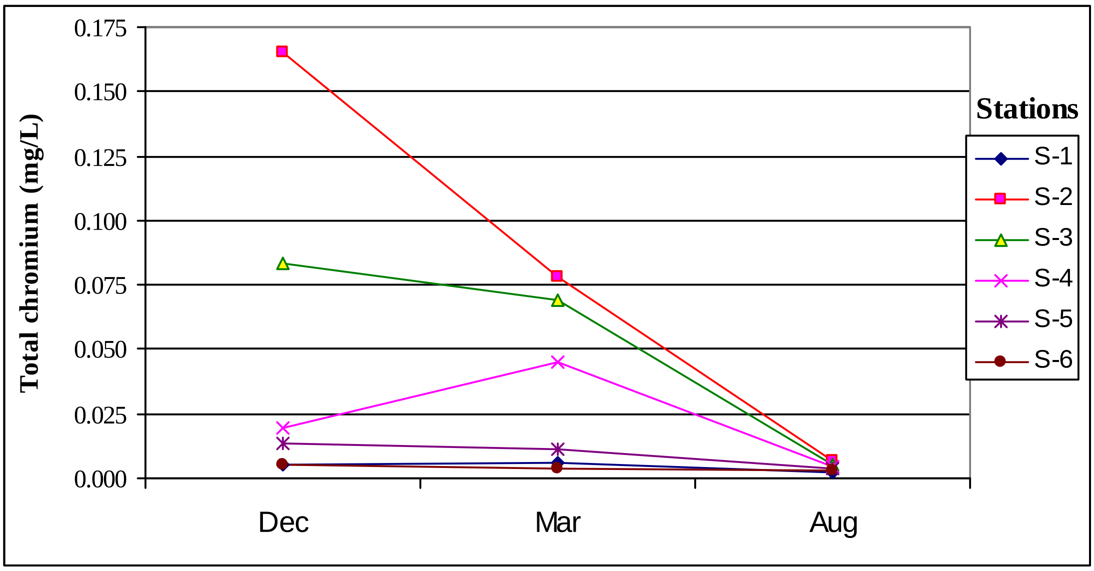

Figure 5.23: Seasonal variation of total chromium of Kolpu Khola for three seasons.

The average total chromium of surface water along the river were recorded as 0.004 ± 0.002 mg/L, 0.084 ± 0.079 mg/L, 0.052 ± 0.042 mg/L, 0.023 ± 0.021 mg/L, 0.010 ± 0.005 mg/L and 0.004 ± 0.001 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively during the study period. The total chromium decreased from site 2 to 6 i.e. upstream to downstream in winter, pre-monsoon and monsoon seasons except from site 4 to 5 on August where the total chromium content remained constant at 0.004 mg/L. The total chromium content varied between 0.011 mg/L and 0.166 mg/L for stations 2, 3, 4 and 5. Throughout the study period, the lowest total chromium of 0.002 mg/L was recorded at station 1 in August and the highest total chromium of 0.166 mg/L was recorded at station 2 in December.

5.1.1.22 Potassium

The seasonal variation of potassium content of surface water of Kolpu Khola over the period of three months viz. three seasons (2007/2008) is shown in figure 5.24. The potassium content of the surface water increased from December i.e. winter (9.12 mg/L at station 1, 10.01 mg/L at station 2; 9.79 mg/L at station 3, 8.68 mg/L at station 4 ; 9.35 mg/L at station 5 and 6.23 mg/L at station 6) till March (pre-monsoon) and then decreased till August i.e. monsoon (6.32 mg/L at station 1, 11.06 mg/L at station 2; 8.46 mg/L at station 3, 7.12 mg/L at station 4 ; 5.27 mg/L at station 5 and 4.43 mg/L at station 6). The potassium content was lesser in monsoon season compared to pre-monsoon and winter. This is most probably due to increase in river discharge and subsequent dilution of potassium content of river water in monsoon.

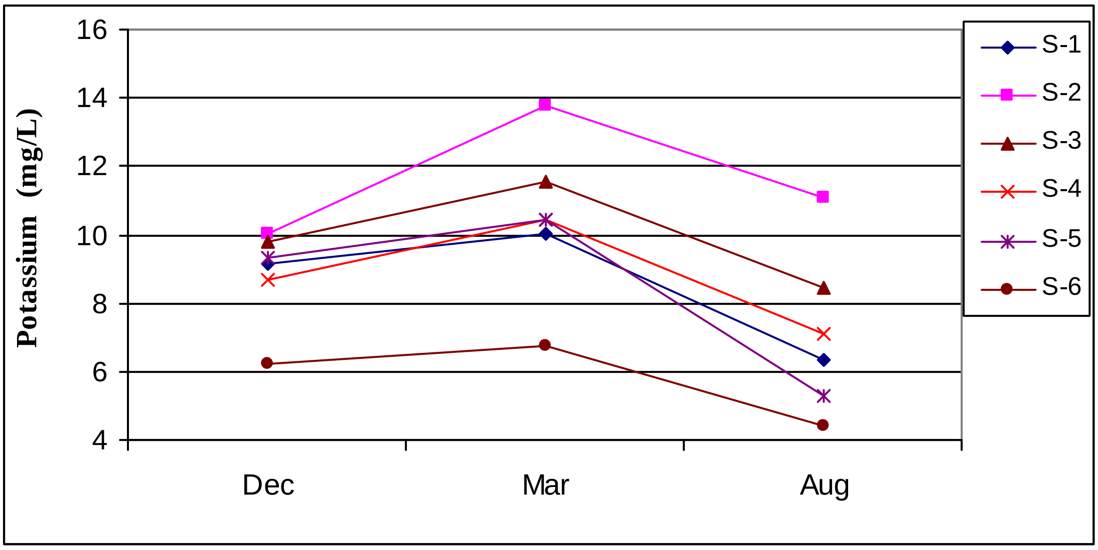

Figure 5.24: Seasonal variation of potassium content of Kolpu Khola for two seasons.

The average potassium content of surface water along the river were recorded as 8.48 ± 1.93 mg/L, 11.62 ± 1.95 mg/L, 9.94 ± 1.56 mg/L, 8.75 ± 1.67 mg/L, 8.36 ± 2.73 mg/L and 5.80 ± 1.21 mg/L at stations 1, 2, 3, 4, 5 and 6 respectively during the study period. During the three months potassium content increased from site S_1 to S_2 and then gradually decreased up to site S_6 except from site S_4 to S_5 in December and March. Throughout the study period, the lowest potassium content of 4.43 mg/L was recorded at station S_6 in August and the highest potassium content of 13.80 mg/L was recorded at station 2 in March.

5.1.2 Physicochemical Parameters of ground water i.e. GW-1 and GW-2 (from December to March)

5.1.2.1 Water temperature

The monthly variation of water temperature of groundwater over the period of three months (2007/2008) is shown in figure 5.25. The water temperature of GW-1 and GW-2 decreased from December (19.0°C at GW-1 and 18.0°C at GW-2) to February and then increased to March (19.5 at station GW-1 and 27.5 at station GW-2)

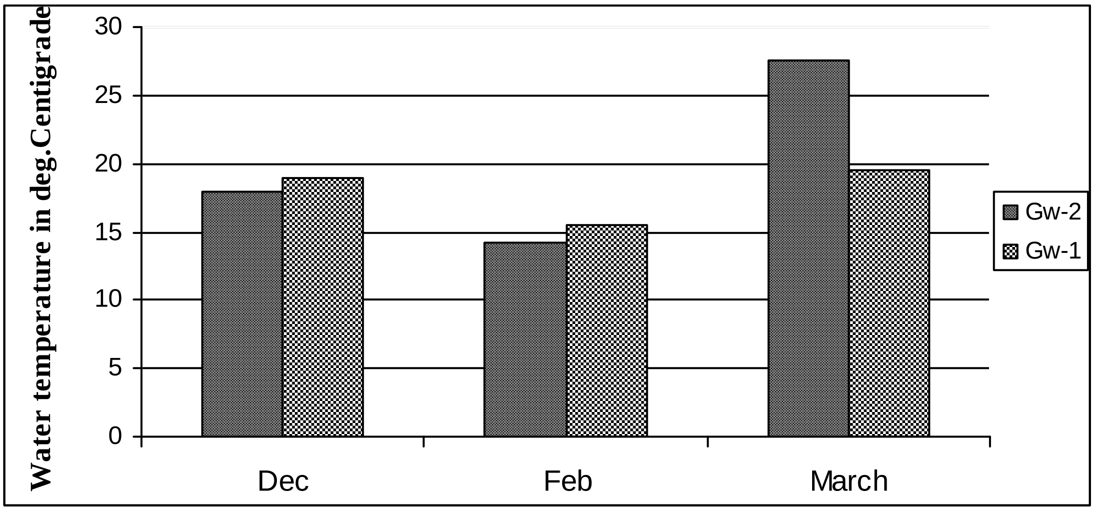

Figure 5.25: Monthly variation of water temperature of groundwater

On the average, water temperature recorded at GW-1 and GW-2 were 18.0 ± 2.2 °C and 19.9 ± 6.8 °C at GW-1 and GW-2 respectively. Throughout the investigation period, the minimum water temperature of 14.2°C was observed at GW-2 in February whereas the maximum water temperature of 27.5°C was observed at GW-2 in March.

5.1.2.2 Electrical conductivity

The monthly variation of electrical conductivity of groundwater over the period of three months (2007/2008) is shown in figure 5.26. The electrical conductivity of GW-2 increased from December (711 µS/cm) till March (936 µS/cm) whereas that of GW-1 increased from December (194 µS/cm) to February (210 µS/cm) and thereafter decreased till March (182 µS/cm).

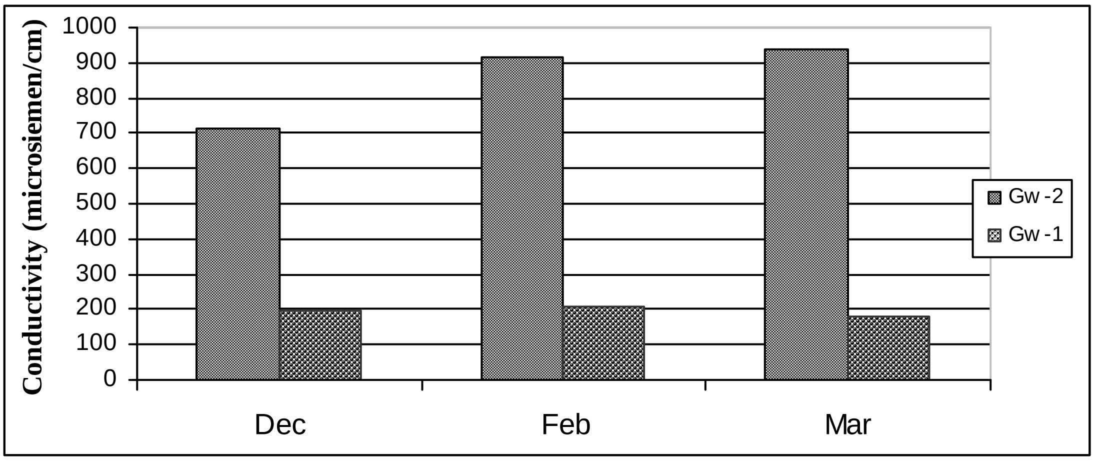

Figure 5.26: Monthly variation of conductivity of groundwater

On the average, electrical conductivity of groundwater recorded were 195.33 ± 14.05 μS/cm at GW-1 and 853.33 ± 123.80 μS/cm at GW-2. Throughout the investigation period, the minimum electrical conductivity of 182μS/cm was found at GW-1 in March and the maximum electrical conductivity of 936μS/cm was found at GW-2.

5.1.2.3 pH

The monthly variation of pH of groundwater over the period of three months (2007/2008) is shown in figure 5.27. The pH of GW-1 increased from December (6.4) till March (6.7) whereas the pH of GW-2 fluctuated from December to March.

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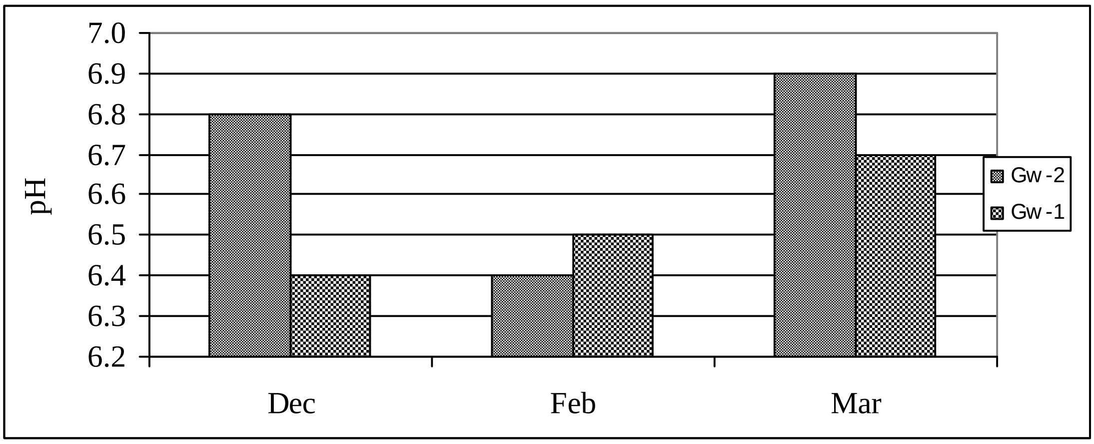

Figure 5.27: Monthly variation of pH of groundwater

On the average, the pH of groundwater recorded were 6.5 ± 0.1 at GW-1 and 6.7 ± 0.2 at GW-2. Throughout the investigation period, the minimum pH of 6.4 was found at GW-1 in December and GW-2 in February whereas the maximum pH of 6.9 was found at GW-2 in March

5.1.2.4 Chloride

The monthly variation of chloride content of groundwater over the period of three months (2007/2008) is shown in figure 5.28. The chloride of GW-1 decreased from December (39.76 mg/L) till March (29.82 mg/L) but the chloride of GW-2 increased from December (107.92 mg/L) till March (130.64 mg/L).

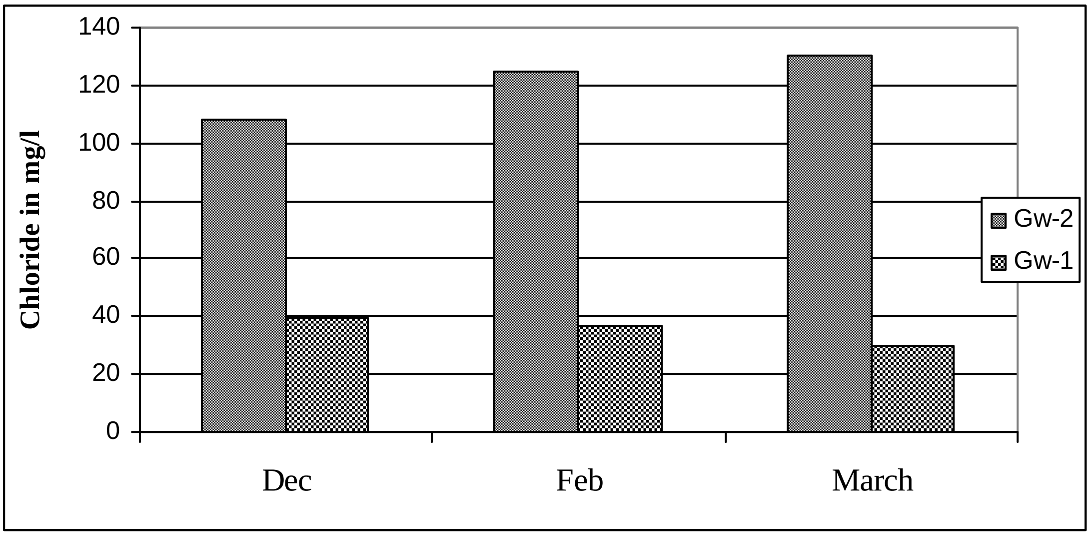

Figure 5.28: Monthly variation of chloride content of groundwater

On the average, the chloride content of groundwater recorded were 35.50 ± 5.12 mg/L at GW-1 and 121.17 ± 11.82 mg/L at GW-2. Throughout the investigation period, the minimum chloride content of 29.82 mg/L was found at GW-1 in March whereas the maximum chloride content of 130.64 mg/L was found at GW-2 in March.

5.1.2.5 Alkalinity

The monthly variation of total alkalinity of groundwater over the period of three months (2007/2008) is shown in figure 5.29. The total alkalinity of GW-1 increased gradually from December (60 mg/L) to March (125 mg/L) but the total alkalinity of GW-2 fluctuated from December (250 mg/L) till March (265 mg/L).

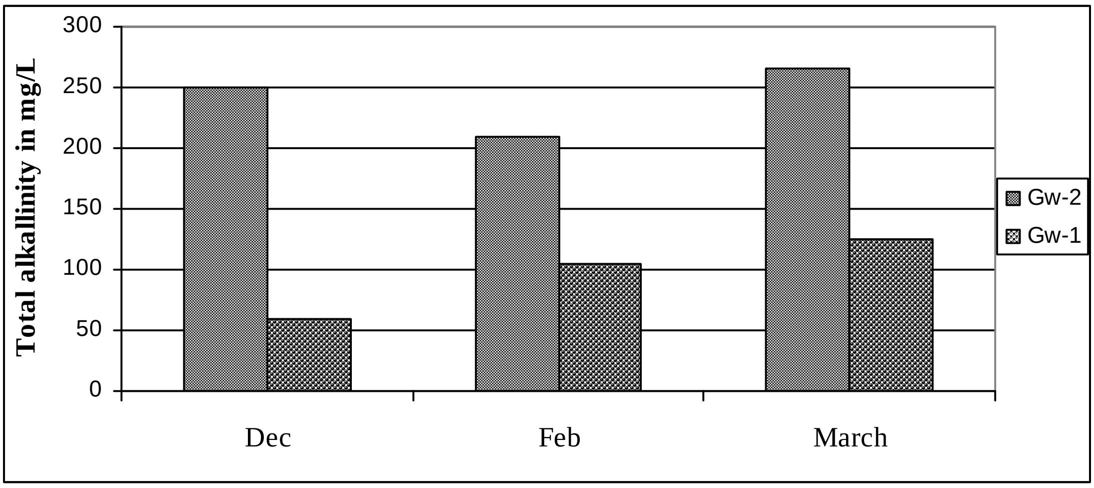

Figure 5.29: Monthly variation of total alkalinity of groundwater

On the average, the total alkalinity content of groundwater recorded were 96 ± 33 mg/L at GW-1 and 242 ± 28 mg/L at GW-2. Throughout the investigation period, the minimum total alkalinity content of 60 mg/L was found at GW-1 in December and the maximum total alkalinity content of 265mg/L was found at GW-2 in March.

5.1.2.6 Dissolved oxygen

The monthly variation of dissolved oxygen content of groundwater over the period of three months (2007/2008) is shown in figure 5.30. The dissolved oxygen content of GW-1 fluctuated from December (4.054 mg/L) to March (4.459 mg/L) whereas that of GW-2 decreased from December (2.838 mg/L) till March (2.230 mg/L).

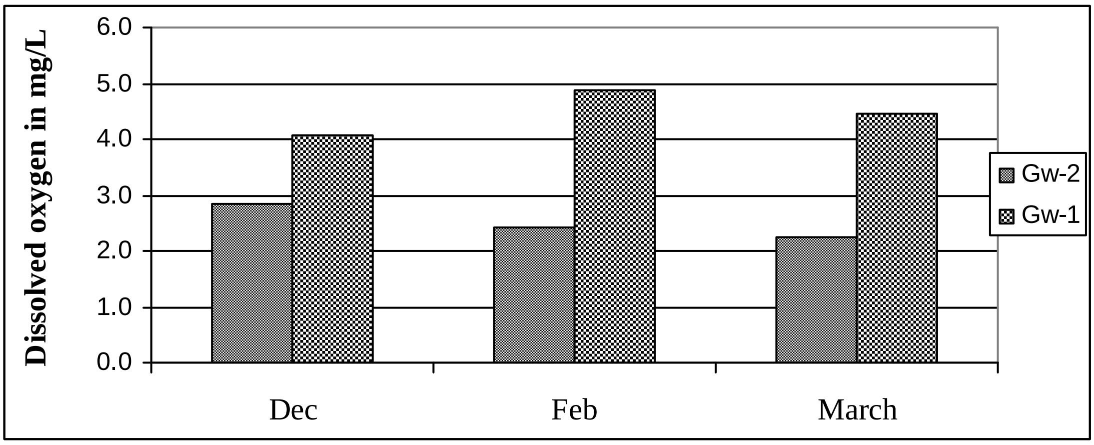

Figure 5.30: Monthly variation of dissolved oxygen content of groundwater

The average dissolved oxygen content of groundwater obtained were 4.46 ± 0.40 mg/L at GW-1 and 2.50 ± 0.31 mg/L at GW-2. Throughout the investigation period, the minimum dissolved oxygen content of 2.23 mg/L was found at GW-2 in March and maximum dissolved oxygen content of 4.86 mg/L was found at GW-1 in February.

5.1.2.7 Free carbon dioxide

The monthly variation of free CO_2 content of groundwater over the period of three months (2007/2008) is shown in figure 5.31. The free CO_2 content of both GW-1 and GW-2 increased from December (18.04 mg/L at GW-1 and 79.20mg/L at GW-2) till March (35.20 mg/L at GW-1 and 88.00mg/L at GW-2)

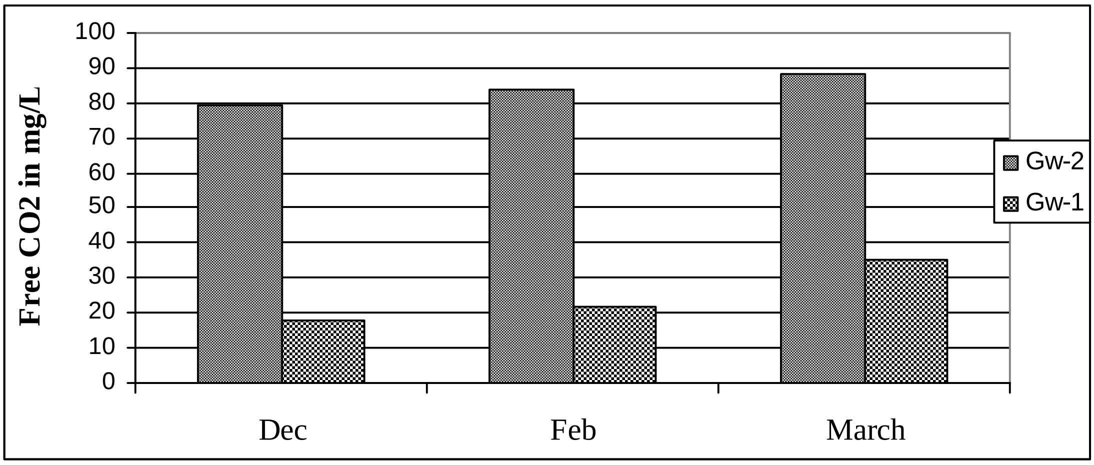

Figure 5.31: Monthly variation of free CO_2 content of groundwater

The average free CO_2 content of groundwater content recorded were 25.08 ± 8.99 mg/L at GW-1 and 83.60 ± 4.40 mg/L at GW-2. Throughout the investigation period, the minimum free CO_2 content of 18.04 mg/L was found at GW-1 in December and the maximum free CO_2 content of 88.00 mg/L was found at GW-2 in March.

5.1.2.8 Hardness

The monthly variation of hardness of groundwater over the period of three months (2007/2008) is shown in figure 5.32. The hardness of GW-1 fluctuated from December (98 mg/L as $CaCO_3$) to March (80 mg/L as $CaCO_3$) whereas the hardness of GW-2 gradually increased from December (384 mg/L as $CaCO_3$) to March (404 mg/L as $CaCO_3$).

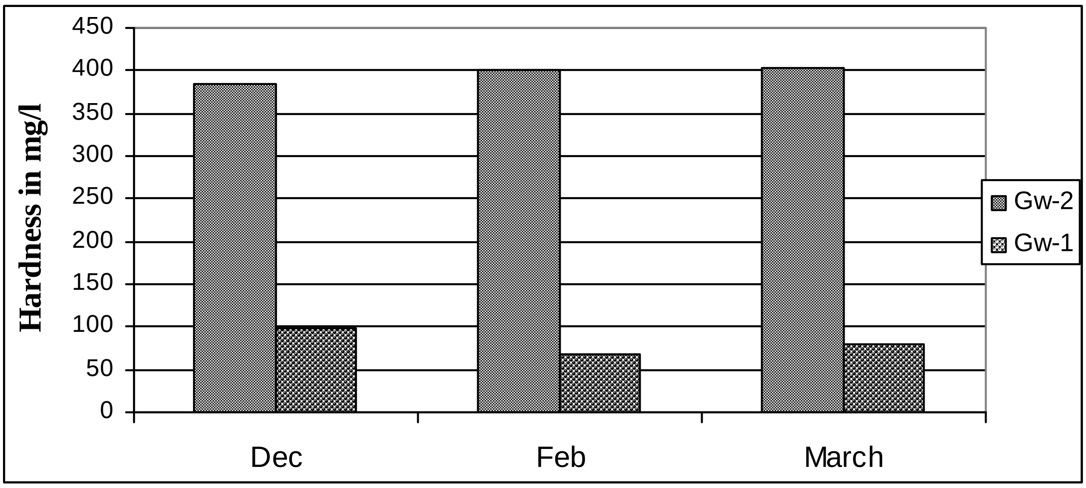

Figure 5.32: Monthly variation of hardness of groundwater.

The average hardness of groundwater recorded were found to be 82 ± 15 mg/L and 396 ± 11 mg/L as $CaCO_3$ at stations GW-1 and GW-2 respectively. Throughout the investigation period, the minimum hardness of 68 mg/L as $CaCO_3$ was found at GW-1 in February (winter) and the maximum hardness of 404 mg/L as $CaCO_3$ was found at GW-2 in March (pre-monsoon).

5.1.2.9 Calcium

The monthly variation of calcium content of groundwater over the period of three months (2007/2008) is shown in figure 5.33. The calcium content of both GW-1 and GW-2 fluctuated from December (32.87 mg/L at GW-1 and 125.85 mg/L at GW-2) to March (26.85 mg/L at GW-1 and 117.84 mg/L at GW-2).

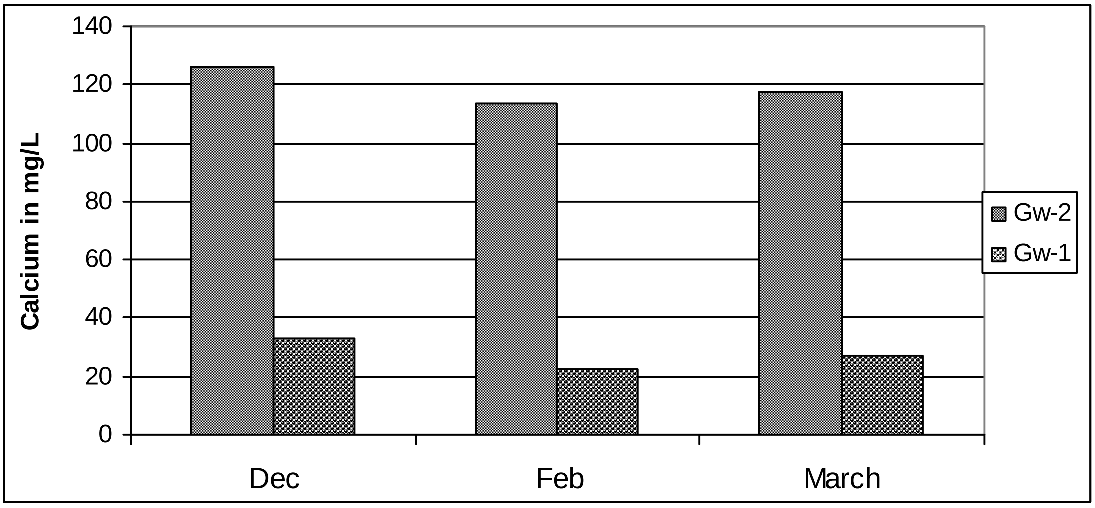

Figure 5.33: Monthly variation of calcium content of groundwater

The average calcium content of groundwater recorded were 27.39 ± 5.23 mg/L at GW-1 and 119.17 ± 6.12 mg/L at GW-2. Throughout the investigation period, the minimum calcium content was recorded at GW-1 in February (22.44 mg/L) and the maximum calcium content was recorded at GW-2 in December (125.85 mg/L).

5.1.2.10 Calcium hardness

The monthly variation of calcium hardness of groundwater over the period of three months (2007/2008) is shown in figure 5.34. At both GW-1 and GW-2 calcium hardness decreased from December (82 mg/L as $CaCO_3$ at GW-1 and 320 mg/L as $CaCO_3$ at GW-2) to February and then increased to March (67mg/L as $CaCO_3$ at GW-1 and 294 mg/L as $CaCO_3$ at GW-2).

The average calcium hardness of groundwater recorded were 68 ± 13 mg/L as $CaCO_3$ at GW-1 and 299 ± 19 mg/L as $CaCO_3$ at GW-2. Throughout the investigation period, the minimum calcium hardness was recorded at GW-1 in February (56 mg/L as $CaCO_3$) and the maximum calcium hardness was recorded at GW-2 in December (320 mg/L as $CaCO_3$).

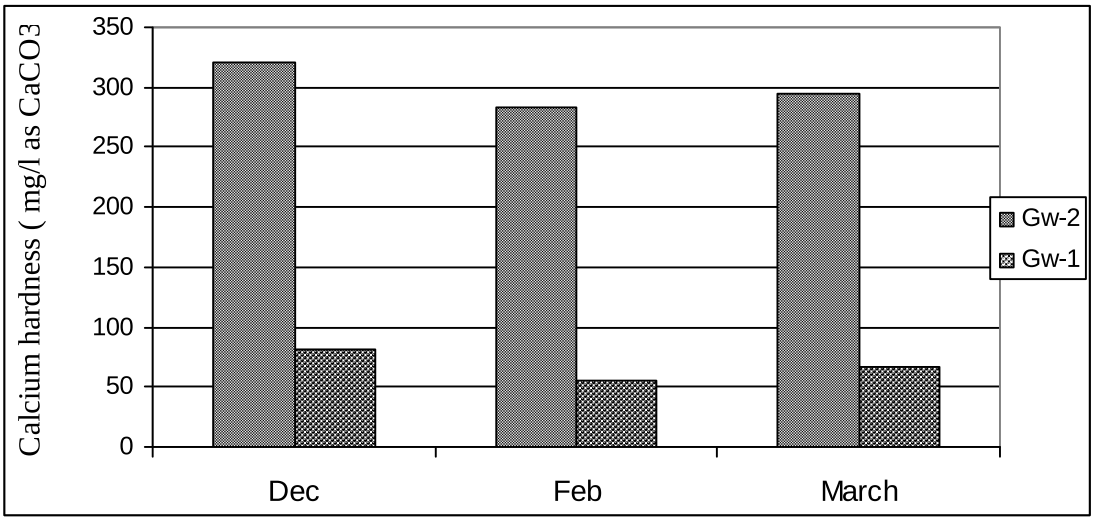

Figure 5.34: Monthly variation of calcium hardness of groundwater

5.1.2.11 Magnesium

The monthly variation of magnesium content of groundwater over the period of three months (2007/2008) is shown in figure 5.35. The magnesium content at both GW-1 and GW-2 fluctuated from December (3.90 mg/L at GW-1 and 15.59 mg/L at GW-2) to March (3.17 mg/L at GW-1 and 26.84 mg/L at GW-2) but the pattern of fluctuation of magnesium content at GW-2 was just opposite to that at GW-1.

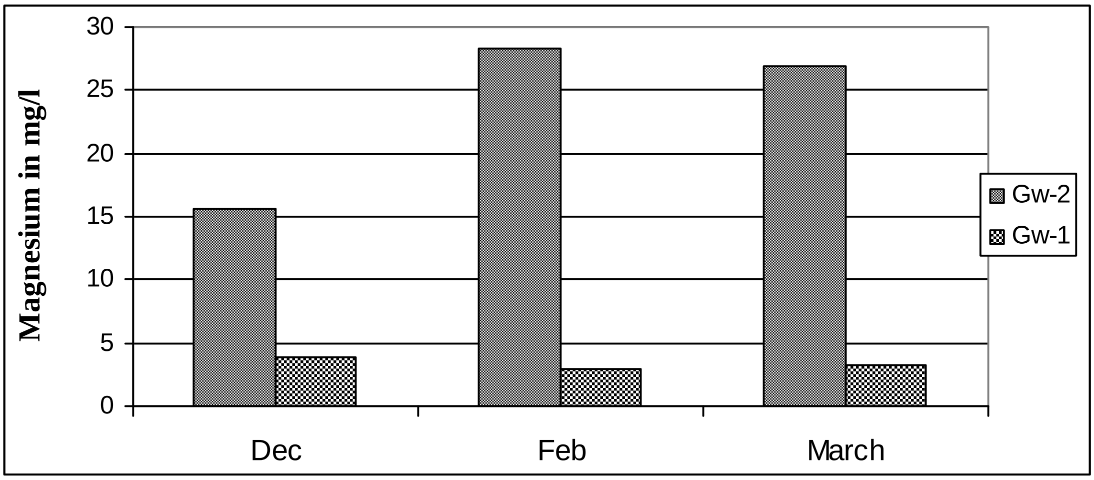

Figure 5.35: Monthly variation of magnesium content of groundwater

5.1.2.12 Biochemical oxygen demand

The monthly variation of biochemical oxygen demand of groundwater over the period of three months (2007/2008) is shown in figure 5.36. BOD at both groundwater stations i.e. GW-1 and GW-2 fluctuated from December (6.16 mg/L at GW-1 and 72.97 mg/L at GW-2) to March (5.18 mg/L at GW-1 and 86.54 mg/L at GW-2).

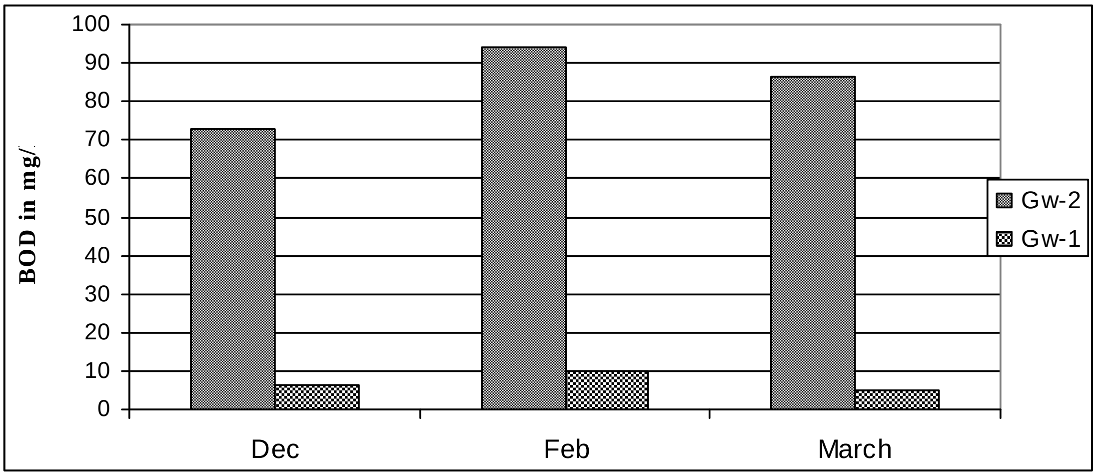

Figure 5.36: Monthly variation of biochemical oxygen demand of groundwater

The average BOD of groundwater recorded were 7.03 ± 2.41 mg/L at GW-1 and 84.61 ± 10.80 mg/L at GW-2. Throughout the investigation period, the minimum BOD of 5.18 mg/L was found at GW-1 in March and the maximum BOD of 94.32 mg/L was found at GW-2 in February.

5.1.2.13 Chemical oxygen demand

The monthly variation of chemical oxygen demand of groundwater over the period of three months (2007/2008) is shown in figure 5.37. COD at GW-1 fluctuated from December (14.00 mg/L) to March (12.00 mg/L) whereas COD at GW-2 increased from December (128.00 mg/L) to March (170.00 mg/L).

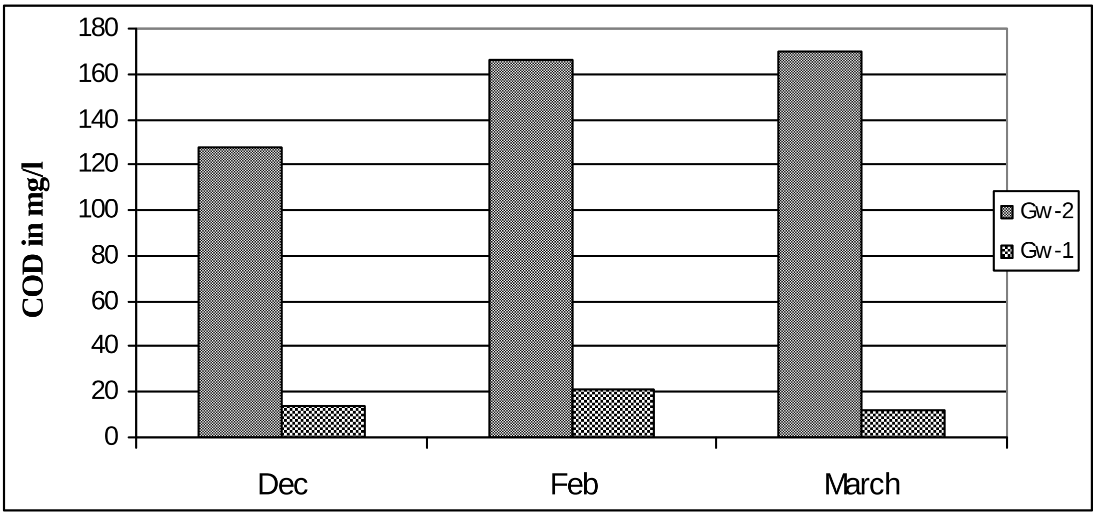

Figure 5.37: Monthly variation of chemical oxygen demand of groundwater

The average COD of groundwater recorded were 15.60 ± 4.61 mg/L at GW-1 and 154.67 ± 23.18 mg/L at GW-2. Throughout the investigation period, both the minimum COD (12.00 mg/L at GW-1) and maximum COD (170.00 mg/L at GW-2) were found in March.

5.1.2.14 Orthophosphate

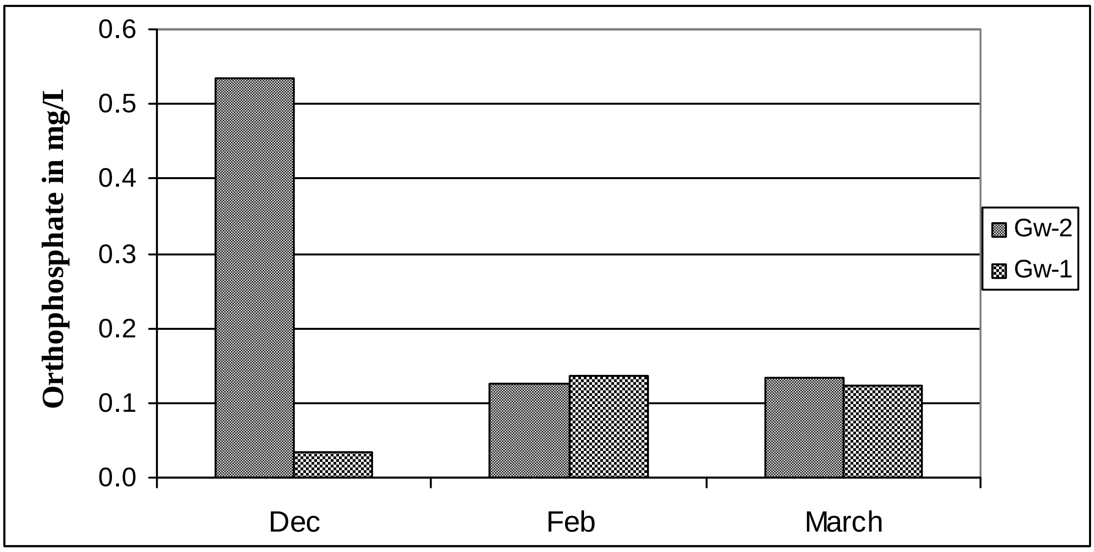

Figure 5.38: Monthly variation of orthophosphate concentration of groundwater

The monthly variation of orthophosphate concentration of groundwater over the period of three months (2007/2008) is shown in figure 5.38. The orthophosphate concentration of GW-1 and GW-2 fluctuated from December (0.035 mg/L at GW-1 and 0.534 mg/L at GW-2) to March (0.124 mg/L at GW-1 and 0.134 mg/L at GW-2).

5.1.2.15 Nitrate-nitrogen

The monthly variation of nitrate-nitrogen of groundwater over the period of three months (2007/2008) is shown in figure 5.39. The nitrate-nitrogen concentration of GW-1 and GW-2 fluctuated from December (2.300 mg/L at GW-1 and 1.699 mg/L at GW-2) to March (0.657 mg/L at GW-1 and 0.465 mg/L at GW-2).

The average nitrate-nitrogen concentration of groundwater found were 1.175 ± 0.975 mg/L at GW-1 and 0.870 ± 0.718 mg/L at GW-2. Throughout the investigation period, the minimum nitrate-nitrogen concentration was found to be 0.447 mg/L at GW-2 in February and the maximum nitrate-nitrogen concentration was found to be 2.300 mg/L at GW-1 in December

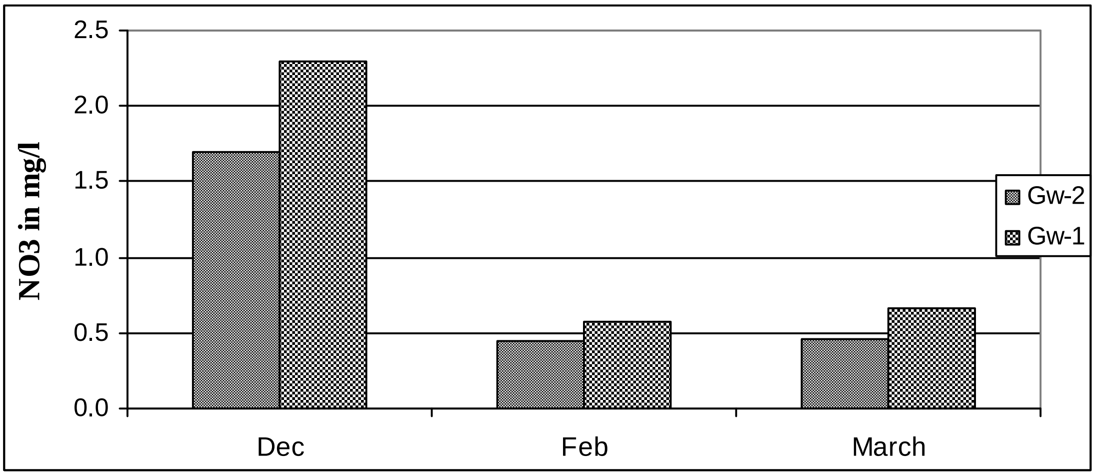

Figure 5.39: Monthly variation of nitrate-nitrogen concentration of groundwater

5.1.2.16 Iron

The monthly variation of iron content of groundwater over the period of three months (2007/2008) is shown in figure 5.40. The iron content of groundwater at GW-1 and GW-2 increased from December (0.10 mg/L at GW-1 and 0.15 mg/L at GW-2) to March (0.46 mg/L at GW-1 and 0.68 mg/L at GW-2).

The average iron content of groundwater found were 0.23 ± 0.20 mg/L at GW-1 and 0.34 ± 0.30 mg/L at GW-2. Throughout the investigation period, the lowest iron content of 0.10 mg/L was recorded at GW-1 in December and the highest iron content of 0.68 mg/L was recorded at GW-2 in March.

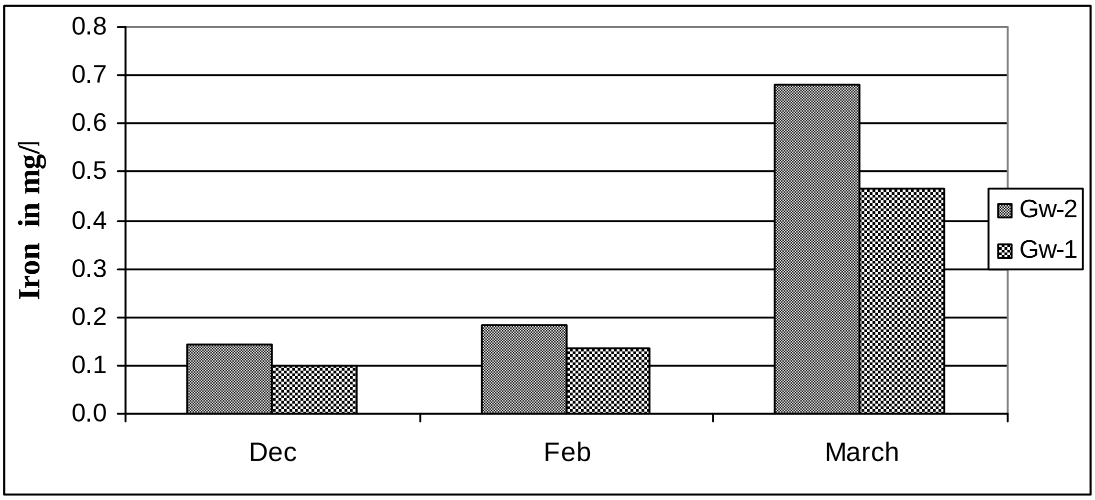

Figure 5.40: Monthly variation of iron content of groundwater

5.1.2.17 Ammoniacal- nitrogen

The monthly variation of ammoniacal nitrogen concentration of groundwater over the period of three months (2007/2008) is shown in figure 5.41. The ammoniacal nitrogen concentration of groundwater at GW-1 and GW-2 increased from December (0.06 mg/L at GW-1 and 0.14 mg/L at GW-2) to March (2.11 mg/L at GW-1 and 0.85 mg/L at GW-2).

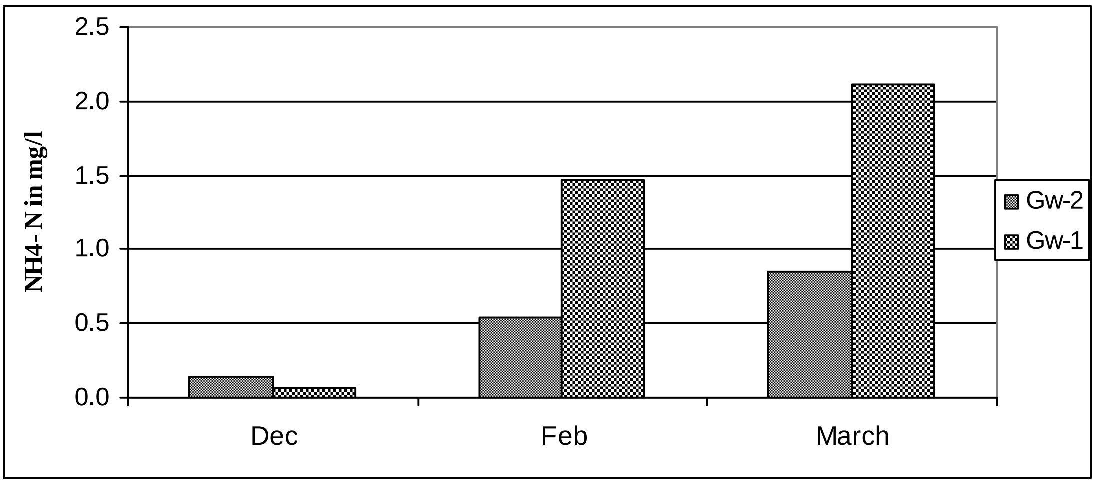

Figure 5.41: Monthly variation of ammoniacal-nitrogen of groundwater

The average ammoniacal nitrogen concentration of groundwater found were 1.21 ± 1.05 mg/L at GW-1 and 0.51 ± 0.35 mg/L at GW-2. Throughout the investigation period, the lowest ammoniacal nitrogen concentration of 0.06 mg/L was found at GW-1 in December and the highest ammoniacal nitrogen concentration of 2.11 mg/L was found at GW-1 in March.

5.1.2.18 Total dissolved solids (TDS)

The monthly variation of total dissolved solids of groundwater over the period of three months (2007/2008) is shown in figure 5.42. The TDS of GW-1 fluctuated from December (106.70 mg/L) to March (100.10 mg/L) but the TDS o GW-2 increased from December (391.05 mg/L) to March (514.80 mg/L).

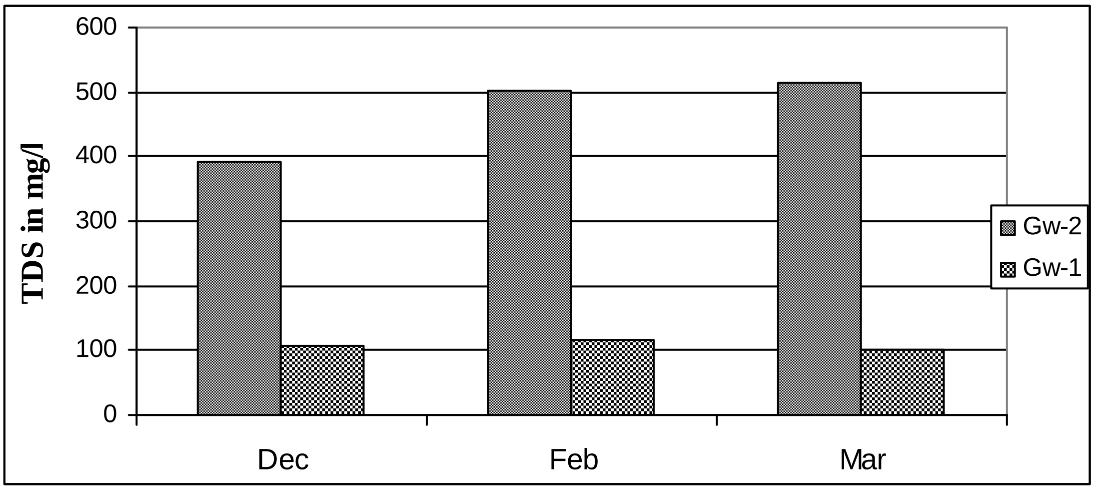

Figure 5.42: Monthly variation of total dissolved solids of groundwater

The average TDS of groundwater found were 107.43 ± 7.73 mg/L at GW-1 and 469.33 ± 68.09 mg/L at GW-2. Throughout the investigation period, both the lowest and the highest TDS (lowest TDS of 100.10 mg/L at GW-1 and the highest TDS of 514.80 mg/L at GW-2) were observed in March.

5.1.2.19 Total suspended solids (TSS)

The monthly variation of total suspended solids of groundwater over the period of three months (2007/2008) is shown in figure 5.43. The TSS of groundwater at GW-1 fluctuated from December (93.30 mg/L) to March (120.00 mg/L) but the TSS at GW-2 increased from December (342.95 mg/L) till March (365.20 mg/L).

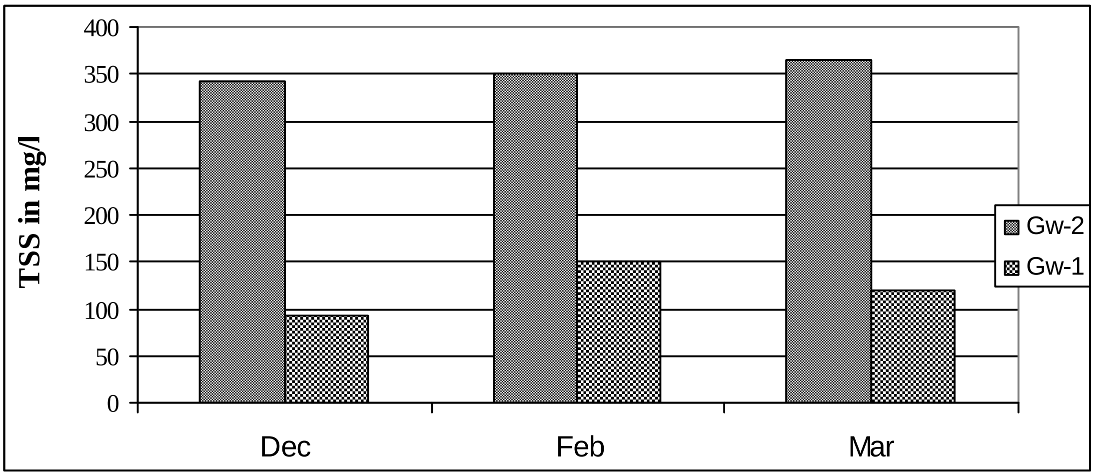

Figure 5.43: Monthly variation of total suspended solids of groundwater

The average TSS of groundwater found were 121.10 ± 28.37 mg/L at GW-1 and 352.72 ± 11.37 mg/L at GW-2. Throughout the investigation period, the lowest TSS (93.30 mg/L) was found at GW-1 in December and the highest TSS (365.20 mg/L) was found at GW-2 in March.

5.1.2.20 Total solids (TS)

The monthly variation of total solids of groundwater over the period of three months (2007/2008) is shown in figure 5.44. The TS at GW-1 fluctuated from December (200.00 mg/L) to March (220.10 mg/L) whereas the TS at GW-2 increased from December (734.00 mg/L) till March (880.00 mg/L).

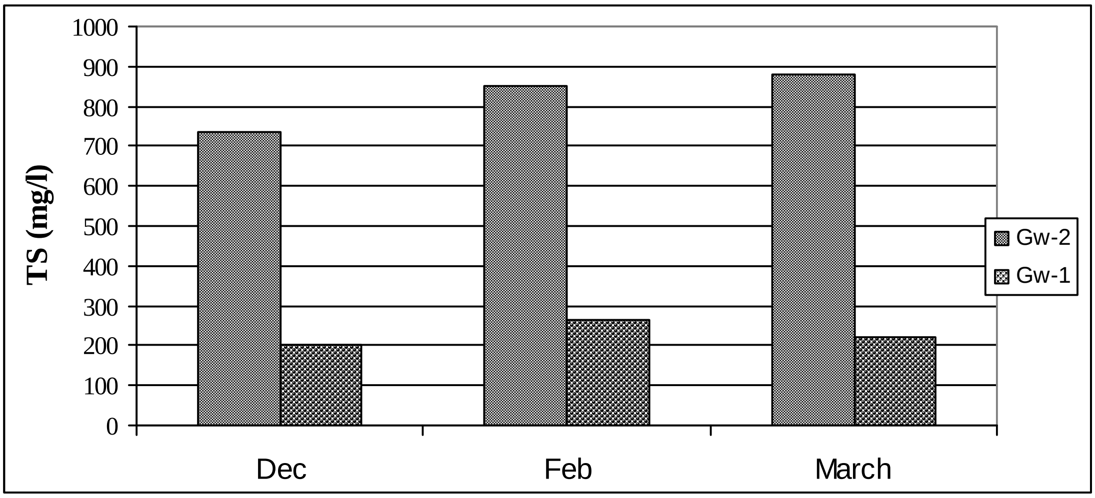

Figure 5.44: Monthly variation of total solids of groundwater

The average TS of groundwater found were 228.53 ± 33.55 mg/L at GW-1 and 734.00 ± 77.51 mg/L at GW-2. Throughout the investigation period, the lowest TS (200.00 mg/L) was obtained at GW-1 in December and the highest TS (880.00 mg/L) was found at GW-2 in March.

5.1.2.21 Total chromium

The seasonal variation of total chromium of groundwater over two seasons i.e. winter and pre-monsoon is shown in figure 5.45. The total chromium at both GW-1 and GW-2 decreased from winter (December) to pre-monsoon (March). The total chromium content was higher at GW-2 than at GW-1 in both seasons. The total chromium content at GW-1 was found to be nil in March.

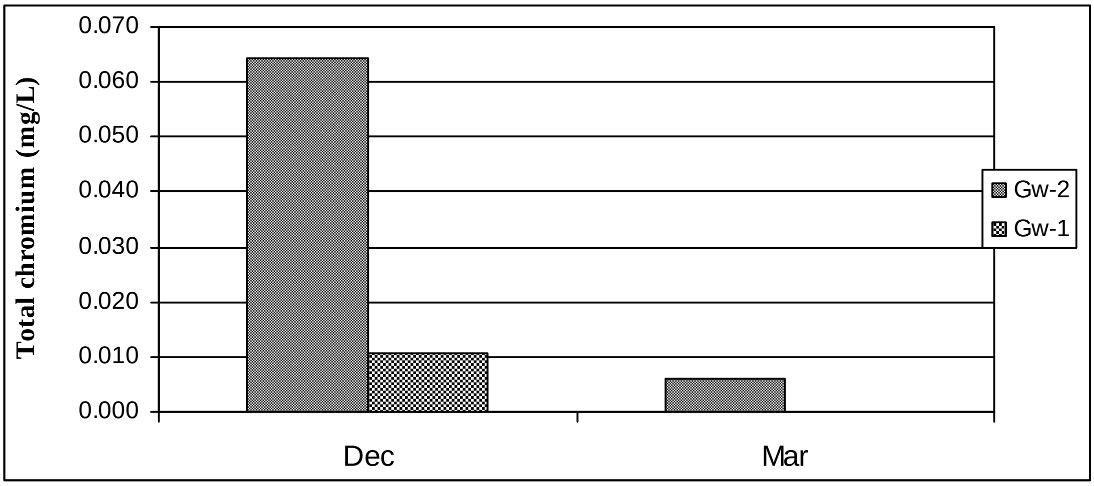

Figure 5.45: Seasonal variation of total chromium of groundwater in winter and pre-monsoon.

5.1.2.21 Potassium

The potassium content at both GW-1 and GW-2 increased from December i.e. winter (4.52 mg/L at GW-1 and 16.02 mg/L at GW-2) till March i.e. pre-monsoon (13.80 mg/L at GW-1 and 17.28 mg/L at GW-2). The potassium content was found higher at GW-2 than that at GW-1 in both seasons.

5.1.3 Physicochemical properties of groundwater of private well (G.W-1) in August, 2008

The pH, temperature and electrical conductivity of groundwater from GW-1 on August were found to be 6.2, 20.0°C and 156 µS/cm respectively. The chloride content was found to be 28.40 mg/L which was within WHO standard for drinking water i.e. 250 mg/L. The dissolved oxygen and total alkalinity were found to be 2.432 mg/L and 50 mg/L respectively. Hardness and calcium hardness were found to be 50 mg/L and 26 mg/L as $CaCO_3$. Hence the hardness of groundwater was fairly well below WHO standard for drinking water i.e. 500 mg/L. The calcium and magnesium content of the groundwater were found to be 10.42 mg/L and 5.86 mg/L respectively.

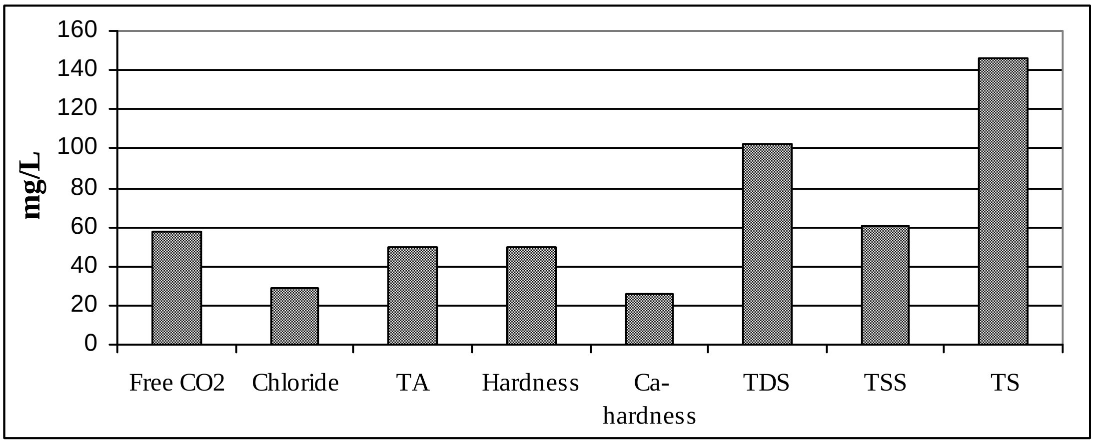

Figure 5.46: Free CO_2, chloride, total alkalinity, hardness, calcium hardness, TDS, TSS and TS of groundwater in August (monsoon)

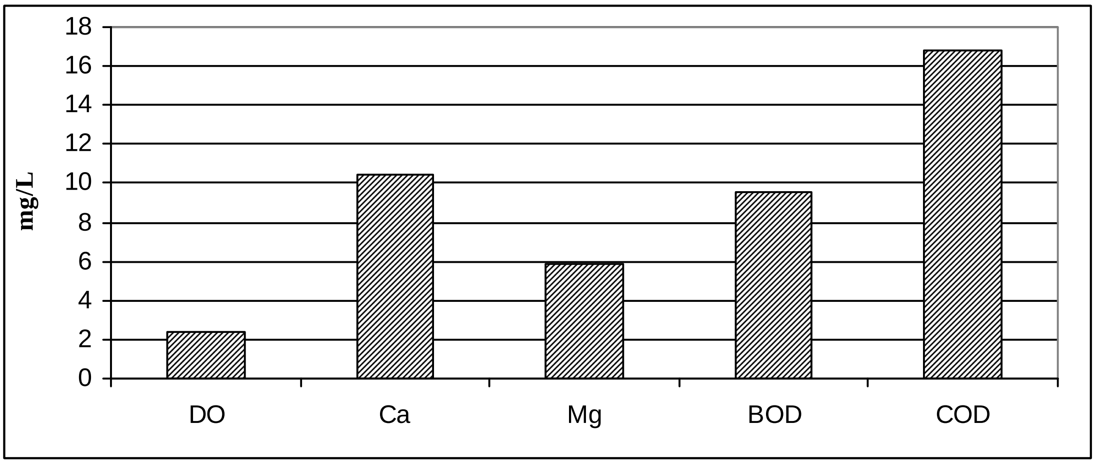

Figure 5.47: Dissolved oxygen, calcium, magnesium, BOD and COD of groundwater in August (monsoon)

The orthophosphate, nitrate- nitrogen, ammoniacal- nitrogen and iron content were found to be 0.066 mg/L, 0.500 mg/L, 0.05 mg/L and 0.20 mg/L respectively in August. Thus orthophosphate content of the groundwater was above WHO limit for drinking water (0.02 mg/L) in August. The BOD and COD of the groundwater were found to be 9.57 mg/L and 16.80 mg/L respectively. The chromium content was found to be 0.002 mg/L. Hence except orthophosphate all the other physicochemical parameters were found within WHO standard for drinking water on August.

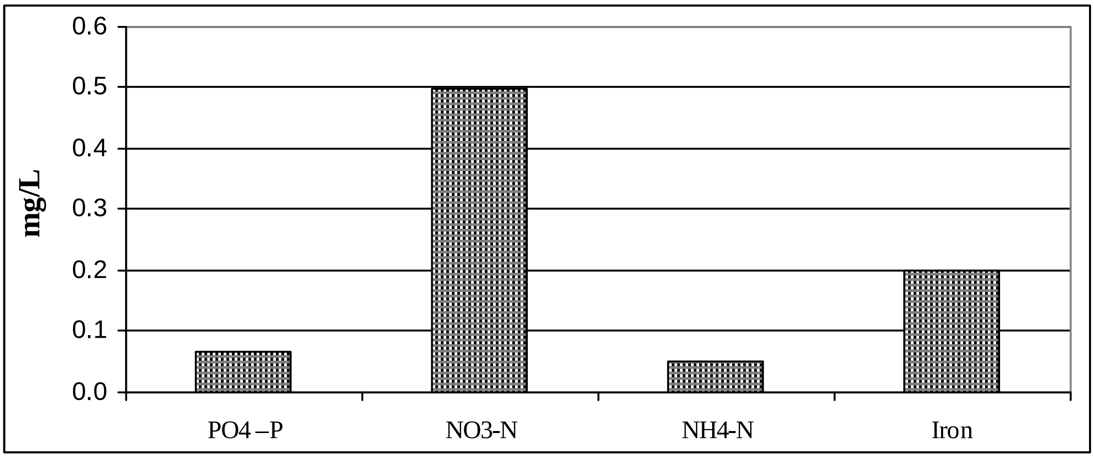

Figure 5.48: Orthophosphate, nitrate-nitrogen, ammoniacal- nitrogen and iron of groundwater in August (monsoon)

5.1.4 Physicochemical Parameters of leachate

The temperature of leachate decreased from December (19.0°C to February (12.5°C) and then gradually increased to 28.0°C in August. The pH of leachate remained constant at 6.9 in December and February. From February pH decreased to 6.8 in March and then increased to 7.0 in August (monsoon). The electrical conductivity of leachate increased sharply from December (17620 µS/cm) till March (41200 µS/cm) and then decreased till August (15495 µS/cm). The dissolved oxygen content of the leachate was nil during the entire investigation period. The free CO_2 content of leachate fluctuated from December (52.80 mg/L) till August (110.00 mg/L).

The chloride content of leachate increased gradually from December (2953.60 mg/L) till March (3408.00 mg/L) and then decreased till August (1988.00 mg/L). The highest chloride content of 3408.00 mg/L was observed in March (pre-monsoon) and the lowest value of 1988.00 mg/L was recorded in August. The phenolphthalein alkalinity was found to be nil during the entire investigation period and the total alkalinity fluctuated from December (8300 mg/L) till August (6500 mg/L) attaining the maximum value of 10800 mg/L in March i.e. pre-monsoon and the minimum value of 5750 mg/L in February (winter).

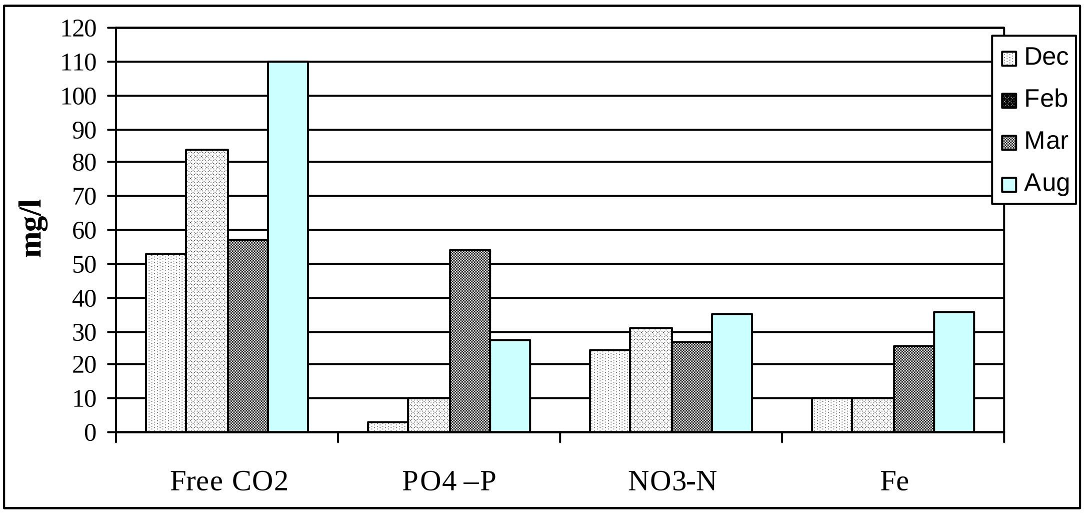

Figure 5.49: Monthly variation of free CO_2, orthophosphate, nitrate-nitrogen and iron of leachate.

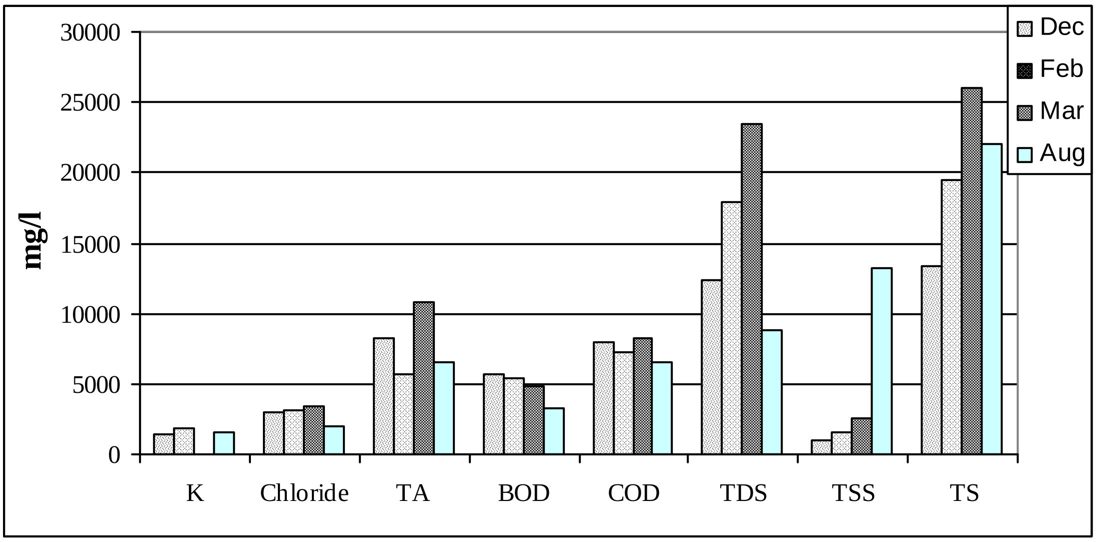

Figure 5.50: Monthly variation of potassium, chloride, total alkalinity, BOD, COD, TDS, TSS and TS of leachate.

The hardness of leachate gradually increased from December (1360 mg/L as $CaCO_3$) till August (5200 mg/L as $CaCO_3$). The calcium hardness of leachate also increased from December (640 mg/L as $CaCO_3$) till August (3160 mg/L as $CaCO_3$). The calcium and magnesium content of leachate also increased from December (256.51

mg/L of calcium and 175.68 mg/L of magnesium) till August (1266.53 mg/L of calcium and 497.76 mg/L of magnesium). The BOD of leachate decreased from December (5675.60 mg/L) till August (3243.20 mg/L). The COD of leachate fluctuated from December (8000.00 mg/L) till August (6520.00 mg/L). The COD of leachate was maximum (8240.00 mg/L) in March i.e. in pre-monsoon and minimum (6520 mg/L) in monsoon i.e. in August.

The orthophosphate concentration of leachate increased from December (3.168 mg/L) till March (54.306 mg/L) and then decreased till August (27.618 mg/L). The nitrate-nitrogen content of leachate fluctuated from December (24.378 mg/L) till August (35.174 mg/L). The ammoniacal nitrogen content of leachate increased from December (138.75 mg/L) till February (674.34 mg/L) and then decreased till August (24.51 mg/L). The iron content of leachate increased gradually from December (10.23 mg/L) till August (35.66 mg/L).

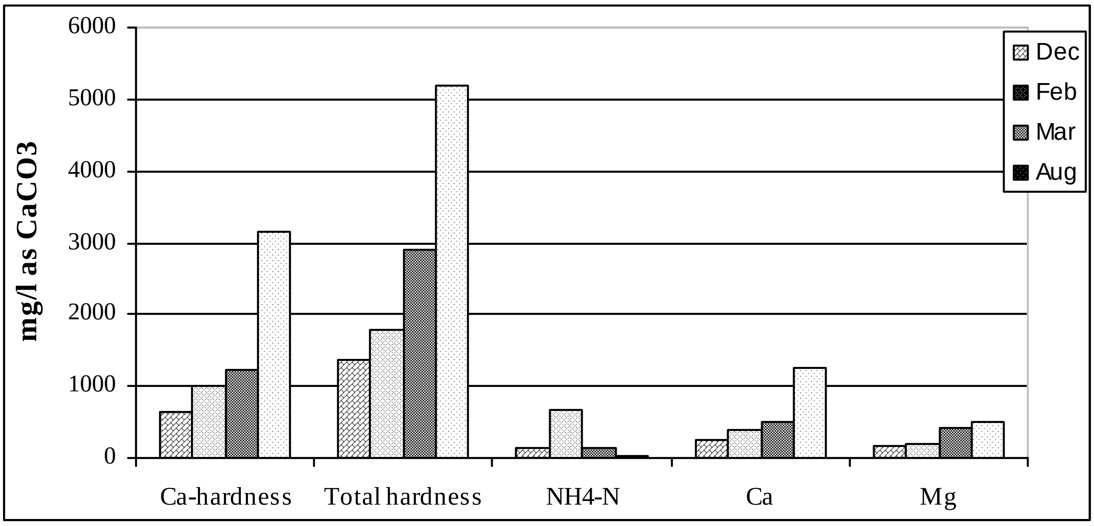

Figure 5.51: Monthly variation of calcium hardness, hardness, ammoniacal- nitrogen, calcium and magnesium of leachate

The total dissolved solids of leachate increased continuously from December (12334.00 mg/L) till March (23484.00 mg/L) and then decreased till August (8832.15 mg/L). The TSS of leachate increased continuously from December (1066.00 mg/L) till August (13167.85 mg/L). The total solids of leachate increased from December (13400.00 mg/L) till March (26000.00 mg/L) and then decreased till August (22000.00 mg/L) with the maximum value in March.

The total chromium content of leachate increased from December i.e. winter (0.460 mg/L) till March i.e. pre-monsoon (0.782 mg/L) and then decreased till August (0.092 mg/L). The average total chromium content of leachate recorded was 0.445 ± 0.345 mg/L.

5.2 Microbiological Parameter

MPN/100 ml of surface water found were 240, ≥2400, ≥2400, ≥2400, ≥2400 and 1600 at stations 1, 2, 3, 4, 5 and 6 respectively in December (Appendix VIII) and 38, ≥2400, 43, 540,170 and 110 at 1, 2, 3, 4, 5 and 6 respectively in March (Appendix IX). The number of fecal coliform at all six sites of Kolpu Khola decreased from December till March (38/ 100 ml at site 1, ≥2400/ 100 ml at site 2, 43/ 100 ml at site 3, 540 / 100 ml at site 4, 170 / 100 ml at site 5 and 110 / 100 ml at site 6) and then increased till August (350/ 100 ml at site 1, 910/ 100 ml at site 3, 1600 / 100 ml at site 4, ≥2400 / 100 ml at site 5 and 540 / 100 ml at site 6) except site 2.

MPN/100 ml of ground water (GW-1) were found to be 350, 2 and 25 in December, March and August respectively whereas that of GW-2 was found to be ≥2400 and 540 in December and March respectively. MPN/100 ml of leachate was found to be ≥2400 in December, March as well as in August.

5.3 Socioeconomic survey

5.3.1 Socioeconomic condition of nearby people

5.3.1.1 General Characteristics of Respondents

For socioeconomic survey the wards of different VDCs that are connected to the stretch of Kolpu Khola from landfill station to station S_6 were taken. Thus the study area of the survey includes Okharpauwa VDC (ward no. 4), Chauthe VDC (ward no. 5 and 6) and Chhatredeurali VDC (6, 8 and 9). Ten percent (10 %) of the households were taken for the socioeconomic study based on latest census of 2001. The total number of male respondents was more than female, even though no discrimination was made with sex. The age of respondents ranged from 15 to 71 years. Most of the respondents are of the age group 30- 50 years in two VDCs (36.67 % in Chhatredeurali VDC and 43.75 % in Chauthe VDC) whereas in Okharpauwa VDC majority of the respondents (45 %) are of >50 years age group. The respondents were from different caste/ethnic groups. The occupation of majority of the respondents is agriculture. At least 75 % of respondents were dependent only on agriculture as their main source of income. Rests of the respondents were involved in services, business and labor. Majority of the respondents are literate except in Okharpauwa VDC.

Table 5.3.1: General Characteristics of Respondent in the Study Area

Category		**Number and % of respondents**					
		Chhatredeurali		Okharpauwa		Chauthe	
		No.	%	No.	%	No.	%
By sex	Male	47	78.33	14	70	13	81.25
	Female	13	21.67	6	30	3	18.75
By age group	<30 yrs	19	31.67	6	30	6	37.50
	30- 50 yrs	22	36.67	5	25	7	43.75
	>50 yrs	19	31.67	9	45	3	18.75
By no. of family members	1 to 3	6	10.00	0	0.00	0	0.00
	4 to 6	32	53.33	11	52.38	8	50.00
	7 to 9	16	26.67	4	19.05	7	43.75
	10 to 13	6	10.00	6	28.57	1	6.25
By education	Illiterate	10	16.67	13	65	4	23.53
	Primary	21	35.00	7	35	7	41.18
	Secondary	25	41.67	0	0	1	5.88

	Intermediate	3	5.00	0	0	1	5.88
	College	1	1.67	0	0	3	17.65
	University	0	0.00	0	0	1	5.88
By occupation	Agriculture	30	66.67	14	38.89	10	58.82
	Business	8	17.78	0	0.00	1	5.88
	Govt. services	3	6.67	0	0.00	2	11.76
	Labor	0	0.00	0	0.00	0	0.00
	Both c and d	4	8.89	4	11.11	0	0.00
	both b and c	0	0.00	0	0.00	1	5.88
	student	15	33.33	2	5.56	3	17.65
By ethnicity	Brahmin	16	30.77	8	40	8	61.54
	Chhetri	4	7.69	8	40	1	7.69
	Tamang/Lama/ Gurung/Magar	28	53.85	0	0	4	30.77
	Newar	4	7.69	4	20	0	0.00

5.3.1.2 Family structure:

The number of families having 4 to 6 members was found to be the maximum in all the three VDCs studied. The families having members ranging from 10- 13 were found to be the maximum i.e. 28.57 % in Okharpauwa VDC. The number of males was found greater than that of females in all the selected areas of three VDCs.

5.3.1.3 Education

Among the respondents the percentage of illiterate people were highest i.e. 65% in Okharpauwa VDC and the least i.e. 16.67 % in Chhatredeurali VDC. One reason behind high literacy in Chhatredeurli VDC may be due to accessibility of school in that VDC. SWMRMC has given incentive for making school building of Mahakali Kisan Ma Vi at ward no. 9 of Chhatredeurali VDC and the school is accessible for people of both ward no. 6 and 9 of that VDC.

5.3.1.4 Ethnicity

The study area was composed of different ethnic groups. In Okharpauwa-4 the proportions of Brahmin and Chhetri are equal. Besides 20% of the households were occupied by the Newars mainly Balamis. Whole of the Okharpauwa-4 is dominated by Balami community. In Chhatredeurali VDC Tamang/ Lama/Magar/ Gurung were dominant (53.85 %) ethnic groups followed by Brahmins (30.77 %). The opposite was true in case of Chauthe VDC i.e. there is dominancy of Brahmins (61.54 %) followed by Tamang/ Lama/Magar/ Gurung (30.77 %).

5.3.1.5 Occupation and Household economy/ economic status

The occupations adapted by households were agriculture, service, unskilled/wage labor and business. Most of the respondents were found to be dependent on agriculture.

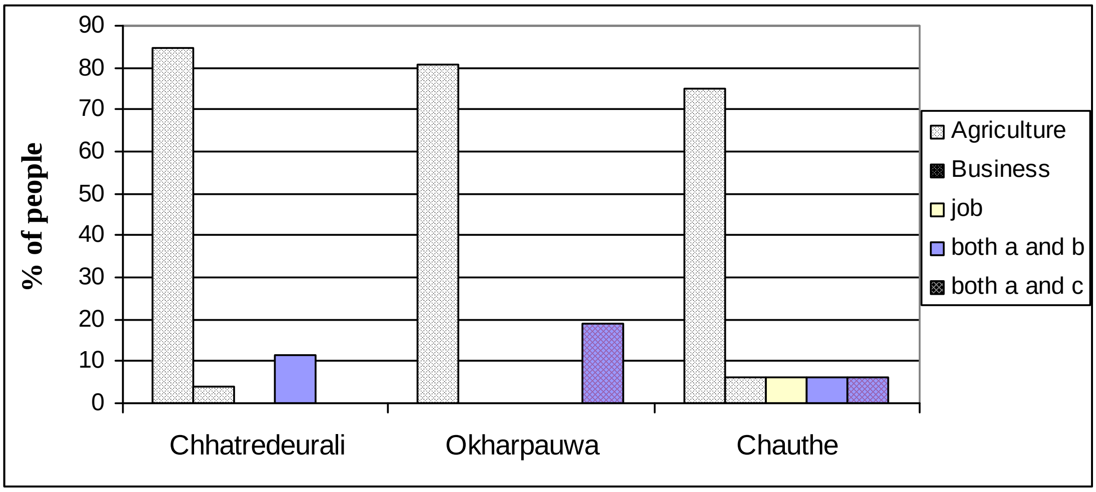

Figure 5.3.1: Percentage of respondents on the basis of main source of income

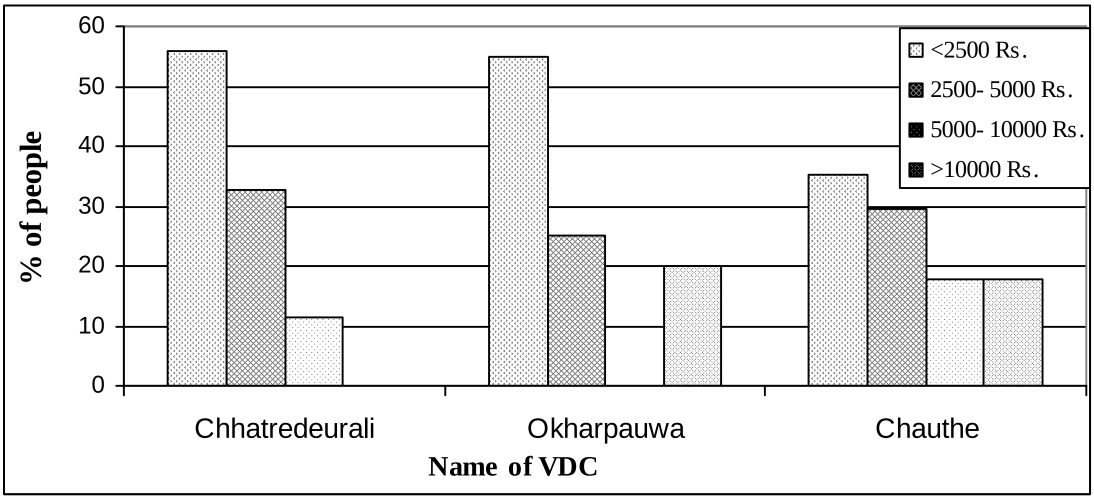

Figure 5.3.2: Percentage of respondents on the basis of income (in Rs.) level

Agriculture as occupation is represented by 66.67 %, 58.82 % and 38.89 % of respondents in Chhatredeurali, Chauthe and Okharpauwa VDC respectively. Agriculture was found to be the most prominent source of income in all the three VDCs. The percentages of families dependent only on agriculture as their main source of income were found to be 84.62 %, 80.95 % and 75.00 % in Chhatredeurali, Okharpauwa and Chauthe VDC respectively.

Most of the people in all the three VDCs under study were found to have income level less than NRs. 2500 (55.77 % in Chhatredeurali, 55.00 % in Okharpauwa and 35.29 % in Chauthe). The number of families having income level more than 10,000 was found to be the highest i.e. 20.00 % in Okharpauwa VDC followed by 17.65 % in Chauthe VDC.

5.3.1.6 Source of energy

Fuelwood and electricity were found to be the main source (80 % in Okharpauwa VDC, 75 % in Chhatredeurali and 62.50 % in Chauthe VDC) of household energy in all the parts of three VDCs under study. Households consuming only fuelwood were highest (31.25 %) in Chauthe because electricity is not available there although transmission line was built a couple of years before.

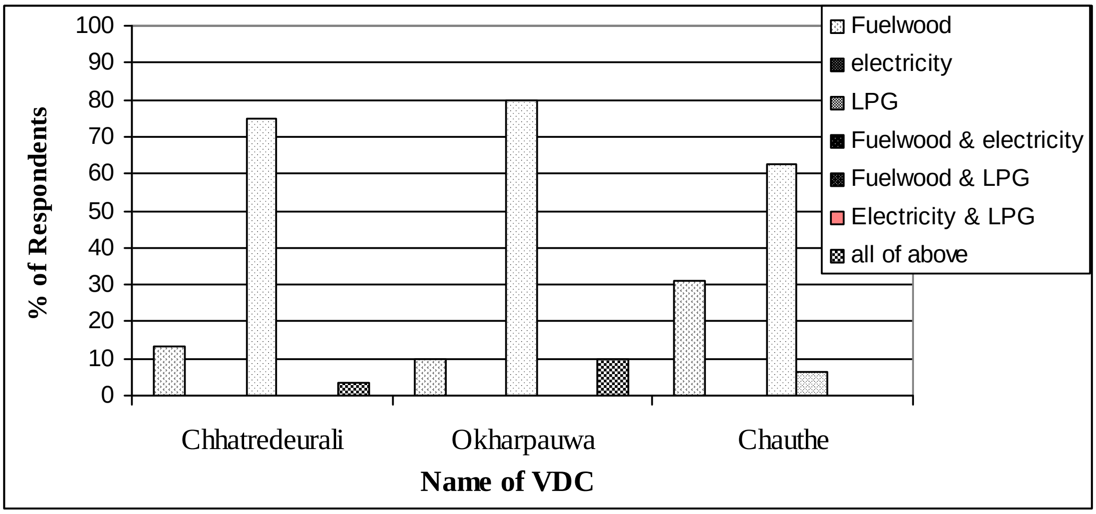

Figure 5.3.3: Percentage of respondents on the basis of source of household energy

5.3.1.7 Use of River water

None of the households was found to use the river water for livestock feeding, washing and bathing activities in all the three VDCs. Those who use the river water were found to use it only for irrigation purpose. Cattle occasionally drink the river water when released for grazing in the floodplains. The percentage of people using river water was found to be the greatest (51.67 %) in Chhatredeurali VDC and the least (41.18 %) in Chauthe VDC. One reason behind this may be due to that three wards namely ward no. 6, 9 and part of ward no. 8 of Chhatredeurali VDC are connected to Kolpu Khola whereas only one ward of Chauthe VDC is connected with the River. The percentage of households using the river water in Okharpauwa VDC was 45.00 %.

5.3.2 Peoples' perception on leachate

The percentages of respondents who know leachate were found to be 66.67 %, 80.95 % and 62.50 % in Chhatredeurali, Okharpauwa and Chauthe VDC respectively. Since people of Chauthe VDC are far away from the landfill site, greater percentage of people doesn't know what leachate is. Most of the respondents in all the three VDCs don't have any idea about suitable method for disposal of leachate. It was found directly related with their education status. In general illiterate respondents were found to have no idea about it.

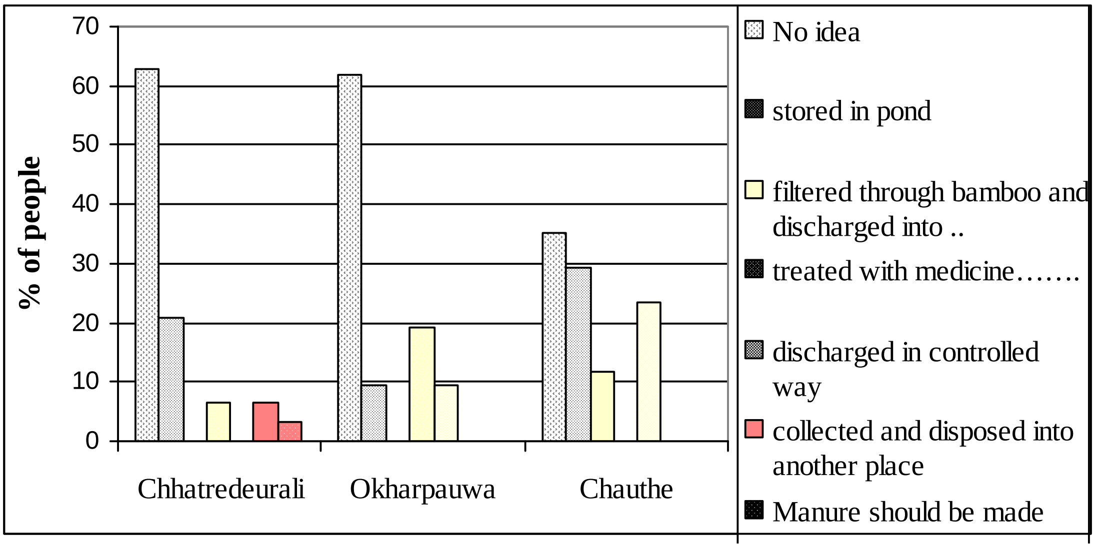

Figure 5.3.4: Percentage of respondents on the basis of their opinion on disposal of leachate

Some of the respondents (6.45 % in Chhatredeurali and 19.05 % in Okharpauwa VDC) said that the leachate should be treated with medicine before disposal into the River. Few of the respondents (3.23 %) in Chhatredeurali VDC said that the leachate may be disposed by making manure from it. Some of them (mainly from Chauthe VDC) said that the leachate should be discharged in controlled way i.e. releasing the leachate in certain fixed days of the month with prior information to the affected people so that people can use the river water for irrigation or other purposes when there is no outflow or discharge of leachate into the River.

5.3.3 Peoples' perception of impact on surface water by leachate

All the respondents said that the present dumping activities along the banks of river is not the better way to dispose waste. Most of the respondents from all the three VDCs said that the river water has been changed extremely after dumping of waste in the landfill. They said that the water quality of Kolpu Khola was very good before dumping started at Sisdol and they even used occasionally the River water for drinking. Most of the respondents in Chhatredeurali and Chauthe VDC said that the impact of leachate may be up to 10 km from SLFS whereas most of those from Okharpauwa VDC (36.36 %) said that the effect is up to more than 10 km from the landfill.

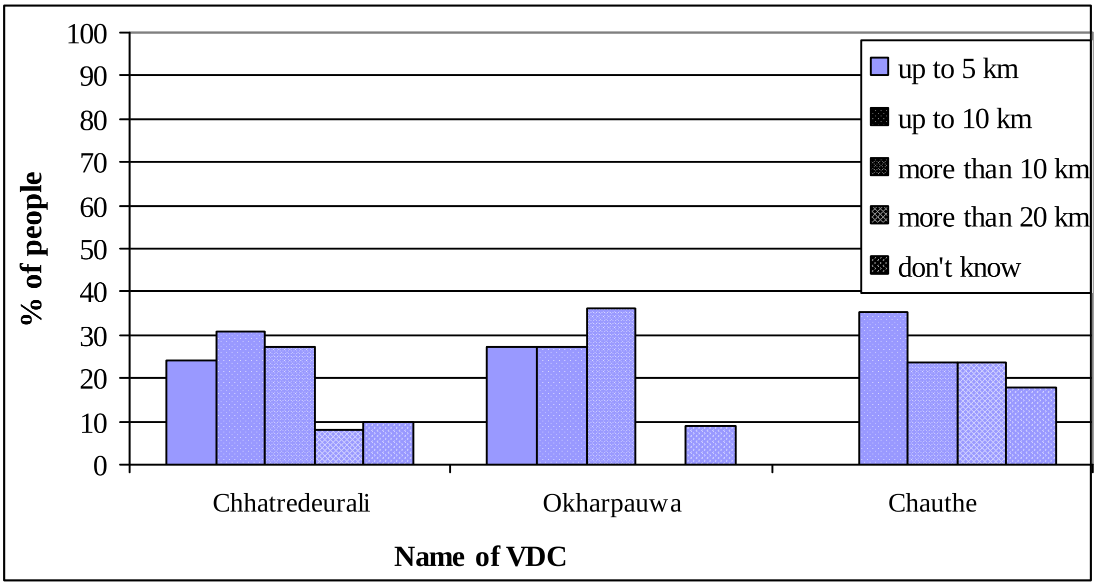

Figure 5.3.5: Percentage of respondents on the basis of their perception on impact on water quality of the River

Table 5.3.2: Percentage of respondents on the basis of their perception on change in water quality of Kolpu Khola

Change in water quality	**Name of VDC**		
	Okharpauwa	Chauthe	Chhatredeurali
significantly	28.57	47.06	35.00
extremely	71.43	52.94	65.00

5.3.4 Peoples' perception on impact on their socioeconomic life

On the basis of respondents' opinion the percentages of people/respondents affected on their socioeconomic life were found to be nearly equal in Chhatredeurali VDC and Okharpauwa VDC (65.38 % in Chhatredeurali VDC and 65.00 % in Okharpauwa VDC) and the least in Chauthe VDC (58.82 %). This is probably due to the fact that the pollutants contributed by the leachate in the surface water get gradually diluted by natural purification when it reaches to Chauthe.

Table 5.3.3: Percentage of respondents on the basis of their perception on effect on their socioeconomic life

Effect on socioeconomic life	**% of respondent**		
	Okharpauwa	Chauthe	Chhatredeurali
People affected	65	58.82	65.38
not affected	35	41.18	34.62

41.18 % of households from Chhatredeurali VDC said that all aspects of their socio-economic life are affected by change in water quality of the River. Households affected on their agriculture were found maximum (20.59 %) in Chhatredeurali followed by Chauthe (20 %) and Okharpauwa (16.67 %).

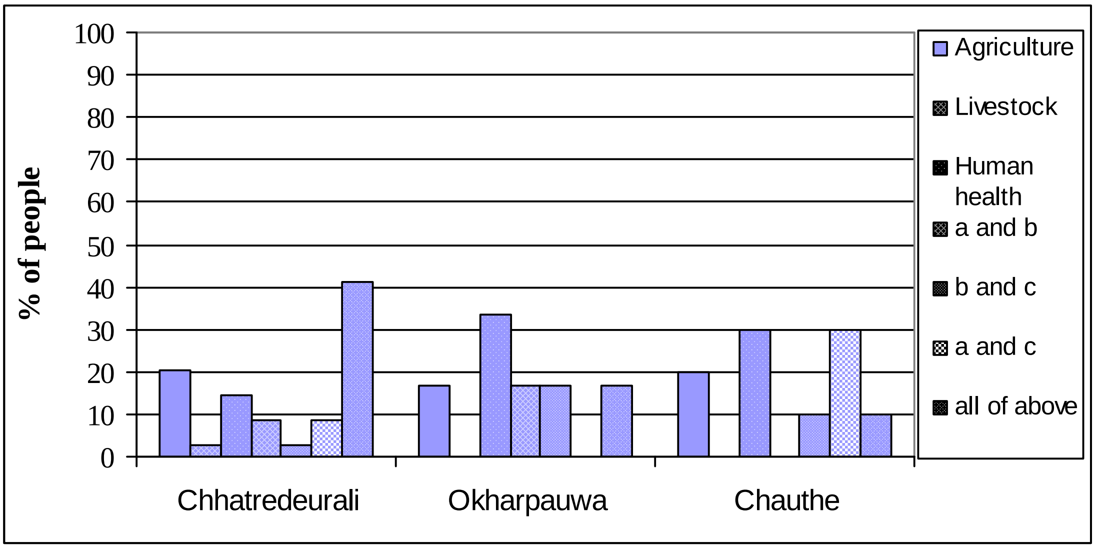

Figure 5.3.6: Percentage of respondents on the basis of aspect of their socioeconomic life affected

The percentages of respondents affected on their health were found to be 72.73 %, 51.92 % and 23.53 % in Okharpauwa, Chhatredeurali and Chauthe VDC respectively.

The percentages of people affected on agriculture were found to be 56.25 %, 50.00 % and 45.45 % in Chhatredeurali, Okharpauwa and Chauthe VDC respectively. Compared to the decline in agricultural production, increment in production has been found greater in Chhatredeurali (56.52 %) and Chauthe VDC (66.67 %) whereas all of the respondents in Okharpauwa VDC said that agricultural production is in declining trend. Few of the respondents from Chauthe said that there has been increase in agricultural production even by use of less amount of fertilizers.

Table 5.3.4: Percentage of respondents on the basis of effect on agricultural production

Effect on agricultural production	**% of respondent**		
	Okharpauwa	Chauthe	Chhatredeurali
Increase in production	0	66.67	56.52
Decrease in production	100	33.33	43.48
no change	0	0	0.00

According to respondents' opinion in the study area people of Okharpauwa VDC are the most affected on their health and those of Chauthe VDC are the least affected. Obviously there is no doubt in the peoples' perception on their health impact. It is because Okharpauwa VDC is quite close to the landfill site and Chauthe VDC is the farthest among the three VDCs.

From the questionnaire survey the frequency of illness was found to be increasing in all the three VDCs- 48.15 %, 61.90 % and 33.33 % in Chhatredeurali, Okharpauwa and Chauthe VDC respectively but the respondents could not say the actual rate of increment.

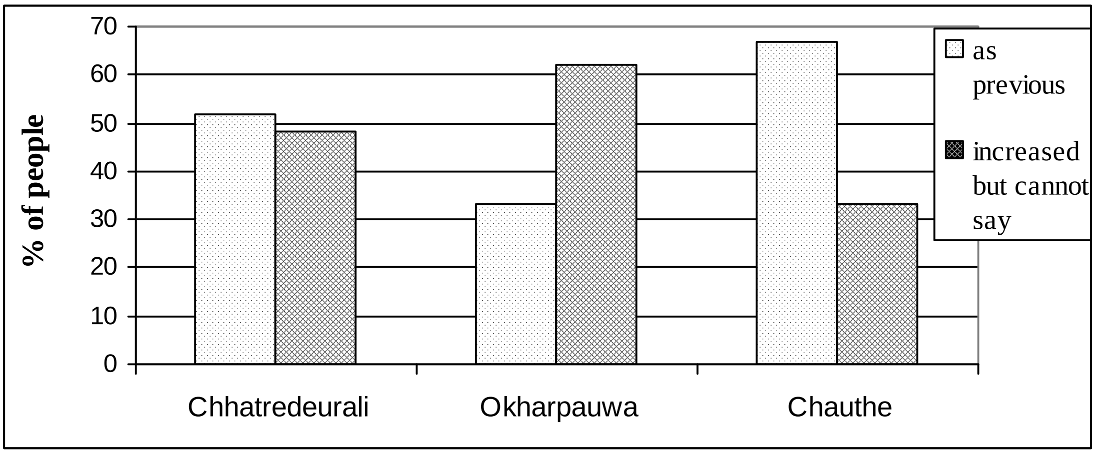

Figure 5.3.7: Percentage of respondents on the basis of frequency of getting illness

Table 5.3.5: Percentage of respondents on the basis of effect on health

Effect on health	**% of respondent**		
	Okharpauwa	Chauthe	Chhatredeurali
Affected	72.73	23.53	51.92
Not affected	27.27	76.47	48.08
	100.00	100.00	100.00

Except ward no. 9 of Chhatredeurali VDC the remaining 5 wards of three VDCs have one health post in each ward. However most of the respondents said that the health posts are inaccessible for them and the health care facilities are not adequate.

Table 5.3.6: Percentage of respondents on the basis of their opinion on sufficiency of health post

sufficiency of health post	**% of respondent**		
	Okharpauwa	Chauthe	Chhatredeurali
Sufficient	0	11.76	11.11
Not sufficient	100	88.24	88.89

5.3.5 Peoples' perception on future of landfill

When the respondents were asked about the future of landfill most of them (75.00 %, 55.00 % and 29.41 % in Chhatredeurali, Okharpauwa and Chauthe VDC respectively) were found to have no idea. Very few of the respondents (1.92 % in Chhatredeurali and 5.88 % in Chauthe VDC) said that the landfill could be exploited as source of methane gas after its closure.

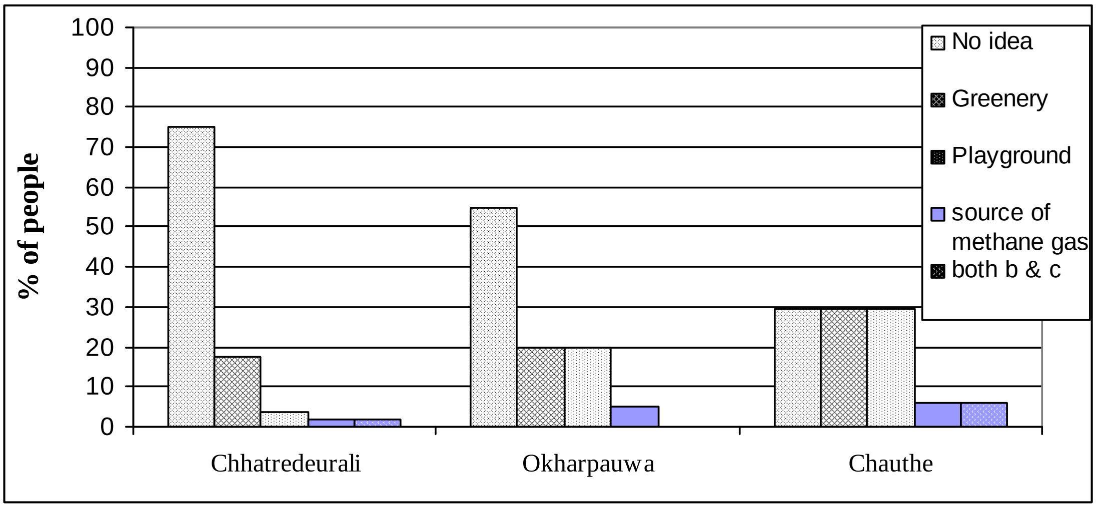

Figure 5.3.8: Percentage of respondents on the basis of their perception on future of landfill

VI. DISCUSSION

Sanitary landfill always has negative impact on the existing environment. The landfill affects the existing environment in different ways. Generally, it is the surface water that gets immediately contaminated through the discharge of leachate. Depending upon the soil characteristics and precautions taken during landfill operation, the extent of ground water pollution could be foresighted (Karki, 2004).

6.1 Surface Water Quality

Temperature is considered as a very important factor in stream ecology (Hynes, 1979). The temperature is basically important for its effect on the chemistry and biological reactions in the organisms in water. A rise in temperature of the water leads to the speeding up of the chemical reactions in water, reduces the solubility of gases and amplifies the tastes and odours (Trivedy and Goel, 1986). The temperature of surface water of Kolpu Khola was found less in winter season (December-February) i.e. 10.5 ºC to 20.0ºC and high in pre-monsoon season (March) i.e. 16.0 ºC to 23.5 ºC. It may be so because the major factor responsible for warming of stream is direct solar radiation and the water temperature varies with the season in temperate climates (Hynes, 1979). Such seasonal variation is significant at 0.01 and 0.05 significance level (two- tailed). The spatial variation of water temperature at different stations along the river is not significant at 0.01 and 0.05 significance level.

Natural water has pH value of 7.0. Sudden change in this value would indicate industrial pollution (APHA, 1995). The pH of the river water varied between 6.7 and 7.6 throughout the investigation period. The WHO drinking water quality standard for pH is 6.5 to 9.5 (WHO, 2004) and Nepal drinking water quality standard (NDWQS, 2062) is 6.5 to 8.5. Thus all the water is safe for drinking from pH point of view. Thus observed variation in pH in the river water at different stations from station 1 to 6 along the river is significant at 0.05 significance level and not at 0.01 significance level whereas the temporal variation in pH is not significant at 0.01 and 0.05 significance levels. The pH at all six sites lie within CCME Guidelines (1999) for Protection of Freshwater Aquatic Life (6.5 to 9.0). Hence all the surface waters from station S_1 to S_6 are suitable for aquatic life from pH point of view.

Electrical conductivity or simply conductivity is a measure of the ability of an aqueous solution (electrolyte) to carry an electric current. This ability depends upon the presence of ions; on their total concentration, mobility and valency; and on the temperature of measurement (APHA, 1995). Such seasonal variation of conductivity is significant at 0.05 significance level and not significant at 0.01 significance level. However the spatial variation of conductivity is not significant at 0.01 and 0.05 significance level. The National Drinking Water Quality Guidelines (2062) for electrical conductivity is 1500 µS/cm. The conductivity of surface water at all stations ranged from 57µS/cm to 194µS/cm. So the conductivity of surface water along the River under study lies within NDWQ guideline (2062).

The greatest temporal variation in transparency was seen at station 5 and 6 during the study period. At stations 4, 5 and 6, the minimum secchi disc transparency was observed on February. The transparency was higher in pre-monsoon (March) compared to winter (December/February) and monsoon (August). The less transparency in winter was due to the disposal of clay produced in excess during the process of agricultural terrace construction in the upstream catchment areas during winter season. The transparency at all stations was less in August i.e. in monsoon compared to March i.e. pre-monsoon. The monthly variation of transparency is significant at 0.01 and 0.05 significance level.

Alkalinity of water is its acid neutralizing capacity. It is the sum of all titrable bases such as carbonates, bicarbonates, hydroxides, phosphates, nitrates, silicates, borates etc. However, in natural water carbonates, bicarbonates and hydroxide are considered to be the predominant bases. Thus the total alkalinity (combining carbonates, bicarbonates and hydroxides) or alkalinity due to individual bases can be expressed (APHA, 1995). In the surface water of the Kolpu Khola, the total alkalinity was only due to the bicarbonate (HCO_3^-) ions. Bicarbonate is the dominant ion in most of the surface water (UNESCO, 1996). Carbonate and hydroxide alkalinity were not observed. Carbonate is uncommon in natural surface water because they rarely exceed pH 9 (UNESCO, 1996). Moreover hydroxide alkalinity was also absent because the phenolphthalein alkalinity was zero at all the stations. The total alkalinity fluctuated from site S_1 to S_5 in December, March and August except from site 2 to 3 on March. However, such monthly and spatial variations of total alkalinity are not significant at

0.01 and 0.05 significance level. Alkalinity in itself is not harmful to human beings; still the water supplies with less than 100 mg/L alkalinity are desirable to domestic use (Trivedy and Goel, 1986). Thus the surface water from stations 1 to 3 and 6 can be used for drinking from alkalinity point of view.

Dissolved oxygen is one of the most important parameters of water quality and is an index of physical, chemical and biological processes going on in water. The dissolved oxygen increased from December (early winter) till February (late winter) and then decreased in March (early pre-monsoon). The increase in dissolved oxygen from December to February may be due to decrease in temperature and the decrease in DO from February to March may be due to increase in temperature since temperature has inverse relationship with oxygen solubility (Cole, 1975; Saxena, 1987). The coefficient of correlation (r) between dissolved oxygen and water temperature is -0.432 (significant at 0.05 significance level, two tailed) indicating negative correlation. The decreased dissolved oxygen at station 2 compared to station 1 was probably due to increasing concentration of chemical load contained in the leachate discharged from the leachate tank. In general, the dissolved oxygen content of the river water increased from station 2 to 4. The dissolved oxygen content increased from station 4 to 6 (except in February). This may be due to natural purification by the biodegradation of organic wastes contained in the leachate. Although variation in dissolved oxygen content in the surface water at different stations along the river was observed in different months, such spatial (upstream to downstream) variation is not significant at 0.01 and 0.05 significance level and such variation may be due to temporary causes such as variation in water temperature, river discharge or leachate discharge varying in time and space etc.

In the river water, the possible sources of dissolved oxygen are diffusion from air (physical phenomena) and photosynthetic activity within the water (biological phenomenon). During the entire study period, all the stations (except station 2 on August) in the Kolpu Khola had dissolved oxygen content well above 5 mg/L which is suitable to support aquatic life including fishes (Trivedy and Goel, 1986; UNESCO, 1996). The dissolved oxygen content observed at all sites except site S_2 on August of the river under study lie between the range 5.5 to 9.5 mg/L which is the CCME, 1999 Water Quality Guidelines for the Protection of Freshwater Aquatic Life. Therefore except site S_2 the surface water of all other five sites are safe for aquatic life from point of view of dissolved oxygen.

Chlorine in water is commonly found in the form of chloride ion. Chloride occurs naturally in all types of water. In natural freshwater, however, its concentration remains quite low and is generally less than that of sulphates and bicarbonates. Portable water may contain small quantity of chloride without any harmful effect. The chloride content of the Kolpu Khola varied between 15.62 mg/L and 63.90 mg/L and since the WHO guideline (1993) value as well as Nepal Drinking water standard (2062 BS) for chloride is 250 mg/L, the surface water along the Kolpu Khola had the chloride content far below the standard. Therefore the water is not polluted from chloride point of view and safe for drinking with respect to chloride content. Throughout the study period, chloride content was minimum at site 6 and maximum at site 2 in all the four months. The higher values of chloride at station 2 may be due to mixing of leachate. In general, chloride content increased from site 1 to 2 and then decreased from site 2 to 6. The chloride content at all sites decreased from March (pre-monsoon) till August (monsoon).

The monthly variation of chloride content of the river water is not significant at 0.01 and 0.05 significance level. However, the spatial variation of chloride content is significant at 0.01 and 0.05 significance level. It may be due to the fact that leachate contains enormous quantity of chloride and the leachate is getting its way into the River at station 2 in one way or the other. The USEPA, 1999 Water Quality Guidelines for chloride (as factor causing chronic toxicity) for the Protection of Freshwater Aquatic life is 230 mg/L (Appendix XV). Since the maximum concentration of chloride observed in the surface water of Kolpu Khola is 63.90 mg/L which is much less than the guideline value, the chloride content of the river is not at the level that can cause chronic effect to the aquatic life.

Carbon dioxide in water is usually found as free carbon dioxide (CO_2) and combined carbon dioxide (i.e. carbonate and bicarbonate)(APHA, 1995). The maximum free CO_2 was observed at station 2 except on August. This may be due to mixing of leachate containing huge amount of organic load increasing the production of CO_2 during breakdown of the organic materials. The decrease in free CO_2 from site 2 to 4 (except from site 3 to 4 in March and August) may be due to gradual decrease in organic load contributed by the leachate. The optimum range of free CO_2 of surface water for fishes is 15- 20 mg/L (HMG/FDD, 1998). The free CO_2 of surface water of station 1 and 6 had always the value below 20.00 mg/L (as shown in figure 5.9) showing the water quality is suitable for fishes and also other aquatic animals from the point of view of free CO_2.

At cleaner sites (1 and 6) the maximum free CO_2 was found in monsoon (August) probably due to increase in organic load caused by increased surface runoff input to the river sweeping off the organic materials from the agricultural land. The observed monthly variation of free CO_2 in the river is not significant at 0.01 and 0.05 significance level. The free CO_2 of the surface water of Kolpu Khola increased from station 1 to 2, decreased from station 2 to 4 (except from station 3 to 4 in March and August) and then fluctuated from station 4 to 6. The spatial variation of free CO_2 is significant at 0.01 and 0.05 significance level.

Hardness is the property of water which prevents the lather formation with soap. Principle cations imparting hardness are Ca^{+2} and Mg^{+2}. Other cations such as strontium, iron and manganese also contribute to the hardness. However the concentration of these ions is very low in natural waters, therefore, hardness is generally measured as concentration of calcium and magnesium (as calcium carbonate), which are far higher in quantities over other hardness producing ions (Trivedy and Goel, 1986). The hardness was recorded maximum on February (winter) at polluted stations (station 2 to 6) whereas in the cleanest station i.e. station 1 the hardness was recorded maximum on March (pre-monsoon). The observed monthly variation of hardness is significant at 0.05 significance level and not at 0.01 significance level.

The hardness fluctuated from station 1 to 5 (upstream to downstream) except from station 3 to 5 in August. Hardness decreased from station 5 to 6 in all the four months under study. The observed spatial variation of hardness from station 1 to 6 is significant at 0.01 and 0.05 significance level.

The WHO guideline value (1993) and NDWQG (2062 BS) for hardness of drinking water is 500 mg/L as $CaCO_3$. The hardness of surface water of Kolpu Khola ranges from 10 to 86 mg/L as $CaCO_3$ throughout the study period. Thus all the stations can be used as source of drinking water from hardness point of view.

The pattern of variation of calcium content is similar to that of calcium hardness because calcium hardness is due to the presence of calcium and they have linear relationship (APHA, 1995). Calcium and calcium hardness increased from December till February. From then both calcium and calcium hardness decreased till August. At all stations calcium and calcium hardness were recorded maximum in February (winter). The observed monthly variation of calcium content and calcium hardness in the river water is significant at 0.05 significance level. Calcium and calcium hardness fluctuated from station 1 to 5 (upstream to downstream) in all the four months. From station 5 both calcium and calcium hardness decreased to station 6. The spatial variation of calcium content and calcium hardness from station 1 to 6 is significant at 0.05 significance level. The source of calcium may be the rocks containing calcium minerals such as limestone, gypsum etc. from which calcium is leached. Another source of calcium is runoff from agricultural land in which calcium is applied as lime. However the greatest contributor of calcium in the Kolpu Khola is the leachate as evident from the leachate quality (Appendix VI). The National Drinking Water Quality Guidelines (2062) for calcium is 200 mg/L. Since the calcium content of the surface water of the river varied from 3.21 mg/L to 28.86 mg/L, the calcium content in the river water is within the NDWQG (2062).

Magnesium is a common constituent of natural water and its concentration is generally lower than calcium (Trivedy and Goel, 1986 and Saxena, 1987). The magnesium content was higher in winter (December/February) than pre-monsoon (March) except at station 1. However the monthly variation of magnesium content in the river water is not significant at 0.01 and 0.05 significance level. The magnesium content increased from station 1 to 2 except in March. From station 2 it decreased to station 3 except in December and August. From station 3 it decreased to station 4 except in March. The magnesium content fluctuated from station 4 to 6 except in December. During February (winter), the magnesium content decreased from station 2 to 5 and then increased to station 6. Such spatial variation of magnesium content is not significant at 0.01 and 0.05 significance level. The increase in magnesium content from station 1 to 2 (except March) is probably due to contribution of magnesium contained in the leachate.

Biochemical Oxygen Demand (BOD) is an empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirement in wastewaters, effluents and polluted waters during a specified incubation period (5 days) for the biochemical degradation of organic materials (carbonaceous compound) and the oxygen used to oxidize inorganic material such as sulfides and ferrous ions (APHA, 1995). BOD of surface water increased from December to February in all the sites. From February BOD at all sites except station 2 decreased to March. From March (pre-monsoon) BOD at all sites except stations 1 and 5 decreased till August (monsoon). During the four months of study, the maximum BOD was observed in February (winter season) except station 2. The maximum BOD (128.43 mg/L) at site S_2 was observed in March (pre-monsoon). The monthly variation of BOD in the river water is not significant at 0.01 and 0.05 significance level. BOD of the river water increased from station 1 (upstream) to station 2 in all the months during the study period. This may be due to the high organic matter and nutrients present in the leachate. The BOD decreased from station 2 to 6 (downstream) throughout the study period. This may be due to natural purification of water. The observed spatial variation of BOD is significant at 0.01 and 0.05 significance level. The BOD of surface water from stations 2 to 5 in all the three months including station 1 in February and August had value above 15 mg/L (WHO standard for BOD).

Chemical Oxygen Demand (COD) is the measure of oxygen consumed during the oxidation of the oxidizable organic matter by a strong oxidizing agent (Trivedy and Goel, 1986). The spatial variation of COD is similar to that of BOD. During the four months of study, the maximum COD was observed in February (winter season) except site 2. The maximum COD (227.00 mg/L) at site 2 was observed in March (pre-monsoon). The monthly variation of COD in the river water is not significant at 0.01 and 0.05 significance level. COD of the river water increased from station 1 (upstream) to station 2 in all the months during the study period. This may be due to the high organic matter and nutrients present in the leachate. The COD decreased from station 2 to 6 (downstream) throughout the study period. This may be due to natural purification of water. The COD of surface water from stations 2 to 5 had value above 30 mg/L (WHO standard for COD) throughout the study period. The observed spatial variation of COD is significant at 0.01 and 0.05 significance level.

Phosphorus is an essential nutrient for living organisms and exists in water bodies as both dissolved and particulate species. Orthophosphate content at station 1 and 2 decreased from December to February and then increased gradually till August. At stations 4, 5 and 6, orthophosphate content fluctuated from December till August. The observed monthly variation of orthophosphate content is not significant at 0.01 and 0.05 significance level. In general the orthophosphate content increased from station 3 to 4 except from station 3 to 4 in March and then decreased from station 4 to 6. The maximum value of orthophosphate (0.435 mg/L) was observed at station 2 in August (monsoon) and the minimum value of orthophosphate (0.042 mg/L) was observed at station 6 in December. The observed spatial variation of orthophosphate content is not significant at 0.01 and 0.05 significance level. Natural sources of phosphorus in the river water may be weathering of phosphorus-bearing rocks and the decomposition of organic matter. However, domestic waste waters (particularly those containing detergents), fertilizer run-off and industrial effluents contribute to elevated level of PO_4-P in the river water. However there is no record for source of industrial effluent discharging into the river. Phosphate has no direct health impact. Phosphorus is a limiting factor and causes eutrophication in surface waters.

High phosphorus concentration in shallow water can originate from domestic pollution but high concentration of phosphate in ground water may be due to the underlying geochemistry and weathering of phosphorus-bearing rocks. In most natural surface water, phosphorus ranges from 0.005 to 0.020 mg/L. Since the water of all the stations have the PO_4-P above this range, the river had PO_4-P beyond the natural condition probably because of washing and bathing in the river from upstream to downstream or the fertilizer run-off from the agricultural field. Throughout the study period, the PO_4-P of the river water fluctuated between 0.042 to 0.435 mg/L.

Nitrogen is essential for living organisms as an important constituent of proteins, including genetic material. Most crop plants require large quantities of nitrogen to sustain high yields. Nitrogen is present in organic and inorganic form in the water.

Nitrate is the common form of combined nitrogen found in natural waters. Nitrate contained in drinking water is the indicator of organic pollution. Nitrate can be expressed as either NO_3 (nitrate) or NO_3-N (nitrate-nitrogen). Nitrate levels above the EPA Maximum Contaminant Level (MCL) of 10 mg/L NO_3-N or 45 mg/L NO_3 may cause methemoglobinemia or blue baby syndrome, a condition found especially in infants under six months. However reports of methemoglobinemia are extremely rare. In moderate amounts, nitrate is a harmless constituent of food and water. The MCL is the highest level of NO_3 or NO_3-N that is allowable in public drinking water supplies by the U.S. Environmental Protection Agency (EPA) (Self et al, 2008).

The WHO guideline value (WHO, 1993) and NDWQG (2062) for nitrate of drinking water is 50 mg/L. The nitrate-nitrogen content of the river water varied from 0.32 to 3.20 mg/L which was far below the standard. So the surface water of all the stations is suitable for drinking purpose from point of view of nitrate-nitrogen. Nitrate- nitrogen content of the surface water fluctuated from December till August. First it decreased from December to February, then increased to March and then finally decreased to August. The maximum NO_3- N was observed at station 3 throughout the study period. The observed monthly variation of nitrate-nitrogen content is significant at 0.01 and 0.05 significance level. The concentration of nitrate- nitrogen increased from station 1 to 3 and then it decreased to station 6 except from station 4 to 5 in August. Such spatial variation of nitrate-nitrogen content is not significant at 0.01 and 0.05 significance level.

Ammonia is present naturally in surface waters. The ammoniacal nitrogen increased from station 1 to 2 in all the four months of study period. After then it decreased up to station 6 except from station 4 to 5 in December. The increase in ammoniacal nitrogen content from station 1 to 2 is probably because the river received leachate containing organic nutrient with low or no oxygen content that caused ammonification of nitrogenous materials of the leachate. Such spatial variation of ammoniacal nitrogen content is significant at 0.01 and 0.05 significance level. The WHO guideline value of ammoniacal nitrogen for drinking water is 0.5 mg/L. Based on this, the water of station 1, 5 and 6 can be used for drinking purpose from ammoniacal nitrogen point of view. But National Drinking Water Quality Standard (NDWQS, 2062) for ammoniacal nitrogen is 1.5 mg/L. Based on this, the surface water of all the stations can be used for drinking purpose from ammoniacal nitrogen point of view. Since ammoniacal nitrogen content at all sites are below 1.37 mg/L throughout the study period and the CCME Guidelines (1999) for freshwater aquatic life ranges from 1.37 mg/L to 2.20 mg/L, all the surface waters of Kolpu Khola under study are suitable for freshwater aquatic life.

Iron is an essential element in human nutrition. Iron can be present in water naturally and due to pollution also. Iron in higher concentrations can be aesthetically unpleasant and can stain clothes, hair and nails. The WHO guideline value (1993) and NDWQS (2062) for iron is 0.3 mg/L and is not a health based value. This value was set as a compromise between iron's use in water treatment and aesthetic considerations. The iron content at all sites of Kolpu Khola under study exceeded both guidelines. The pattern of spatial (upstream to downstream) variation of iron content from station 1 to 5 in winter (December/February) and August (monsoon) was just opposite to that in March (pre-monsoon). The observed monthly and spatial variation of iron content is not significant at 0.01 and 0.05 significance level. Throughout the study period the iron content fluctuated from 0.15 to 4.05 mg/L. Iron content of surface water at all stations except station 3 in December and February exceed 300 µg/L i.e. 0.3 mg/L (CCME Guidelines for Protection of Freshwater Aquatic Life, 1999). Hence all the surface waters are unsuitable for freshwater aquatic life from point of view of iron. However in USEPA, 1999 Water Quality Guidelines for the Protection of Freshwater Aquatic Life the guideline value of iron which can cause chronic effect is 1000 µg/L i.e. 1mg/L. Based on USEPA guideline for iron surface water of only site S_1 and S_6 are suitable for freshwater aquatic life and the iron content at these two sites is not enough to cause chronic effect on aquatic life.

Total solids include total suspended solids and total dissolved solids. From December, the TS at stations 1, 2, 3, 5 and 6 decreased till February and from then it increased till August except for station 5 where the TS decreased from March (1400.00 mg/L) till August (1200.00 mg/L). The TS at site 4 fluctuated from December till August. However such monthly variation in TS is not significant at 0.01 and 0.05 significant level. The TS fluctuated from site 1 to 5 i.e. upstream to downstream in all the months under investigation. The TS decreased from station 5 to 6 except in August. The spatial variation of TS is significant at 0.01 and 0.05 significance level.

Total suspended solids are that portion of solid present in water which are not dissolved and can be held upon a filter paper of 2.0 µm (or smaller) pore size under specific condition. It also includes the settleable solids. They give the water a muddy or dirty appearance reducing the visibility for aquatic animals and retard light penetration. They make the water unfit for drinking and other domestic needs. From December, the TSS at stations 1, 2, 3, 5 and 6 decreased till February and from then it increased till August except station S_5 where the TSS decreased from March till August. Such temporal variation in TSS is not significant at both 0.01 and 0.05 significance level whereas the spatial variation in TSS is significant at both significance levels.

The TDS fluctuated from station 1 to 5 in February, March and August except from station 4 to 5 in February. Such spatial variation in TDS is significant at 0.05 significance level but not at 0.01 level whereas the seasonal or temporal variation in TDS is not significant at 0.01 level and significant at 0.05 significance level. The TDS of the surface water varied from 26.95 mg/L to 126.10 mg/L throughout the study period. The WHO guideline value (1993) and Nepal Drinking Water Quality Standard (NDWQS, 2062) of TDS is 1000 mg/L. Based on these, the surface water of all the stations are within WHO guideline (1993) and NDWQS (2062) from TDS point of view.

The total chromium decreased from station 2 to 6 in all three seasons under study i.e. winter, pre-monsoon and monsoon seasons. However the spatial variation of total chromium is not significant at 0.01 and 0.05 significance levels. The total chromium decreased from December (winter) to March (pre-monsoon) and then to August (monsoon) except at site S_1 and S_4 from December to March. Thus observed temporal variation in total dissolved chromium is not significant at both 0.01 and 0.05 significance level. The WHO guideline value (1993) and NDWQG (2062) for chromium in drinking water is 0.05 mg/L. Based on these guideline the total chromium content at stations 2 and 3 exceed both limit in all three seasons whereas the total chromium at the other four stations of the River were within both guidelines during the entire study period. The CCME, 1999 Water Quality Guidelines for chromium for the Protection of Freshwater Aquatic Life is 9.9 µg/L or 0.0099 mg/L. The total chromium content at site S_1 and S_6 in December (winter) and March (pre-monsoon) and all the six sites of the River in August (monsoon) were found to contain total chromium content below this guideline. Therefore station S_1 and S_6 seem to be safe for aquatic life from total chromium point of view.

The potassium content increased from December to March reaching the maximum value and then decreased in August. The observed temporal variation in potassium content is significant at 0.05 significance level and not significant at 0.01 level. The potassium content increased from site S_1 to S_2 and then decreased to S_6 with few exceptions. However such spatial variation in potassium content is not significant at 0.01 and 0.05 significance levels.

From multiple tube fermentation technique all surface waters are contaminated with faecal coliforms. Except station 1 and 6, all other sites of Kolpu Khola were found to contain ≥2400 faecal coliform per 100 ml in December. Less number of coliform organisms was found in March i.e. pre-monsoon compared to December i.e. winter except station S_2. Water sample from station S_1 was found to contain the least number of fecal coliform in completed test in all the three months under study (240/100 ml in December, 38/100 ml in March and 350/ 100 ml in August).

Suitability of surface water for agricultural uses (Irrigation)

Since there is no national water quality guideline for agricultural uses or irrigation the observed surface water quality during the study period was compared with CCME-1999 Water Quality Guidelines for Agricultural uses (Appendix XVI). Electrical conductivity of surface waters at all sites of Kolpu Khola is below 200 µS/cm. Since the CSU, USDA (Bauder et al, 2007) guideline value (Appendix XIX) of conductivity for class I irrigation water is ≤250 µS/cm. Hence surface waters of Kolpu Khola under study are excellent for irrigation from conductivity point of view based on Irrigation Water Quality Criteria for conductivity (Bauder et al, 2007).

Chloride is essential to plants in very low amounts; it can cause toxicity to sensitive crops at high concentrations (Appendix XX and XVI). Chloride content at all six sites of Kolpu Khola are below 70 mg/L. The CSU, USDA (2007) Irrigation Water Quality Criteria (Appendix XX) for chloride is <70 mg/L and CCME -1999 Water Quality Guidelines for Agricultural Uses (Appendix XVI) is 100- 700 mg/L. Based on these guidelines the surface water of the River is generally safe for all plants when used for irrigation from chloride point of view.

The iron content of the river water varied from 0.15 mg/L to 4.05 mg/L. The CCME -1999 Water Quality Guidelines of iron for Agricultural Uses is 5 mg/L. Therefore the river water is safe for agricultural uses from point of view of iron. The maximum value of total dissolved solids recorded in the river water was 126.10 mg/L. Since CCME -1999 Water Quality Guidelines of TDS for Agricultural Uses is 500- 3500 mg/L the river water is safe for agricultural use from TDS point of view.

The faecal coliform found in the surface water at different sites was more than 100/100 ml except at site S_1 and S_3 on March. Since the CCME -1999 Water Quality Guidelines of coliform bacteria (faecal) for Agricultural Uses is 100/100 ml, the surface water is not safe for agricultural uses from microbiological point of view.

Suitability of surface water for Livestock drinking

The total chromium content of all surface waters of Kolpu Khola was found to be less than 1.0 mg/L. Since the recommended upper limit (Soltanpour et al, 1999; Peterson, 1999) of chromium as toxic substance in drinking water of livestock is 1.0 mg/L, the surface waters of Kolpu Khola are suitable for use as drinking water for livestock from total chromium point of view. The recommended upper limit of nitrate- nitrogen (Soltanpour et al, 1999) as toxic substance in drinking water for livestock is 90 mg/L (see Appendix XVII). Since the highest concentration of NO_3-N observed in the surface water of the river is 3.197 mg/L, the river water is safe for livestock drinking from point of view of nitrate- nitrogen.

The recommended upper limit of total dissolved solids (Soltanpour et al, 1999) as toxic substance in drinking water for livestock is 10,000 mg/L and the maximum concentration of TDS recorded in the river water was 126.10 mg/L, the surface water of Kolpu Khola is safe for livestock drinking from point of view of TDS. The recommended maximum value of pH in Livestock Drinking Water (Peterson, 1999) is 6.5- 8.5. Since the pH of the river water recorded during the study period lies in the range, the river water of the Kolpu Khola is safe for livestock drinking from point of view of pH. If pH is less than 5.5, acidosis and reduced feed intake may occur in cattle, but is unlikely to have an effect on pigs. A low pH may cause precipitation of some antibacterial agents delivered through the water system (for example sulphonamides).

The alkalinity in the surface water of Kolpu Khola varied from 26 mg/L to 115 mg/L. Since the recommended maximum alkalinity in Livestock Drinking Water (Peterson, 1999) is 500 mg/L, the river water is safe for livestock drinking from point of view of alkalinity. Alkalinity levels above 500 mg/L can have a laxative effect. Lower levels may have a laxative effect if sulphate is present in the water. The recommended maximum concentration of nitrate- nitrogen (NO_3-N) in Livestock Drinking Water (Peterson, 1999) is 100 mg/L. The highest level of nitrate- nitrogen recorded in the river water is 3.197 mg/L which is much less than the maximum recommended guideline for livestock drinking water. Therefore from point of view of nitrate-nitrogen also the surface water of Kolpu Khola is safe for livestock drinking. Nitrate may impair the oxygen carrying capacity of the blood by reducing hemoglobin to methemoglobin. At the guideline level i.e. 100 mg/L there has been small increase in methemoglobin in pigs.

The recommended maximum concentration of chloride in Livestock Drinking Water (Peterson, 1999) is 15000 mg/L. The highest level of chloride recorded in the river water is 63.90 mg/L which is much less than the maximum concentration recommended. Therefore the river water is safe for livestock drinking from chloride point of view. The recommended maximum concentration of iron in Livestock Drinking Water (Peterson, 1999) is 0.3 mg/L. The observed value of iron content in the river water is greater than 0.3 mg/L except at site S_3 on December and February. There is no evidence to show that iron will cause any problems with livestock or poultry. Because iron from natural sources is absorbed with efficiency less that 10 percent, the iron in water should not pose a hazard to animals. Under these circumstances, a 'no limit' recommendation is reasonable. High doses of the more available forms of iron, however, are toxic." (Griffith, 1998)

6.2 Ground Water Quality

6.2.1 Ground Water Quality (from December to March or winter to pre-monsoon)

The water temperature of groundwater was higher in March (pre-monsoon) than in winter (December/ February). The water temperature of GW-2 was less than that of GW-1 in winter (December/ February) whereas the reverse was true in March (pre-monsoon). GW-1 is open type of well and so groundwater is exposed to sunlight. Hence the solar energy increases the water temperature of GW-1 in winter. Water bodies undergo temperature variation along with normal climatic fluctuations and seasonal variation.

The pH of ground water varied from 6.4 to 6.9 throughout the study period. The WHO drinking water quality standard for pH is 6.5 to 9.5 (WHO, 2004) and Nepal drinking water quality standard for pH is 6.5 to 8.5. Thus both the ground water lies below the standards from pH point of view. The electrical conductivity of GW-2 was found greater than that of GW-1 from December to March. This has also been reflected by the higher values of TDS of GW-2 compared to GW-1. The higher value of conductivity at GW-2 was probably due to concentration of more ions seeping from the landfill and less mobility of ions.

The alkalinity of GW-1 varied from 60 to 125 mg/L whereas that of GW-2 varied from 210 to 265 mg/L. The water supplies with less than 100 mg/L alkalinity are desirable to domestic use (Trivedy and Goel, 1986). Thus the water from both GW-1 and GW-2 is undesirable for domestic use from alkalinity point of view.

The dissolved oxygen content of GW-2 was found less than that of GW-1 from December to March. One reason for the decreased value of DO at GW-2 may be due to less diffusion of oxygen from the atmosphere since it is closed type of well i.e. covered with lid. The free CO_2 content of GW-2 was found greater than that of GW-1 in all the three months of study period. This may be due to mixing of leachate (containing huge amount of organic load) coming through seepage from the soil increasing the production of CO_2 during breakdown of the organic materials.

The hardness of GW-2 was found greater than that of GW-1 from December to March. The WHO guideline value of hardness for drinking water is 500 mg/L as $CaCO_3$ (WHO, 1993). The hardness of the ground water ranges from 68 mg/L to 404 mg/L as $CaCO_3$ in winter (December/ February) and premonsoon (March). Thus both the ground water lies within WHO guideline from hardness point of view.

Similarly both calcium and calcium hardness of GW-2 were higher compared to those of GW-1. The pattern of variation of calcium is similar to that of calcium hardness in both groundwater i. e. GW-1 and GW-2 because calcium hardness is due to presence of calcium and they have linear relationship. The magnesium content of GW-2 was higher compared to GW-1 in both winter and premonsoon. The increase in magnesium content of GW-2 was probably due to contribution of magnesium contained in the leachate.

BOD and COD at both groundwater stations i.e. GW-1 and GW-2 fluctuated from December to March. The BOD and COD of GW-2 were found far greater than those of GW-1. This may be due to contamination of leachate containing high organic matter and nutrients through seepage. The BOD of GW-1 and GW-2 fluctuated from 5.18 mg/L to 9.75 mg/L and 72.97 mg/L to 94.32 mg/L respectively throughout the study period. The COD of GW-1 and GW-2 fluctuated from 12.00 mg/L to 20.80 mg/L and 128.00 mg/L to 170.00 mg/L respectively throughout the study period. Since the WHO guideline value for BOD and COD are 15 mg/L and 30 mg/L respectively, the ground water of GW-2 exceeds the WHO guideline from both BOD and COD point of view.

The orthophosphate concentration of groundwater of GW-1 and GW-2 fluctuated from December to March but the pattern of fluctuation of orthophosphate of GW-1 was just opposite to that of GW-2. Throughout the study period, the PO_4-P of the ground water fluctuated between 0.035 mg/L to 0.534 mg/L. Phosphorus as such is not harmful to the human beings but its analysis is useful for pollution study.

The nitrate-nitrogen concentration of GW-1 and GW-2 fluctuated from December to March. The WHO guideline value of nitrate for drinking water is 50 mg/L (WHO, 1993). The nitrate-nitrogen content of the ground water varied from 0.447 mg/L to 2.300 mg/L which was far below the standard. So both the ground water lies within WHO guideline from nitrate point of view. The ammoniacal nitrogen content of GW-1 and GW-2 varied from 0.06 mg/L to 2.11 mg/L and 0.14 mg/L to 0.85 mg/L respectively. Both the groundwater exceeds the WHO guideline value for ammoniacal nitrogen of drinking water (0.5 mg/L).

Both TSS and TDS of GW-2 were found greater than those of GW-1. The TDS and TSS of GW-1 fluctuated from December till March but those of GW-2 increased from December till March. The TDS of GW-1 fluctuated from 100.10 mg/L to 115.50 mg/L but the TDS of GW-2 increased from 391.05 mg/L to 514.80 mg/L. The WHO guideline value and Nepal Drinking Water Quality Standard for TDS is 1000 mg/L. Both the ground water lies within these guidelines from TDS point of view. Except GW-2 in December the total chromium content at both groundwater stations were within the WHO standard for drinking water (1993) in both seasons.

The iron content of groundwater at GW-1 and GW-2 increased from December till March. The WHO guideline value of iron is 0.3 mg/L and is not a health based value. Throughout the study period, the iron content of the ground water varied from 0.10 mg/L to 0.68 mg/L. The number of faecal coliform found in GW-2 was far greater compared to GW-1 in both December and March. As per the WHO standard, drinking water should not contain coliform in 100 ml of sample taken. Thus both ground water exceeded the WHO limit for faecal coliform in December and March.

6.2.2 Groundwater Quality of GW-1 (Private well) in monsoon

Temperature of groundwater at GW-1 was found to increase gradually from February i.e. winter (15.5 °C) and reached maximum value in August i.e. monsoon (20.0°C). pH and total alkalinity of GW-1 gradually increased from December i.e. winter (pH of 6.4 and total alkalinity of 60 mg/L) till March i.e. premonsoon (pH of 6.7 and TA of 125 mg/L) and then decreased till August i.e. monsoon (pH of 6.2 and TA of 50 mg/L). Conductivity and total solids of GW-1 were found to be minimum in August i.e. monsoon season (conductivity of 156 µS/cm and total solids of 146.00 mg/L) and maximum in February i.e. winter (conductivity of 210 µS/cm and total solids of 265.50 mg/L).

Chloride content of GW-1 decreased gradually from December (39.76 mg/L) till August (28.40 mg/L). Hardness, calcium-hardness, calcium content and nitrate-nitrogen of GW-1 fluctuated from December till August. These four parameters were recorded maximum in December (98 mg/L as $CaCO_3$ of hardness, 82 mg/L as $CaCO_3$ of Ca- hardness, 32.87 mg/L of calcium and 2.300 mg/L of nitrate- nitrogen) and minimum in August (50 mg/L as $CaCO_3$ of hardness, 26 mg/L as $CaCO_3$ of Ca-hardness, 10.42 mg/L of calcium and 0.500 mg/L of nitrate-nitrogen).

Similarly BOD and COD also fluctuated from December (6.16 mg/L of BOD and 14.00 mg/L of COD) till August (9.57 mg/L of BOD and 16.80 mg/L of COD). But the pattern of monthly variation of BOD and COD is just reverse to that of hardness. The magnesium content increased gradually from February (2.93 mg/L) till August (5.86 mg/L). The concentration of iron and ammoniacal- nitrogen increased from December (0.10 mg/L of iron and 0.06 mg/L of NH_4-N) till March and then decreased till August (0.20 mg/L of iron and 0.02 mg/L of NH_4-N).

6.3 Leachate Quality

The water temperature and pH of leachate varied from 12.5°C to 28.0 °C and 6.8 to 7.0 respectively throughout the study period. pH of the leachate was found within Generic standard (2003) for industrial (wastewater) effluents discharged into inland surface water (Appendix XIII). ENPHO obtained similar result for pH viz. 6.98 (ENPHO, February, 2007).

The electrical conductivity of leachate increased sharply from December till March and then decreased till August. The phenolphthalein alkalinity was found to be nil during the entire investigation period and the total alkalinity varied from 5750 mg/L to 10800 mg/L. The dissolved oxygen content of the leachate was nil during the entire investigation period indicating enormous load of organic matter in it. The free CO_2 content of leachate fluctuated from December (52.80 mg/L) till August (110.00 mg/L).

The chloride content recorded in February was 3152.40 mg/L which is similar to the result obtained by ENPHO (2007) which recorded 3100 mg/L in February, 2007. The higher value of chloride has shown the indication of the contamination of domestic organic matter. Since the leachate has been derived from large quantity of domestic and municipal solid waste, the leachate received huge amount of chloride. The hardness, calcium hardness, calcium and magnesium content of leachate all increased from December (winter) till August (monsoon). The hardness of leachate varied from

1360 mg/L as $CaCO_3$ (December) to 5200 mg/L as $CaCO_3$ (August). The pattern of variation of calcium is similar to that of calcium hardness because calcium hardness is due to presence of calcium and they have linear relationship (APHA, 1995).

The BOD of leachate decreased from December (5675.60 mg/L) to August (3243.20 mg/L). The COD of leachate varied from 8240.00 mg/L (March) to 6520.00 mg/L (August). Thus both BOD and COD of leachate in all the four months had value above Generic standard for industrial effluent, 2003 (100 mg/L for BOD and 250 mg/L for COD). The values of BOD and COD of leachate recorded during the study period were far less than those recorded by ENPHO in February, 2007 (BOD of 29750 mg/L and COD of 65500 mg/L) indicating that the chemistry of leachate in the landfill is undergoing rapid change.

The orthophosphate concentration of leachate varied from 3.168 mg/L (December) to 54.306 mg/L (March) which were far greater than the phosphorus range for most natural surface water (0.005 to 0.020 mg/L). The nitrate-nitrogen content of leachate varied from 24.378 mg/L (December) to August (35.174 mg/L). The ammoniacal nitrogen content of leachate varied from 24.51 mg/L (August) to 674.34 mg/L (February) which were far above the Generic standard of ammoniacal nitrogen for industrial effluent (50 mg/L).

The iron content of leachate varied from 10.23 mg/L (December) to 35.66 mg/L (August). The total dissolved solids of leachate increased from December till March. From March both TDS and TS decreased till August (8832.15 mg/L of TDS and 22000.00 mg/L of TS). The TSS of leachate increased from December (1066.00 mg/L) till August (13167.85 mg/L). Thus TSS of the leachate was far above the Generic standard for TSS of industrial effluent, 2003 (30 – 200 mg/L) except August.

The total chromium content of leachate was above the Generic standard for hexavalent chromium (Cr-VI) in industrial effluent i.e. 0.1 mg/L in December (winter) and March (pre-monsoon) while the total Cr content was below the Generic standard in August (monsoon) i.e. 0.092 mg/L. The total chromium content of leachate was approximately double in March compared to December. The lesser value of chromium in December may be partly due to stoppage of waste dumping in the landfill for more than two weeks in December reducing the release of pollutants including heavy metals like Cr in the leachate.

MPN per 100 ml of leachate obtained by multiple tube fermentation technique was ≥2400 in December, March as well as in August i.e. from winter to monsoon. Hence the leachate is obviously contaminated with sewage or faecal matter.

Leachate that has been produced from the solid waste is mainly acidic. However, the clay liners are basic and there is possibility of reaction between leachate and clay liner. The reaction may increase hydraulic conductivity of the clay liner. Thickness of the clay liner is not sufficient and the gradient of the base is also very low. Therefore, thickness and gradient of the clay liner should be increased. As geo-membrane has not been used, the gradient of the base should also be increased (Panthee, 2008).

6.4 Socioeconomic condition and people's perception

The study area (covering three VDCs and six wards of Nuwakot and Dhading districts) around the periphery of Kolpu Khola comprises people from various ethnic groups and social status differing in their perception on leachate, impact on their socioeconomic life etc. Households of Brahmins and Chettris are nearly equal in Okharpauwa-4. Tamang/Lama/Magar/Gurung was dominant ethnic groups in Chhatredeurali VDC whereas Brahmins are dominant in Chauthe VDC.

Majority of the respondents were literate except in Okharpauwa VDC. Most of the families have 4 to 6 members and use fuelwood and electricity both as source of energy. Very few (5% or less) households use LPG (liquid petroleum gas). Households are predominantly farmers. A few are wage laborers and others are small business and service holders. Agriculture as occupation is represented by 66.67 %, 58.82 % and 38.89 % of respondents in Chhatredeurali, Chauthe and Okharpauwa VDC respectively. Agriculture was found to be the most prominent source of income in all the three VDCs. Most of the households in all the three VDCs under study were found to have low income level.

The percentage of people using surface water of Kolpu Khola was found to be the greatest (51.67 %) in Chhatredeurali VDC and the least (41.18 %) in Chauthe VDC. Households who use the river water were found to use it only for irrigation purpose. Most of the farmlands in Okharpauwa used the river water for irrigation before but these days they do not use the river water while in Chauthe VDC most of the people have irrigation facilities derived from other nearby Rivers like Bachhbichhe Khola and other rivulets.

Prior to construction of SLFS the Kolpu Khola water was used exclusively for irrigation of lands within the SLF area. The other use of the water was for cattle feeding (limited to grazing cattle). Because of the high turbidity it had very little recreational and human consumption use. However, in the dry season, a few kilometres downstream from the SLF, it is also said to be used for recreation and rarely for human consumption (SWMRMC, 2005).

Peoples' perception on leachate

Most of the respondents (at least 60 %) know what leachate is. Since Chauthe VDC is far away from the landfill site greater proportion of respondents of the VDC do not know about leachate compared to other two VDCs. Most of the respondents in all the three VDCs don't have any idea about suitable method for disposal of leachate. Mostly people deprived of education were found to have no idea about it. Some of the respondents in all the three VDCs argued that the leachate shouldn't be disposed into the river and should be stored anyway.

Peoples' perception on impact on surface water by leachate

Most of the respondents believe that the surface water quality of Kolpu Khola has changed or degraded extremely after operation of landfill at Sisdol. It is because the leachate has been discharged into the River by the landfill authority when the leachate collecting tanks get filled up. On the other hand there has been leakage of leachate into the river due to malfunctioning of the valve present therein. People said that the water of Kolpu Khola was very clean before operation of the landfill site. There used to be fish in the river and people used the river water for bathing, washing and even for drinking sometimes. Most of them said that the effect of leachate is up to 10 km from the landfill while others argued that the effect may be up to more than 10 km. The respondents said that the discharge of leachate into the River affects the River up to Kumari VDC. Others argued that the effect is up to Galchhi.

Peoples’ perception on impact on their socioeconomic life

From the questionnaire survey the socioeconomic life of Chauthe VDC is the least (56 %) affected and that of Chhatredeurali VDC and Okharpauwa VDC are almost equally (65 %) affected. Households affected on all aspects of their socioeconomic life due to degradation in surface water were found to be the maximum (41.18 %) in Chhatredeurali VDC and the least (10 %) in Chauthe VDC. Households affected on agriculture were found to be minimum in Chauthe VDC because most of the households in this ward do not use Kolpu River water for irrigation and depend on other rivers like Bachhbichhe for irrigating their lands. People affected on agriculture were found to be the maximum (56.25 %) in Chhatredeurali VDC and those affected on health were found to be the maximum (72.73 %) in Okharpauwa. Accordingly people experiencing decline in agricultural production were found to be the highest in Okharpauwa (100.00 %) VDC. Some people affected on their agriculture believe that the damage on crops may be due to gases arising from the landfill because they don’t irrigate their agricultural lands with the river water.

The highest percentage of respondents (61.90 %) are of the opinion that the frequency of illness has increased was from Okharpauwa VDC. However they couldn’t say the increment of illness precisely. As reported by the respondents the diseases and symptoms caused due to contact with the river water are allergy, itching and skin diseases, wounds, cholera and diarrhea. Most of the respondents said that the effect has also been seen on livestock. There has been increased incidence of diseases on livestock but no disease has been identified due to unavailability of veterinary doctors. Respondents from Okharpauwa and Chauthe claimed that there have been a number of incidences of death of cattle by drinking water of Kolpu Khola.

Peoples’ perception on future of landfill

Most of the respondents have no idea about what may or should be done after closure of the landfill. They think that SWMRMC should manage the landfill site in such a way that it will cause minimal impact on the air and surface water of the River that ultimately affect their socioeconomic lives even after its closure. On average about 20 % of the respondents were of the opinion that the landfill site should be changed into greenery after its closure. Very few of the respondents know that the landfill site could be exploited as source of methane gas and be used as important source of household energy.

Regarding incentives SWMRMC has constructed road, made taps and also allocated budget for school in Chauthe VDC as reported by the respondents. However people said that this is not sufficient. In Okharpauwa VDC some public taps and roads have been made by SWMRMC as a part of incentive. There is no health post in the Okharpauwa-4 and there is only one health post in the VDC as a whole. SWMRMC has constructed road and has also given budget for making school building. People of Okharpauwa- 4 seem to be the most affected because they are the closest to the landfill site among all the three VDCs and in turn they are not getting sufficient incentives even a health post.

While taking into an agreement for making Sisdol, Okharpauwa an official dumping site of KMC, SWMRMC has agreed to contribute on various developmental activities such as constructing roads, schools, hospitals, creating job opportunities with one home 1 job scheme, providing with electricity and water pipelines. Till date roads have been constructed, electricity poles have been placed and even some parts have already benefited by electricity services and water pipelines are being constructed. Schools and hospitals have not been established yet but health checkups of the locals are done monthly or once in two months but the problem is that the people are provided with old date expired medicines so the people feel that they have been cheated by the government. Though the schools have not been built, the government provides certain amount to the operating school at the village (Pradhanang, date not mentioned).

VII. CONCLUSION AND RECOMMENDATION

7.1 Conclusions

The Sisdol sanitary landfill site is situated at ward no. 4 of Okharpauwa VDC. The Kolpu Khola originates at surrounding hills from the west slope of a mountain 2200 m high and situated at the north-eastern edge of Kathmandu valley. Number of springs and natural drainage systems join and make the flow in the river. Surface water samples from Kolpu Khola at various distances from the landfill, groundwater and leachate corresponding to valley 2 of the landfill site were collected and analyzed to determine the impact of the leachate contamination on the ground water and surface water nearby landfill site. The physicochemical parameters such as pH, free $CO_{2,}$ chloride, hardness, calcium and calcium hardness, BOD, COD, ammoniacal nitrogen, TS, TSS and TDS vary significantly from station S_1 to S_6 whereas the monthly variations of only temperature, electrical conductivity, transparency, TDS, hardness, calcium and calcium hardness, nitrate-nitrogen and potassium were significant over the investigation period.

It was found that leachate was severely polluted with most of the physicochemical parameters being higher than the Generic standard (2003) for industrial (wastewater) effluents discharged into inland surface water (Appendix VI). The physicochemical parameters of the leachate that exceeded the tolerance limit for industrial effluent (Appendix XIII) were TSS, BOD, COD, ammoniacal- nitrogen and total chromium. The less values of BOD and COD of leachate compared to those recorded in previous studies indicate that the chemistry of leachate in the landfill is undergoing rapid change.

From the present study, most of the parameters (electrical conductivity, hardness, calcium hardness, BOD, free CO_2, TDS and total chromium) of surface water of Kolpu Khola showed sudden increase in values at station S_2 i.e. confluence compared to station S_1 (upstream) probably due to mixing of pollutants present in the leachate indicating the increased level of pollution. The BOD and COD of stations S_2 to S_5 in all the four months including station S_1 in February and August had value above WHO guideline. From multiple tube fermentation technique all surface waters of all six sites are contaminated with faecal coliforms.

However the ammoniacal nitrogen content, electrical conductivity and calcium at all sites of Kolpu Khola were within Nepal Drinking Water Quality Guidelines (2062). Similarly the surface waters of all the stations are within WHO guideline (1993) and NDWQG (2062) from pH, TDS, hardness, chloride and nitrate- nitrogen point of view.

Except site S_2 the surface water of all other five sites are safe for aquatic life from point of view of dissolved oxygen. However only the surface water of station S_1 and S_6 are suitable for fishes and other aquatic animals from the point of view of free $CO_{2,}$ iron content and total chromium. Similarly all the surface waters of Kolpu Khola under study are suitable for freshwater aquatic life from ammoniacal- nitrogen point of view.

Surface waters of Kolpu Khola under study are excellent for irrigation from conductivity point of view and also safe for all plants when used for irrigation from the chloride (Appendix XX) and TDS (Appendix XVI) point of view based on CSU, USDA (2007) and CCME -1999 Water Quality Guidelines for Agricultural Use. However the surface water is not safe for agricultural uses from microbiological point of view. The river water is safe for livestock drinking from point of view of nitrate-nitrogen, TDS, pH, alkalinity, nitrate- nitrogen and chloride based on Livestock drinking water quality (Soltanpour, et al, 1999 and Peterson, 1999). However the iron content in the river water has exceeded the recommended maximum concentration in livestock drinking water.

The groundwater from GW-2 (bore hole-2) was found to possess more values for most of the physicochemical parameters including BOD and COD (Appendix V) compared to groundwater from private well (GW-1) from December (winter season) till March (pre-monsoon). This is due to the fact that GW-1 is situated in the adjoining area of upstream part of Kolpu Khola and is about 150 m away from the landfill station. Therefore there is much less chances of contamination of its groundwater by the leachate seepage from the landfill. The ground water quality of both GW-1 and GW-2 exceeded the WHO guideline (1993) with respect to alkalinity and ammoniacal nitrogen content whereas both ground water were below the WHO limit with respect to pH, hardness, nitrate-nitrogen and TDS. Thus it is obvious that the groundwater in the landfill site has been contaminated. Based on field observation, the source of groundwater contamination should be the ditch (that is close to the borehole-2) that stores the leachate from where the leachate might have leached into the borehole-2. However, it is also possible that the leachate might have moved into the groundwater from the landfill site itself.

Compared to other seasons, the water pollution was less in monsoon season probably as the pollutants were diluted in the season. All the surface water, ground water and leachate were found to contain faecal coliform indicating the faecal contamination of leachate and consequently surface water and groundwater.

From the socioeconomic survey agriculture was found to be the most prominent source of income in all the three VDCs namely Okharpauwa, Chhatredeurali and Chauthe. Most of the households in all the three VDCs under study were found to have low income level. Most of the households were found to use the river water for irrigation only.

Most of the respondents (at least 60 %) know what leachate is but they don't have any idea about suitable method for disposal of leachate. Most of the respondents believe that the surface water quality of Kolpu Khola has changed or degraded extremely after operation of landfill at Sisdol. Most of them said that the effect of leachate is up to 10 km from the landfill while others argued that the effect may be up to more than 10 km. Households affected on agriculture were found to be the maximum in Chhatredeurali VDC and those affected on health were found to be the maximum in Okharpauwa. People have experienced increase in frequency of illness after operation of landfill; however they couldn't say the increment of illness precisely. Most of the respondents said that the effect has also been seen on livestock.

7.2 Recommendations

The periodic monitoring of water quality around the landfill site and of the leachate is indispensable as their composition vary continuously. The substantial decrease in the BOD and COD values (compared to last year) of the leachate indicates the leachate chemistry is changing rapidly and the solid waste is undergoing decomposition.

However the leachate quality is still poor with no dissolved oxygen and contains high concentration of ammoniacal nitrogen, total suspended solids, chloride and other chemicals. In the rainy season the water level of river as well as leachate level may rise, which could contaminate the river water. Special care should be taken to prevent such possibilities. Based on the present study, the following recommendations were identified:

1. As far as possible river side should not be used as landfill site. However, when there is no alternative, proper precaution should be taken before using it as landfill site.

2. Emphasis should be given at source reduction and adopting alternative waste management practices to the possible extent, like composting, recycling etc. Segregating waste should be started from household level and the municipalities should also segregate the organic, inorganic and hazardous wastes and dispose it separately, which will also be helpful in creating employment opportunities. Hospital and other hazardous wastes according to their type should be well segregated, incinerated and then only be allowed for land filling.

3. Emphasis should be given on the waste to energy concept and mobilizing waste as resources. The Scrap Tax, which discourages recycling of waste, should be abolished and incentives should be provided for promoting recycling.

4. The government should define hazardous waste and formulate appropriate policies, legislation and guidelines for its management. Special law for handling, transportation, collection, storage and disposal of hazardous, medical and industrial wastes should also be introduced.

5. The land should be properly lined with impermeable layer (such as clay lining) during the construction of the landfill site to check the downward flow or seepage of leachate to the groundwater. To prevent the leachate contamination to groundwater, clay lining is important. Pure clay is not found everywhere therefore, clay having little amount of silt and/or sand should be used.

6. The drainage system of leachate should be properly maintained. Trenches should be well designed facilitating leachate collection to avoid leachate seepage.

7. Stormwater drainage facility should be installed surrounding the landfill site to prevent the outside stormwater from flowing into the landfill site so that the amount of leachate generated from landfill site will be reduced. Simultaneously, stormwater dropped on the landfill site will also be discharged without any contact with solid wastes.

8. Recommendation for treatment of leachate

There are different methods of leachate treatment such as physical, biological and chemical treatments. The type of treatment depends upon the quality of the leachate. Since the leachate produced from the Sisdol Landfill Site comprises of chemical compounds like heavy metals, ammoniacal nitrogen etc. above the Generic standard chemical treatment is the appropriate method of treatment. However for chemical treatment process initial investment cost is quite high and its operation cost is substantially high. Hence physical and biological treatments are recommended for the leachate treatment of SLFS.

The heavy metals and chemical compounds resulting from industrial and hospital wastes can only be treated by chemical process, but it is economically not viable because of the high cost in the operation of the system. Therefore it is necessary to make utmost efforts to separate industrial and hospital wastes from the wastes entering the site by adopting separate collection system for these waste types and monitoring the waste at the transfer stations and as the waste arrives to the landfill.

The leachate could be biologically treated by making constructed wetlands. *Phragmites Karka* (terrestrial), *Eicornia crassipes* (aquatic), *Rumex* sp. and *Lippianodi* sp. (amphibian species) are recommended species for biological treatment. Moreover more efficient aeration system could improve the leachate quality. This will considerably reduce the contaminants present in the leachate decreasing the level of water pollution in the adjoining areas of the landfill.

9. The capacity of leachate collection pond should be increased as the half filled pond could be filled soon and over spilling of such polluted leachate could contaminate fresh water damaging the ecological system around. For valley 2, a big pond should be made that should hold all the leachate so that temporary ditches should not be dug out to collect leachate.

10. Scientific approach of landfilling should be adopted and that a long term landfill site should be constructed considering the social, economic, legal and technical aspects and promoting the local life standard and providing proper incentives.

11. As sophisticated technology and material in landfill site are costly, simple and easily available techniques and material are convenient for the developing countries like Nepal. The techniques should also be economic and environmental friendly.

12. Leachate suction wells: The wells should be installed at the base of the landfill site. Suction of leachate from the landfill site will reduce possibility of infiltration and contamination. The leachate thus removed should be well treated prior to disposal.

13. Appropriate plantation/ greenery in and around the site should be done.

14. Public awareness should be raised on the importance of water resources and the ways for their conservation.

References

ADB, 2004. Country environment analysis for Nepal. Asian Development Bank, Philippines.

Alker, S. C., Sarsby, R. W. and Howell, R. (1995). Composition of leachate from waste disposal sites. Proceedings, Waste Disposal by Landfill- Green'93 (pp. 215–221), Balkena, Rotterdam.

Aneja, K. R. (2005). *Experiments in Microbiology, Plant Pathology and Biotechnology*, Fourth edition, New Age International Publishers, India.

Annonymous (2005). Final Report on 'The Study on the solid waste management for the Kathmandu valley'. Submitted by Nippon Koei Co., Ltd. and Yachiyo Engineering Co., Ltd. to MOLD/HMGN and JICA, 2005.

Annonymous (2008). Water and Leachate Quality test at Sisdol Landfill Site. Submitted by Water, Engineering and Training Centre (P) Ltd to SWMRMC, MOLD/HMG, Shreemahal, Pulchowk, Lalitpur.

Annonymous (2009). Alternative landfill site to give relief soon. Contributed by UrbWatSan Nepal, The Rising Nepal, 28 January 2009.

Available from:

http://www.urbwatsan.org.np/index2.php?option=com_content&do_pdf=1&id=173 [Accessed on January 11, 2009]

Annonymous (2009). Solid Waste Management (Maintenance and Improvement of the Landfill Site), Environmental Technology Information, Environmental Pollution Control Center, Osaka Prefecture, Japan.

Available from:

http://www.menlh.go.id/apec_vc/osaka/eastjava/wst_mng_en/page1.html

[Accessed on June 10, 2008]

APHA/AWWA/WEF (1995). *Standard Methods for the Examination of Water and Waste Water*, American Public Health Association, Washington DC, 19th edition.

Bandyopadhyay, J. (1995). The Mountains and Uplands as Water-Towers for Humanity: Need for a New Perspective in the Context of the 21st Century Compulsions. International Academy of the Environment. Geneva, Switzerland.

Barlaz, M. A., Ham, R. K. and Schaefer, D. M., 1990. Methane production from municipal refuse: a review of enhancement techniques and microbial dynamics. *Critical Reviews in Environmental Control* 19 (6): 557–584.

Bauder, T. A; Waskom, R. M. and Davis, J. G. (2007). Irrigation Water Quality Criteria. Series no. 0.506. Soil and crop sciences. 7/03. Revised 3/07.

Bilgili, M. S., Demir, A., Ozkaya, B. (2006). Quality and Quantity of Leachate in Aerobic Pilot-Scale Landfills". *Environmental Management,* 38 (2): 189–196.

Blight, G. E., (1995). Ground-water pollution from a landfill in a semi-arid climate.

Canadian Council Ministries of Environment, (1999). Surface Water Quality Guidelines for Use in ALBERTA, November 1999; Environmental Assurance Division, Science and Standards Branch.

Available from: http://www.environment.gov.ab.ca/info/library/5713.pdf [Accessed on April 25, 2008]

CBS (2001) "Population of Nepal, Municipalities and VDCs" National Planning Commission Secretariat/ Central Bureau of Statistics/ United Nation Environment Program.

CBS (2003) Statistical Year Book of Nepal 2003,. Central Bureau of Statistics, Kathmandu.

Chhipi Shrestha, G. K., 2007. Assessment of Water Quality of Manahara River, Kathmandu Valley by using Macroinvertebrates as Biological Indicator. M. Sc. Thesis, Central Department of Environmental Science, Tribhuvan University, Kathmandu, 2007.

Chian E. S. K and DeWalle F. B. (1976) Sanitary landfill leachates and their treatment. *Journal of the Environmental Engineering Division* 102(2): 411–431.

Christensen, T. H. and Kjeldsen, P. (1989). Basic biochemical processes in landfills. Pages 29–49, in: Bilgili, M. S., Demir, A., Ozkaya, B. "Quality and Quantity of Leachate in Aerobic Pilot-Scale Landfills". *Environmental Management* 38 (2): 189-196, 2006.

Christina, A. and Veronica, B., 2004. Solid Waste Management in the City of Kathmandu, Nepal. Evaluation of the Vaxjo Risk Assessment Model Applied on Gokarna Landfill Site. B.Sc. Thesis, Department of Technology, University of Kalmar, Sweden.

CKV, 2002. The study of the solid waste management for Kathmandu Valley. Interim Report (2) of Clean Kathmandu Valley, Kathmandu.

CKV and JICA, 2002. Detail design on landfill sites. Joint Report of Clean Kathmandu Valley and Japan International Cooperation Agency.

Cole, G. A. (1975). *Textbook of Limnology,* Second Edition, C. V. Mosby Company, Saint Louis, Missouri, United States.

Cossu, R. and Rossetti, D. (2003). Pilot scale experiences with sustainable landfilling based on the PAF conceptual model. *Proceedings of the Ninth International Waste Management and Landfill Symposium*, 6–10 October 2003. Cagliari, Italy.

Dangol, D. (2000). Country Paper Nepal: Presented to the Asian Approach to Resource Conservation and Environment Protection. Published by Asian Productivity Organization, Tokyo, pp: 186-187.

De, A. K., 2000. *Environmental Chemistry*, Fourth Edition, New Age International Publishers, New Delhi.

Devkota, D. C. and Watanabe, K. (2005). Impact of solid waste on water quality of Bishnumati River and surrounding areas in Kathmandu, Nepal**.** *Journal of Nepal Geological Society* 31: 19–24, 2005.

Devkota, D.C, Watanabe, K., and Dangol, V. (2003) Solid waste management issues in Nepal- Gokarna landfill site and its impact on groundwater. *Proceedings of the Seminar on Solid Waste Issue: An Environmental Problem*.18th, December, 2003, Kathmandu, Nepal.

Devkota, D. C., Watanabe, K. and Dangol, V. (2004a). Assessment of impact on ground water quality of Gokarna by solid waste of Kathmandu Valley. Seminar paper on Disaster management in Nepal, Nepal Engineering Association, pp: 193-205.

Devkota, D. C., Watanabe, K. and Dangol, V. (2004b). Need for Alternative Approaches in Solid Waste Management - Case Study Kathmandu Valley. Paper presented to 30th WEDC International Conference, Vientiane, Lao PDR, 2004.

Durmusoglu, Ertan and Yilmaz, Cihan, (2006). Evaluation and temporal variation of raw and pre-treated leachate quality from an active solid waste landfill. *Water, Air, and Soil Pollution* 171 (1-4): 359-382.

Eldho, T. I. (2001). Groundwater Contamination: The challenge of pollution control and Protection. *Journal of Indian Water Works Association* 33: 171–180.

ENPHO, (2002). Environmental Impact Assessment of Medical Waste management in Kathmandu. Final report (August, 2002) submitted to Kathmandu Valley Mapping Program, Kathmandu Metropolitan City, Kathmandu.

ENPHO, (2007). ‘Surface Water, Groundwater and Leachate Quality Monitoring at Sisdol Semi-aerobic Landfill Site’ submitted to SWMRMC, MOLD, Lalitpur.

Fatta, D., Papadopoulos, A. and Loizidou, M. (1999). Study on the landfill Leachate and its impact of the groundwater quality of the greater area**.** *Environmental Geochemistry and Health* 21 (2): 175–190.

Flyhammar, P. (1995). ‘Leachate quality and environmental effects at active Swedish municipal landfill’, In: R. Cossu, H. T. Christensen and R. Stegmann (eds), Regulations, Environmental Impact and Aftercare. *Proceedings Sardinia ’95, Fifth International Landfill Symposium*. Vol. III, Sardinia, Italy, pp: 549–557.

Freeze, R. A. and Cherry, J. A. (1979). *Ground Water*. Englewood Cliffs, New Jersey: Prentice-Hall.

Gailey, R. M. and Gorelick, S. M. (1993). Design of optimal, reliable plume capture schemes: Application to the Gloucester landfill ground-water contamination problem, *Ground Water* 31(1): 107–114.

Goodall, D. C. and Quigley, R. M. (1977). Pollutant migration from two sanitary landfill sites near Sarnia, Ontario. *Canadian Geotechnical Journal* 14: 223–236.

Gopal, D., Singh, R. P. and Kapoor, R. C. (1991). Ground water pollution by solid wastes: A case study. Pollution Research, *Enviro Media* 10: 111–116.

Griffith, C., 1998. Water Quality for livestock. AG News and Views, the Samuel Roberts Noble Foundation, Inc.

Available from: http://www.noble.org/Ag/Forage/WaterQuality/index.html

[Accessed on March 18, 2009]

Gurung, H. (1999). *Mountains of Asia: A Regional Inventory*. International Centre for Integrated Mountain Development, Kathmandu.

Gustard, A. and Cole, G. A., 2002. *Friend- a global perspective 1998- 2002*. Centre for Ecology and Hydrology, Wallingford, UK.

HMG/FDD, 1998. *Fisheries Manual: Matsya Prasar Karyakartako Laagi: Matsya Palan Srinkhala no. 2* (For Fisheries Extension workers, Fish farming series no. 2). HMG/ Fisheries Development Division (FDD), Kathmandu, Nepal, Pp: 44, 113.

HMG/MOPE (2003). Nepal Gazette, Generic Standard: Tolerance Limit for Industrial (Wastewater) Effluents Discharged into inland surface water, as cited in ADB, 2004. Country Environment Analysis for Nepal.

HMG/NPC Secretariat, 2005 (2062 BS). Nuwakot District Profile. Central Bureau of Statistics, Statistics Office Branch –Nuwakot 2062.

HMG/NPC Secretariat, 2006. Dhading District Profile 2063. Statistics Office Branch-Makwanpur (Makawanpur and Dhading).

Hynes, H. B. N., 1979. *The Ecology of Running Waters*. Fourth impression, Liverpool University Press, United Kingdom.

ICIMOD, MOEST and UNEP, 2007. *Kathmandu Valley Environment Outlook*, Kathmandu.

IUCN (1996). *Solid waste management in urban Nepal*, IUCN, Kathmandu, Nepal.

JICA, 2004. Detailed Design for Development of Semi-aerobic System Pilot Project at Sisdol Landfill Site. Submitted by East Consult (P.) Ltd., Kathmandu.

Jodha, N. S. (2005). Adaptation strategies against growing environmental and social vulnerabilities in mountain areas. *Himalayan Journal of Sciences* 3 (5): 33- 42.

Karki, S. (2004). Sanitary landfill along the banks of Bagmati River in Kathmandu and its impact on the environment. M. Sc. Thesis, Central Department of Environmental Science, Tribhuvan University, Kathmandu.

Kelley, W. E. (1976). Groundwater pollution near a landfill. *Journal of the Environmental Engineering Division* 102 (6): 1189–1199.

Khanal, S. C., 2005. Post project environmental monitoring and impact assessment- A case of Gokarna Sanitary Landfill Site after operation and closure. M. Sc. thesis, Central Department of Environmental Science, Tribhuvan University, Kathmandu.

Kjeldsen, P., Barlaz, M. A., Rooker, A. P., Baun, A., Ledin, A. and Christensen, T. H.. 2002. Present and long-term composition of MSW leachate: A Review. *Critical Reviews in Environmental Science and Technology* 32: 297–336.

Kouzeli-Katsiri, A., Bosdogiannia, A. and Christoulas D. (1999). Prediction of leachate quality from sanitary landfills. *Journal of the Environmental Engineering Division* 125 (10): 950–958.

Kumar, D. and Alappat, B. J. (2005). Evaluating leachate contamination potential of landfill sites using leachate pollution index. *Clean Technical Environment Policy* 7: 190–197.

Kumar D, Khare M. and Alappat, B. J. (2002). Threat to groundwater from the municipal landfills in Delhi, India. In: *Proceedings of the 28th WEDC Conference on sustainable environmental sanitation and water services*. Kolkata (Calcutta), pp: 377–380.

Leckie J. O., Pacey J. G. and Halvadakis C. (1979). Landfill management with moisture control. *Journal of the Environmental Engineering Division* 105 (2): 337–355.

Lerner, D. N. (2003). Estimating urban loads of nitrogen to groundwater. *The Journal* 17 (4): 239-244.

Lo IMC (1996) Characteristics and treatment of leachate from domestic landfills. *Environment International* 22 (4): 433- 442.

Mass (1990). Crop Salt Tolerance. Agricultural Salinity Assessment and Management Manual. K.K. Tanji (ed.). ASCE, New York, pp: 262-304.
Available from: http://www.ext.colostate.edu/PUBS/crops/00506.html
[Accessed on July 8, 2008]

Masters, G. M. (1998). *Introduction to environmental engineering and science*. Prentice-Hall of India Private Limited, New Delhi.

Miller, G. T. (2002). *Living in the Environment*. Wadsworth Publishing Company, Belmont, California.

MOPE/ HMGN (2001). Final Report on “The study of contamination of soil and ground water by heavy metals and mineral oils due to disposal of solid wastes”. Submitted by Central Department of Chemistry to MOPE, Kathmandu.

Mor, S., Ravindra, K., Dahiya, R. P. and Chandra, A. (2006). Leachate characterization and Assessment of Ground water pollution near municipal solid waste disposal site. *Environmental Monitoring and Assessment* 118: 435– 456.

NESS, 1997. Groundwater Investigation at the Gokarna Landfill Site. Report submitted to Environmental Geology Project, Department of Mines and Geology and Geological Survey of Germany, Kathmandu.

OECD (2007). Glossary of Statistical Terms., In: Glossary of Environment Statistics, Studies in Methods, Series F, No. 67, United Nations, New York., 1997.

Panthee, S. (2008). Possible methods of preventing groundwater contamination at landfill sites; case studies from Nepal. *Bulletin of the Department of Geology*, Tribhuvan University, Kathmandu, Nepal 11: 51–60.

Peterson, H. G. (1999). Livestock and Water Quality. Agriculture and Agri-Food Canada- Prairie Farm Rehabilitation Administration.

Pohland, F. G. (1980). Leachate recycle as landfill management option. *Journal of Environmental Engineering Division* 106(6): 1057–1069.

Pradhanang, D. (2008). Dissertation on Solid Waste Management Laws and Practices. Kathmandu School of Law, Purbanchal University.
Available from:
http://www.ksl.edu.np/legal_title_contect.asp?id=67&thread=Reading%20Materials [Accessed on August 7, 2008]

Prasai, A. (2007). Assessment of leachate contamination in the groundwater quality of Gokarna Landfill Site. M. Sc. thesis, Central Department of Environmental Science, Tribhuvan University, Kathmandu.

Sanchez Ledesma, D. M., Dorronsoro, J. L., Fernandez-Serrano M. E. and Herraez., I. (1993). Study of the Leachates generated by two different landfills located in the municipality of Madrid.

Saxena, M. M., 1987. *Environmental Analysis: Water, Soil and Air*. Agro Botanical Publishers, Old Ginnani, Bikaner 334 001 India.

Self, J. R. and Waskom R. M., 2008. Fact sheet no. 517. Nitrates in drinking water. Reviewed 10/08. Colorado State University Cooperative Extension.
Available from: http://www.ext.colostate.edu/PUBS/crops/00517.html
[Accessed on August 13, 2008]

Sharma, T., Upadhyaya, N. P. and Shah, K. B. (1995). Leachate characteristics: Bishnumati Landfill site, Kathmandu. Research on Environmental pollution and management, Kathmandu, Nepal I: 52-55.

Shrees, C. B. (2002). Environmental Economics of Solid Waste Management in Kathmandu Valley. M. Sc. Thesis, School of Environmental Management and Sustainable Development (SchEMS), Pokhara University.

Shrestha, R. M. (2007). Solid waste management in Kathmandu City.
Available from:
http://www.iges.or.jp/kitakyushu/mtgs/network/kin4/ppt/12.Shrestha.pdf
[Accessed on September 9, 2008]

Shrestha et al., 1995. Preliminary Design and Environmental Studies of Proposed sanitary landfill at Okharpauwa, Project Report, July 1995, Kathmandu., In:

SWMRMC, (2005). Environmental Impact Assessment for Solid Waste Treatment Plant and Development of Sanitary Landfill Site at Sisdol-ko-Gairo, Okharpauwa VDC, Nuwakot. SWMRMC, MOLD/HMG, Shreemahal, Pulchowk.

Shrestha, S. (1998). Epidemiological study of Gokarna Landfill Site. Report submitted for B. Sc. Honors in Environmental Science, Kathmandu University

Soltanpour, P. N and Raley, W. L. (1999). Livestock Drinking Water Quality. Livestock Series no. 4.908. Colorado State University. Cooperative Extension. 10/93, Reviewed 3/99.

Stegmann, R. (1983). New aspects on enhancing biological processes in sanitary landfill. *Waste Management and Research* 1: 201–208.

SWMRMC, (2002). Detailed Design of Short term Sanitary Landfill Site Sisdol-ko-Gairo: Volume 1: Main report (Draft Report), Solid Waste Management and Resource Mobilization Centre, Ministry of Local Development, Shreemahal, Pulchowk, Lalitpur.

SWMRMC, (2004) A Diagnostic report on state of solid waste management in municipalities of Nepal., SWMRMC, MOLD/HMG, Shreemahal, Pulchowk, Lalitpur.

SWMRMC, (2005) Environmental Impact Assessment for Solid Waste Treatment Plant and Development of Sanitary Landfill Site at Sisdol-ko-Gairo, Okharpauwa VDC, Nuwakot. SWMRMC, MOLD/HMG, Shreemahal, Pulchowk, Lalitpur.

SWMRMC, (2007) Environmental Impact Assessment Study of Banchare Danda long term landfill site. Interim report submitted by GEOCE Consultants (P.) Ltd., Kathmandu.

Tejero, M. I., Fantelli, L. M., Diaz, I. R. and Szanto, N. M. (1993). Characteristics and treatment of leachates in the ‘Meruelo landfill’ (Spain).

Thapa, G. B. and Devkota, S. R. (1999). Managing Waste in Metro Kathmandu.Asian Institute of Technology, Bangkok.

Trivedy, R. K. and Goel, P. K., (1986). *Chemical and Biological Methods for Water Pollution Studies.* Environmental Publication, Karad 415110, India.

Tsanis, I. K. (2006) Modeling Leachate Contamination and Remediation of Groundwater at a Landfill Site. *Water Resources Management* 20: 109–132.

Tuladhar, B. (2003). The search for Kathmandu's new landfill. *Himalayan Journal of Sciences* 1(1): 7-8.

UNEP (1999). *Global Environment Outlook 2000*. Division of Environmental Information, Assessment and Early Warning (DEIA & EW), United Nations Environment Programme, Nairobi, Kenya.

UNEP (2001). *Nepal: State of environment*. UNEP and ICIMOD, Kathmandu, Nepal.

UNESCO (1996). *Water Quality Assessments- A Guide to Use of Biota, Sediments and Water in Environmental Monitoring*, Second Edition. Chapman, D. (ed.), United Nations Educational, Scientific and Cultural Organization (UNESCO), World Health organization (WHO), United Nations Environment Program (UNEP), University Press, London.

Vasanthi, P., Kaliappan, S. and Srinivasaraghavan, R. (2007). Impact of poor solid waste management on ground water. *Environmental Monitoring Assessment* 143 (1-3): 227-238, 2008.

Viviroli, D., Weingartner, R. and Messerli, B. (Date not mentioned) “Water Towers of the World: The Hydrological Significance of Mountains”

WHO, 1993. Guidelines for Drinking water quality. Volume I, II and III; World Health Organization, Geneva.

WHO, 2004. Guidelines for Drinking water quality. Third edition; Volume 1; World Health Organization, Geneva.
Available from: http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en [Accessed on October 5, 2007]

WHO, 2006. Guidelines for Drinking water quality. First addendum to third edition, Volume I: Recommendations, World Health Organization, Geneva.

WVIN, 2002. Environmental baseline study of CLEAN working area along Bishnumati Corridor. World Vision International- Nepal, Kathmandu, Nepal.

Zheng, C., Bennett, G. D. and Andrews, C. B., 1991. Analysis of ground-water remedial alternatives at a superfund site, *Ground Water* 29(6): 838–848.

Appendix I

Physicochemical parameters of surface water of Kolpu Khola in December

	Study site					
Physicochemical parameters	**1**	**2**	**3**	**4**	**5**	**6**
1. Temperature (ºC)	16.0	20.0	17.0	16.0	17.0	16.5
2. pH	7.0	7.2	7.2	7.3	7.1	7.1
3. Electrical Conductivity, (µS/cm)	57	142	113	161	135	127
4. Velocity (m/s)	0.46	0.69	0.66	0.71	0.75	0.70
5. Secchi disc transparency (cm)	20	11	16	15	25	28
6. Chloride (mg/L)	21.30	63.90	53.96	25.56	22.72	15.62
7. Dissolved oxygen (mg/L)	6.081	5.676	5.878	6.486	7.297	7.500
8. Alkalinity (mg/L)	26	95	80	115	50	45
9. Hardness (mg/L)	16	60	58	70	64	56
10. Calcium hardness (mg/L)	8	38	34	58	52	42
11. Calcium (mg/L)	3.21	15.23	13.62	23.25	20.84	16.83
12. Magnesium (mg/L)	1.95	5.86	5.86	2.93	2.93	3.42
13. TS (mg/L)	400.00	2345.10	1800.00	2749.00	1200.00	964.20
14. TDS (mg/L)	31.35	73.45	85.20	88.55	74.25	69.85
15. TSS (mg/L)	368.65	2271.65	1714.80	2660.45	1125.75	894.35
16. Orthophosphate (mg/L)	0.326	0.203	0.112	0.130	0.063	0.042
17. Nitrate-nitrogen (mg/L)	1.080	1.285	1.682	1.545	1.042	0.411
18. Ammoniacal nitrogen (mg/L)	0.33	0.48	0.44	0.36	0.41	0.27
19. Total iron (mg/L)	0.39	0.45	0.15	2.97	1.03	0.51
20. Total chromium (mg/L)	0.011	0.133	0.113	0.108	0.059	0.039
21. Potassium, mg/L	9.12	10.01	9.79	8.68	9.35	6.23

Appendix II

Physicochemical parameters of surface water of Kolpu Khola in February

	Study site					
Physicochemical parameters	**1**	**2**	**3**	**4**	**5**	**6**
1. Temperature (ºC)	12.0	10.5	13.0	13.5	14.5	13.0
2. pH	7.1	7.3	6.9	7.4	7.6	7.3
3. Electrical conductivity (µS/cm)	58	194	118	157	157	148
4. Velocity (m/s)	0.42	0.52	0.42	0.63	0.61	0.59
5. Secchi disc transparency (cm)	23	16	13	4	5	11
6. Chloride (mg/L)	21.30	51.12	39.76	28.40	22.44	17.75
7. Dissolved oxygen (mg/L)	8.310	7.297	7.703	8.108	7.703	8.108
8. Alkalinity (mg/L)	48	60	95	113	105	86
9. Hardness (mg/L)	20	86	58	82	70	64
10. Calcium hardness (mg/L)	14	50	40	72	60	49
11. Calcium (mg/L)	5.61	20.04	16.03	28.86	24.05	19.64
12. Magnesium (mg/L)	1.37	8.78	4.39	2.44	2.32	3.66
13. TS (mg/L)	181.90	2226.10	370.80	4336.35	886.35	647.60
14. TDS (mg/L)	31.90	126.10	70.80	86.35	86.35	81.40
15. TSS (mg/L)	150.00	2100.00	300.00	4250.00	800.00	566.20
16. Ortho-phosphate (mg/L)	0.146	0.126	0.143	0.304	0.163	0.134
17. Nitrate-nitrogen (mg/L)	0.855	1.018	1.427	1.172	0.500	0.320
18. Ammoniacal nitrogen (mg/L)	0.20	0.35	1.03	0.76	0.25	0.22
19. Total iron (mg/L)	0.43	0.49	0.19	3.02	1.07	0.58

Appendix III

Physicochemical parameters of surface water of Kolpu Khola in March.

	Study site					
Physicochemical parameters	**1**	**2**	**3**	**4**	**5**	**6**
1. Temperature (ºC)	18.5	19.0	16.0	23.5	23.5	22.0
2. pH	7.2	7.0	6.7	7.5	7.4	7.1
3. Electrical conductivity (µS/cm)	62	137	108	173	168	165
4. Velocity (m/s)	0.64	0.76	0.62	0.66	0.85	0.79
5. Secchi disc transparency (cm)	25	20	23	19	28	35
6. Chloride (mg/L)	21.30	41.18	35.50	32.66	25.56	19.17
7. Dissolved oxygen (mg/L)	7.703	5.676	5.878	6.081	7.095	7.297
8. Alkalinity (mg/L)	45	90	90	115	110	80
9. Hardness (mg/L)	22	45	41	72	66	58
10. Calcium hardness (mg/L)	11	35	32	63	59	46
11. Calcium (mg/L)	4.37	14.03	12.83	25.25	23.65	18.44
12. Magnesium (mg/L)	2.71	2.44	2.20	2.20	1.71	2.93
13. TS (mg/L)	479.10	2600.00	800.00	2900.00	1400.00	1038.20
14. TDS (mg/L)	34.10	89.05	64.80	95.15	92.40	90.75
15. TSS (mg/L)	445.00	2510.95	735.20	2804.85	1307.60	947.45
16. Orthophosphate (mg/L)	0.179	0.196	0.210	0.192	0.156	0.128
17. Nitrate-nitrogen (mg/L)	0.971	1.249	3.197	2.412	1.954	1.424
18. Ammoniacal nitrogen (mg/L)	0.16	0.35	1.20	0.85	0.25	0.22
19. Total iron (mg/L)	0.55	0.48	0.70	0.56	0.63	0.36
20. Total chromium (mg/L)	0.015	0.094	0.084	0.074	0.064	0.035
21. Potassium, mg/L	10.01	13.80	11.57	10.46	10.46	6.74

Appendix IV

Physicochemical parameters of surface water of Kolpu Khola in August

	Study site					
Physicochemical parameters	**1**	**2**	**3**	**4**	**5**	**6**
1. Temperature (ºC)	22.0	26.0	23.5	24.5	25.0	26.0
2. pH	7.1	7.2	7.0	7.1	7.2	7.1
3. Electrical conductivity (µS/cm)	49	94	75	89	63	51
4. Velocity (m/s)	1.05	0.86	0.85	0.93	0.89	0.82
5. Secchi disc transparency (cm)	18	15	12	14	16	19
6. Chloride (mg/L)	19.88	25.56	21.30	24.14	21.30	16.33
7. Dissolved oxygen (mg/L)	6.486	4.865	6.486	6.689	6.892	7.905
8. Alkalinity (mg/L)	35	85	35	60	55	40
9. Hardness (mg/L)	10	38	34	32	36	24
10. Calcium hardness (mg/L)	6	22	16	24	16	12
11. Calcium (mg/L)	2.40	8.82	6.41	9.62	6.41	4.81
12. Magnesium (mg/L)	0.98	3.90	4.39	1.46	4.88	3.42
13. TS (mg/L)	2600.00	3200.00	2400.00	3200.00	1200.00	1342.00
14. TDS (mg/L)	26.95	61.10	45.00	48.95	34.65	28.05
15. TSS (mg/L)	2573.05	3138.90	2355.00	3151.05	1165.35	1313.95
16. Orthophosphate (mg/L)	0.281	0.435	0.120	0.243	0.203	0.146
17. Nitrate-nitrogen (mg/L)	0.705	0.891	0.915	0.713	0.801	0.661
18. Ammoniacal nitrogen (mg/L)	0.12	0.62	0.56	0.49	0.22	0.03
19. Total iron (mg/L)	0.63	4.05	1.48	1.86	1.05	0.64
20. Total chromium (mg/L)	0.002	0.007	0.005	0.004	0.004	0.003
21. Potassium, mg/L	6.32	11.06	8.46	7.12	5.27	4.43

Appendix V

Physicochemical parameters of Groundwater

Parameters	Site name	Dec	Feb	Mar	Aug
1. Temperature (°C)	Gw-2	18.0	14.2	27.5	
	Gw-1	19.0	15.5	19.5	20.0
2. Conductivity (µS/cm)	Gw-2	711	913	936	
	Gw-1	194	210	182	156
3. pH	Gw-2	6.8	6.4	6.9	
	Gw-1	6.4	6.5	6.7	6.2
4. TDS (mg/L)	Gw-2	391.05	502.15	514.80	
	Gw-1	106.70	115.50	100.10	85.80
5. TSS (mg/L)	Gw-2	342.95	350.00	365.20	
	Gw-1	93.30	150.00	120.00	60.20
6. TS (mg/L)	Gw-2	734.00	852.15	880.00	
	Gw-1	200.00	265.50	220.10	146.00
7. TA (mg/L)	Gw-2	250	210	265	
	Gw-1	60	105	125	50
8. Chloride (mg/L)	Gw-2	107.92	124.96	130.64	
	Gw-1	39.76	36.92	29.82	28.40
9. Total hardness (mg/L as $CaCO_3$)	Gw-2	384	400	404	
	Gw-1	98	68	80	50
10. Ca hardness (mg/L as $CaCO_3$)	Gw-2	320	284	294	
	Gw-1	82	56	67	26
11. DO	Gw-2	2.838	2.432	2.230	
	Gw-1	4.054	4.865	4.459	2.432
12. Free CO_2 (mg/L)	Gw-2	79.20	83.60	88.00	
	Gw-1	18.04	22.00	35.20	57.20
13. Orthophosphate (mg/L	Gw-2	0.534	0.126	0.134	
	Gw-1	0.035	0.135	0.124	0.066
14. Nitrate- nitrogen (mg/L)	Gw-2	1.699	0.447	0.465	
	Gw-2	2.300	0.568	0.657	0.500
15. Fe (mg/L)	Gw-2	0.15	0.19	0.68	
	Gw-1	0.10	0.14	0.46	0.20
16. NH_3 (mg/L)	Gw-2	0.14	0.54	0.85	
	Gw-1	0.06	1.47	2.11	0.02
17. COD (mg/L l)	Gw-2	128.00	166.00	170.00	
	Gw-1	14.00	20.80	12.00	16.80
18. BOD (mg/L)	Gw-2	72.97	94.32	86.54	
	Gw-1	6.16	9.75	5.18	9.57
19. Ca (mg/L)	Gw-2	125.85	113.83	117.84	

		Gw-1	32.87	22.44	26.85	10.42
20.	Mg (mg/L)	Gw-2	15.59	28.30	26.84	
		Gw-1	3.90	2.93	3.17	5.86
21.	Cr (mg/L)	Gw-2	0.064		0.006	
		Gw-1	0.011		0.000	0.002
22.	K (mg/L)	Gw-2	16.02		17.28	
		Gw-1	4.52		13.80	

Appendix VI

Physicochemical Parameters of leachate

Parameters	**Month**			
	December, 2007	February, 2008	March, 2008	August, 2008
1. Water temperature (°C)	19.0	12.5	25.0	28.0
2. pH	6.9	6.9	6.8	7.0
3. Electrical conductivity (µs/cm)	17620	25640	41200	15495
4. Dissolved oxygen (mg/L)	0	0	0	0
5. Free CO_2 (mg/L)	52.80	83.60	57.20	110.00
6. Chloride (mg/L)	2953.60	3152.40	3408.00	1988.00
7. Total alkalinity (mg/L)	8300	5750	10800	6500
8. Hardness (mg/L as $CaCO_3$)	1360	1800	2900	5200
9. Calcium hardness (mg/L as $CaCO_3$)	640	1000	1240	3160
10. Calcium (mg/L)	256.51	400.80	496.99	1266.53
11. Magnesium (mg/L)	175.68	195.20	405.04	497.76
12. PO_4–P (mg/L)	3.167	10.150	54.306	27.618
13. NO_3-N (mg/L)	24.378	30.596	26.495	35.174
14. NH_4-N (mg/L)	138.75	674.34	138.09	24.51
15. Iron (mg/L)	1.02	10.30	25.63	35.66
16. BOD (mg/L)	5675.60	5462.50	4763.45	3243.20
17. COD (mg/L)	8000.00	7280.00	8240.00	6520.00
18. TDS (mg/L)	12334.00	17948.00	23484.00	8832.15
19. TSS (mg/L)	1066.00	1500.00	2516.00	13167.85
20. TS (mg/L)	13400.00	19448.00	26000.00	22000.00

Appendix VII

Most probable number (MPN) of coliform bacteria present in 100 ml water, for various combinations of positive and negative results when five 10 ml portions, five 1 ml portions and five 0.1 ml portions are used.

Number of five tubes giving a positive reaction					**Number of five tubes giving a positive reaction**			
10 ml	1.0 ml	0.1 ml	MPN Index/100 ml		10 ml	1.0 ml	0.1 ml	MPN Index/100 ml
0	0	1	2		4	3	0	25
0	1	0	2		4	3	1	31
1	0	0	2		4	4	0	32
1	0	1	4		4	4	1	38
1	1	0	4		5	0	0	22
1	2	0	5		5	0	1	29
2	0	0	4		5	0	2	41
2	0	1	5		5	1	0	31
2	1	0	5		5	1	1	43
2	1	1	7		5	3	0	75
2	2	0	7		5	3	1	110
2	3	0	11		5	3	2	140
3	0	0	7		5	3	3	175
3	0	1	9		5	3	4	210
3	1	0	9		5	4	0	130
3	1	1	13		5	4	1	170
3	2	0	13		5	4	2	220
3	2	1	16		5	4	3	280
3	3	0	16		5	4	4	345
4	0	0	11		5	5	0	240
4	0	1	14		5	5	1	350
4	1	0	16		5	5	2	540
4	1	1	20		5	5	3	910
4	2	0	20		5	5	4	1600
4	2	1	25		5	5	5	≥2400

Appendix VIII

Microbiological analysis of water by multiple tube fermentation technique (December)

1. Presumptive Test (December)

Sites	Number of tubes showing positive reaction		
	D.S.(10 ml)	S.S.(1.0 ml)	S.S.(0.1 ml)
Site-1	5	5	5
Site-2	5	5	5
Site-3	5	5	5
Site-4	5	5	5
Site-5	5	5	5
Site-6	5	5	5
GW-2	5	5	5
GW-1	5	5	5
Leachate	5	5	5

2. Confirmed and Completed Test (December)

Type of test	Sites	Number of tubes showing positive reaction			
		D.S. (10 ml)	S.S. (1.0 ml)	S.S. (0.1 ml)	MPN/100ml
2. Confirmed Test	Site-1	5	5	0	240
	Site-2	5	5	5	≥2400
	Site-3	5	5	5	≥2400
	Site-4	5	5	5	≥2400
	Site-5	5	5	5	≥2400
	Site-6	5	5	5	≥2400
	GW-2	5	5	5	≥2400
	GW-1	5	5	1	350
	Leachate	5	5	5	≥2400
3. Completed Test	Site-1	5	5	0	240
	Site-2	5	5	5	≥2400
	Site-3	5	5	5	≥2400
	Site-4	5	5	5	≥2400
	Site-5	5	5	5	≥2400
	Site-6	5	5	4	1600
	GW-2	5	5	5	≥2400
	GW-1	5	5	1	350
	Leachate	5	5	5	≥2400

Appendix IX

Microbiological analysis of water by multiple tube fermentation technique (March, 2008)

1. Presumptive Test (March, 2008)

Sites	Number of tubes showing positive reaction		
	D.S.(10 ml)	S.S.(1.0 ml)	S.S.(0.1 ml)
Site-1	5	4	2
Site-2	5	5	5
Site-3	5	3	2
Site-4	5	5	3
Site-5	5	5	4
Site-6	5	5	4
GW-2	5	5	4
GW-1	2	0	0
Leachate	5	5	5

2. Confirmed and Completed Test (March, 2008)

Type of test	Sites	Number of tubes showing positive reaction			
		D.S. (10 ml)	S.S. (1.0 ml)	S.S. (0.1 ml)	MPN/100ml
2. Confirmed Test	Site-1	5	4	1	170
	Site-2	5	5	5	≥2400
	Site-3	5	3	1	110
	Site-4	5	5	2	540
	Site-5	5	4	3	280
	Site-6	5	3	2	140
	GW-2	5	5	2	540
	GW-1	1	0	0	2
	Leachate	5	5	5	≥2400
3. Completed Test	Site-1	4	4	1	38
	Site-2	5	5	5	≥2400
	Site-3	5	1	1	43
	Site-4	5	5	2	540
	Site-5	5	4	1	170
	Site-6	5	3	1	110
	GW-2	5	5	2	540
	GW-1	1	0	0	2
	Leachate	5	5	5	≥2400

Appendix X

Microbiological analysis of water by multiple tube fermentation technique (August, 2008)

1. Presumptive Test (August, 2008)

Sites	Number of tubes showing positive reaction		
	D.S.(10 ml)	S.S.(1.0 ml)	S.S.(0.1 ml)
Site-1	5	5	1
Site-2	5	5	5
Site-3	5	5	3
Site-4	5	5	4
Site-5	5	5	5
Site-6	5	5	4
GW-1	5	5	4
Leachate	5	5	5

2. Confirmed and Completed Test (August, 2008)

Type of test	Sites	Number of tubes showing positive reaction			
		D.S. (10 ml)	S.S. (1.0 ml)	S.S. (0.1 ml)	MPN/100ml
2. Confirmed Test	Site-1	5	5	1	350
	Site-2	5	5	5	≥2400
	Site-3	5	5	3	910
	Site-4	5	5	4	1600
	Site-5	5	5	5	≥2400
	Site-6	5	5	4	1600
	GW-1	4	3	1	31
	Leachate	5	5	5	≥2400
3. Completed Test	Site-1	5	5	1	350
	Site-2	5	5	5	≥2400
	Site-3	5	5	3	910
	Site-4	5	5	4	1600
	Site-5	5	5	5	≥2400
	Site-6	5	5	2	540
	GW-1	4	3	0	25
	Leachate	5	5	5	≥2400

Appendix XI

WHO Standard for portable water

Parameters	Unit	Guideline value
1. Temp	ºC	No value set
2. pH		6.5-8.5
3. Turbidity	NTU	5 NTU
4. Taste and Odor		Not offensive
5. Chloride	mg/L	250
6. TDS	mg/L	1000
7. Dissolved O_2	mg/L	5
8. Total hardness	mg/L	500
9. Orthophosphate	mg/L	0.02
10. Iron (Fe)	mg/L	0.3
11. Ammonia (NH_3)	mg/L	0.5
12. Nitirite (NO_2^-)	mg/L	< 1
13. Nitrate (NO_3^-)	mg/L	50
14. Biochemical oxygen demand (BOD_5)	mg/L	15
15. Chemical oxygen demand (COD)	mg/L	30
16. Sodium (Na)	mg/L	200
17. Arsenic (As)	mg/L	0.01 (P)
18. Chromium (Cr)	mg/L	0.05
19. Lead (Pb)	mg/L	0.05
20. Cadmium (Cd)	mg/L	0.005
21. Manganese (Mn)	mg/L	0.1
22. Coliform organism	No./ 100 ml	Nil

Source: Guidelines for drinking water quality; WHO, 1993

P = provisional guideline value, as there is evidence of a hazard, but the available information on health effects is limited

Appendix XII

National Drinking Water Quality Guidelines

Categories	Parameters	Maximum Concentration Limits, (MCLs)	Remarks
Physical	1. Turbidity (NTU)	5 (10)	
	2. pH	6.5-8.5*	
	3. Colour (TCU)	5 (15)	
	4. TDS (mg/L)	1000	
	5. Taste and odour	-	
	6. Electrical Conductivity	1500	
Chemical	1. Fe (mg/L)	0.3 (3)	
	2. NH_3 (mg/L)	1.5	
	3. NO_3^- (mg/L)	50	
	4. As (mg/L)	0.05	
	5. Cr (mg/L)	0.05	
	6. Cd (mg/L)	0.003	
	7. Copper (Cu)	1	
	8. Mn (mg/L)	0.2	
	9. Total hardness (mg/L)	500	
	10. Calcium (mg/L)	200	
	11. Zinc (mg/L)	3	
	12. Mercury (mg/L)	0.001	
	13. Aluminium (mg/L)	0.2	
	14. Chloride (mg/L)	250	
	15. Cyanide (mg/L)	0.07	
	16. Fluoride (mg/L)	0.5- 1.5*	
	17. Lead (mg/L)	0.01	
	18. Sulphate (mg/L)	250	
	19. Residual chlorine (mg/L)	0.1- 0.2*	Only for chlorinated systems
Microbiology	E-Coli (MPN Index/ 100 ml)	0	
	Total Coliform, (MPN Index/ 100 ml)	0 (95%)	

Ref: National Drinking water Quality Standard 2062 and National Drinking water quality guidelines 2062; Nepal Government, Ministry of Physical Planning and Works. [Translate in Nepali]

Note: 1*: Represents the range values.

2. ( ): The indicated values inside the brackets represent for those water if other alternative options are unavailable.

3. Following schemes and water suppliers must comply the guideline values within five years of first phase implementation.

a. All town water supply projects and small town water supply schemes up to service population of ten thousands.
b. The water supply projects and schemes must comply this guideline values after the approval of this guidelines.
c. Applicable for those implementing water supply schemes and town water supply projects in areas vulnerable for other diseases even though the service population is less than ten thousands.
d. Applicable for town water supplier, private industry and health related institutions.

4. Following drinking water supply system must comply the guidelines after setting of guidelines in second phase from five to ten years.

a. All drinking water supply networks of district headquarters must comply the guidelines within first three years of second phase implementation
b. All community rural water supply systems must comply the guidelines from the beginning of second phase implementation within five years.

Appendix XIII

Generic standard for Industrial effluents discharged into inland surface water coming from combined sewage treatment plant.

Characteristics	Tolerance limit
pH Value	5.5- 9.0
TSS, mg/L	30- 200
Temperature [1]	< 40
BOD for 5 days at 20 ºC, mg/L, Max	30- 100
COD, mg/L, Max	250
Ammoniacal nitrogen (NH_4-N), mg/L, Max	50
Lead (Pb) , mg/L , Max	0.1
Cadmium (Cd) , mg/L, Max	2.0
Arsenic (As) , mg/L, Max	0.2
Copper (Cu) , mg/L, Max	3.0
Hexavalent chromium, Cr (VI) , mg/L , Max	0.1

Source: Nepal gazette (2003) HMG/MOPE as cited in ADB, 2004.

[1] Shall not exceed 40 ºC in any section of the stream within 15 m downstream from the effluent outlet.

Appendix XIV

Canadian Council Ministries of Environment, CCME, 1999: Water Quality Guidelines for the Protection of Freshwater Aquatic Life.

S. N.	Parameters	Category	CCME, 1999 Guidelines
1.	Ammonia, (mg/L)	Nutrient	1.37 - 2.20 [2]
2.	Iron , (µg/L)	Metal	300 (i.e. 0.3 mg/L)
3.	Nitrate [a], (mg/L)	Nutrient	[8]
4.	Oxygen, Dissolved, (mg/L)	Ions and general	5.5 to 9.5 [9]
5.	pH	Ions and general	6.5 to 9.0
6.	Suspended Solids, (mg/L)	Physical	[10]
7.	Chromium III, (µg/L)	metal	8.9
8.	Chromium VI, (µg/L)	metal	1.0

(Ref. Canadian Council Ministries of Environment, CCME, 1999 -Surface Water Quality Guidelines for Use in ALBERTA, November 1999; Environmental Assurance Division Science and Standards Branch)

Note:

[a]: Although not directly toxic to freshwater aquatic life, these values are included due to their broader influence on conditions that affect aquatic life.

[2]: CEQG guideline for ammonia: 1.37mg/L at pH 8.0, 10ºC; 2.20mg/L at pH 6.5, 10ºC.

[8]: CEQG guideline for nitrate: Concentrations that stimulate weed growth should be avoided.

[9]: CEQG Dissolved oxygen guideline**:**

For warm water biota:

Early life stages = 6mg/L.

Other life stages = 5.5mg/L.

For cold biota:

Early life stages = 9.5mg/L.

Other life stages = 6.5mg/L.

[10]: CEQG suspended solids guidelines:

For clear flow – Maximum increase of 25mg/L from background levels for any short-term exposure (e.g., 24 hour period). Maximum increase of 5mg/L from background levels for any long-term exposure (e.g., inputs lasting between 24 hours and 30 days).

For high flow- Maximum increase of 25mg/L from background levels at any time when background levels are between 25 and 250mg/L. Should not increase more than 10% of background levels when background is >250mg/L.

Appendix XV

USEPA, 1999 Water Quality Guidelines for the Protection of Freshwater Aquatic Life

S. N.	Parameters	Category	USEPA, 1999	
			Acute	Chronic
1.	Alkalinity as $CaCO_3$, (mg/L)	Ions and General	-	20 [1]
2.	Chloride, (mg/L)	Ions and General	860	230
3.	Iron , (µg/L)	Metal	-	1000
4.	Oxygen, Dissolved, (mg/L)	Ions and general	3 - 9.5 [10]	-
5.	pH	Ions and general	-	6.5 - 9.0
6.	Chromium VI, (µg/L)	metal	16[6]	11[6]
7.	Suspended Solids, (mg/L)	Physical	[12]	

(Ref. Canadian Council Ministries of Environment, CCME, 1999 –Surface Water Quality Guidelines for Use in ALBERTA, November 1999; Environmental Assurance Division Science and Standards Branch)

Note:

[1]: USEPA guideline for alkalinity is 20mg/L or more as $CaCO_3$ except where natural conditions are less.

[6]: USEPA guideline values for most metals are expressed in terms of the dissolved metal in the water column. To convert dissolved concentrations to total recoverable metal in the water column; the guidelines given can be divided by a conversion factor (CF). The CF for chromium (VI) is 0.982 for the maximum concentration guideline (acute) and 0.962 for the continuous concentration guideline (chronic). The CF for mercury is 0.85 for both maximum and continuous concentrations.

[10]: USEPA dissolved oxygen guidelines:

For warm water biota:
Early life stages = 6mg/L (7day mean), 5.0mg/L (1day minimum)

Other life stages = 5.5mg/L (30 day mean), 4.0mg/L (7 day mean minimum), 3.0mg/L (1day minimum).

For cold water biota:

Early life stages = 9.5mg/L (7 day mean intergravel DO concentration), 6.5mg/L (7 day mean water column DO concentration), 8.0mg/L (1 day minimum mean intergravel DO concentration), 5.0mg/L (1 day mean water column DO concentration)

Other life stages = 6.5mg/L (30 day mean), 5.0mg/L (7 day mean), 4.0mg/L (1 day minimum).

[12]: USEPA suspended solids guideline: Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonably established norm for aquatic life (for solids – suspended, settleable, and turbidity).

Appendix XVI

Water Quality Guidelines for Agricultural Uses, CCME – 1999

S. N.	Parameters	Category	Guideline Values	
			Irrigation Water	Livestock Water
1.	Chloride, (mg/L)	Ions and General	100 - 700 [3]	-
2.	Iron, (µg/L)	Metal	5000 µg/L (i.e. 5 mg/L)	-
3.	Lead , (µg/L)	Metal	200	100 µg/ L (i.e.0.1 mg/L)
4.	Manganese, (µg/L)	Metal	200	-
5.	Calcium, (mg/L)	Ions and General	-	1000
6.	Chromium VI, (µg/L)	metal	8.0	50
7.	Total Dissolved Solids, (mg/L)	Ions and General	500- 3500[8]	3000
8.	Coliform bacteria (faecal), No./100 ml)	Biological	100	-
9.	Total Coliform bacteria (faecal), No./100 ml)	Biological	1000	-

(Ref. Canadian Council Ministries of Environment, CCME, 1999 –Surface Water Quality Guidelines for Use in ALBERTA, November 1999; Environmental Assurance Division Science and Standards Branch)

Note:

[3]**: Chloride guideline:**

Foliar damage: 100 - 178 mg/L: for almonds, apricots and plums
178 - 355 mg/L: for grapes, peppers, potatoes and tomatoes
355 - 710 mg/L: for alfalfa, barley, corn and cucumbers
> 710 mg/L: for cauliflower, cotton, safflower, sesame, sorghum, sugar beets and sunflowers.

Rootstocks: 180 - 600 mg/L: for stone fruit (peaches, plums, etc.
710 - 900 mg/L: for grapes

Cultivars: 110 - 180 mg/L: for strawberries
230 - 460 mg/L: for grapes
250 mg/L: for boysenberries and raspberries

[8]**: Total dissolved solids guidelines:**

500 mg/L: for strawberries, raspberries, beans and carrots
500- 800 mg/L: for boysenberries, currants, blackberries, plums, grapes, apricots, peaches, apples, onions, radishes, peas, pumpkins, lettuce, peppers, sweet potatoes, potatoes, cabbage, cauliflower, broadbeans, sunflower and corn.
800- 1500 mg/L: for spinach, cucumbers, tomatoes, broccoli, turnips,
1500- 2500 mg/L: for sorghum, beet and perennials ryegrass.
3500 mg/L: for asparagus, soybeans, oats, rye, wheat, barley, and tall grass.

Appendix XVII

Livestock Drinking Water Quality [Soltanpour et al, 1999]

Recommendations for levels of toxic substances in drinking water for livestock

Constituent	Upper limit	Constituent	Upper limit
1. Aluminum (Al)	5.0 mg/L	2. Lead (Pb)	0.1 mg/L[1]
3. Arsenic (As)	0.2 mg/L	4. Manganese (Mn)	no data
5. Beryllium (Be)	no data	6. Mercury (Hg)	0.01 mg/L
7. Boron (B)	5.0 mg/L	8. Molybdenum (Mo)	no data
9. Cadmium (Cd)	0.05 mg/L	10. Nitrate + nitrite (NO_3-N + NO_2- N)	100 mg/L
11. Chromium (Cr)	1.0 mg/L	12. Nitrite (NO_2-N)	10 mg/L
13. Cobalt (Co)	1.0 mg/L	14. Selenium (Se)	0.05 mg/L
15. Copper (Cu)	0.5 mg/L	16. Vanadium (V)	0.10 mg/L
17. Fluorine (F)	2.0 mg/L	18. Zinc (Zn)	24 mg/L
19. Iron (Fe)	no data	20. TDS	10,000 mg/L

[1] Lead is accumulative and problems may begin at threshold value=0.05 mg/L.

Sources: Environmental Studies Board, National Academy of Science, National Academy of Engineering, Water Quality Criteria, 1972.

Ayers, R.S. and D.W. Wescot. Water Quality for Agriculture. Food and Agriculture Organization of the United Nations, Rome, 1976.

Appendix XVIII

Recommended Maximum Concentrations for Selected Chemicals and Microorganisms in Livestock Drinking Water (Peterson, 1999)

Chemical Name	**Guideline**	**Application**
1. pH	6.5- 8.5	Guideline values. If pH is lower than 5.5, acidosis and reduced feed intake may occur in cattle, but is unlikely to have an effect on pigs. Chlorination efficiency is reduced at high pH. A low pH may cause precipitation of some antibacterial agents delivered through the water system (for example sulphonamides)
2. Alkalinity (as $CaCO_3$)	500 mg/L	Alkalinity levels above 500 mg/L can have a laxative effect. Lower levels may have a laxative effect if sulphate is present in the water.
3. Chloride	15,000 mg/L	Reduced growth in immature chickens, but affect largely overcome by adding Na and K
4. Hardness (as $CaCO_3$)	No guideline	Hardness has no effect on water safety, but can result in the accumulation of scale in water delivery pipes. The scale mainly consists of magnesium, manganese, iron and calcium carbonates. Water with more than 120 mg/L as $CaCO_3$ is considered hard.
5. Iron (Fe)	300 µg/L	No toxicity guideline established. Veal calves will have increased coloration of meat at iron levels as low as 0.1 mg/L; this level can also give milk an oxidized flavor. Iron can present problems in restricted flow drinking water lines where iron precipitation may plug the line. Iron will also present problems when water is disinfected and can encourage bacterial slime growth in water supply lines.
6. Nitrate (NO_3-N)	100 mg/L	Guideline value. Nitrate may impair the oxygen carrying capacity of the blood by reducing hemoglobin to methemoglobin. At the guideline level there has been small increase in methemoglobin in pigs.
7. Chromium (Cr)	1000 (µg/L)	Guideline

Ref: Livestock and Water Quality; H.G. Peterson; Copyright © 1999 by Agriculture and Agri-Food Canada- Prairie Farm Rehabilitation Administration.

Appendix XIX

Suggested criteria for irrigation water use based upon conductivity.

Classes of water	Electrical Conductivity (dS/m)*	Electrical Conductivity (µS/cm)
Class 1, Excellent	≤0.25	≤250
Class 2, Good	0.25 - 0.75	250-750
Class 3, Permissible[1]	0.76 - 2.00	760-2000
Class 4, Doubtful[2]	2.01 - 3.00	2010-3000
Class 5, Unsuitable[2]	≥3.00	≥3000

*dS/m at 25ºC = mmhos/cm

1Leaching needed if used.

2Good drainage needed and sensitive plants will have difficulty obtaining stands

Source: Bauder et al, 2007

Appendix XX

Chloride classification of irrigation water

Chloride (ppm)	Effect on Crops
Below 70	Generally safe for all plants.
70-140	Sensitive plants show injury.
141-350	Moderately tolerant plants show injury.
Above 350	Can cause severe problems.

Source: Mass (1990) Crop Salt Tolerance. Agricultural Salinity Assessment and Management Manual. K.K. Tanji (ed.). ASCE, New York. pp 262-304.

(As cited in Bauder et al, 2007)

Appendix XXI

One way ANOVA of test of significance of spatial variation of physico-chemical parameters at different stations of Kolpu Khola

Parameters		**Sum of Squares**	**df**	**Mean square**	**F**	**Sig.**
Temperature	Between groups	26.833	5	5.367	.192	.962
	Within Groups	502.500	18	27.917		
	Total	529.333	23			
Velocity	Between Groups	.057	5	.011	.383	.854
	Within Groups	.537	18	.030		
	Total	.594	23			
pH	Between Groups	.430	5	.086	3.521	.021
	Within Groups	.439	18	.024		
	Total	.869	23			
DO	Between Groups	8.164	5	1.633	2.517	.068
	Within Groups	11.677	18	.649		
	Total	19.841	23			
BOD	Between Groups	28040.032	5	5608.006	42.002	.000
	Within Groups	2403.299	18	133.517		
	Total	30443.331	23			
COD	Between Groups	85233.064	5	17046.613	54.445	.000
	Within Groups	5635.808	18	313.100		
	Total	90868.872	23			
Free CO_2	Between Groups	2636.366	5	527.273	7.664	.001
	Within Groups	1238.390	18	68.799		
	Total	3874.756	23			
TA	Between Groups	8840.333	5	1768.067	3.123	.033
	Within Groups	10192.125	18	566.229		
	Total	19032.458	23			
Hardness	Between Groups	5700.053	5	1140.011	4.091	.012
	Within Groups	5015.540	18	278.641		
	Total	10715.593	23			
Ca hardness	Between Groups	4682.419	5	936.484	3.973	.013
	Within Groups	4242.508	18	235.695		
	Total	8924.926	23			
Ca (mg/L)	Between Groups	752.343	5	150.469	3.973	.013
	Within Groups	681.640	18	37.869		

	Total	1433.983	23			
Mg (mg/L)	Between Groups	29.276	5	5.855	2.423	.076
	Within Groups	43.503	18	2.417		
	Total	72.779	23			
Chloride	Between Groups	2341.650	5	468.330	6.065	.002
	Within Groups	1389.940	18	77.219		
	Total	3731.589	23			
NO_3	Between Groups	3.156	5	.631	1.732	.178
	Within Groups	6.559	18	.364		
	Total	9.715	23			
PO_4	Between Groups	.058	5	.012	1.825	.159
	Within Groups	.115	18	.006		
	Total	.174	23			
Iron	Between Groups	7.871	5	1.574	1.890	.146
	Within Groups	14.992	18	.833		
	Total	22.863	23			
Ammonia	Between Groups	1.167	5	.233	6.816	.001
	Within Groups	.616	18	.034		
	Total	1.783	23			
Conductivity	Between Groups	20044.708	5	4008.942	2.708	.054
	Within Groups	26646.250	18	1480.347		
	Total	46690.958	23			
TDS	Between Groups	7577.176	5	1515.435	3.075	.035
	Within Groups	8871.469	18	492.859		
	Total	16448.645	23			
Transparency	Between Groups	301.208	5	60.242	1.184	.356
	Within Groups	915.750	18	50.875		
	Total	1216.958	23			
TSS	Between Groups	18930277.487	5	3786055.497	7.536	.001
	Within Groups	9042547.291	18	502363.738		
	Total	27972824.778	23			
TS	Between Groups	19434544.136	5	3886908.827	7.871	.000
	Within Groups	8889172.059	18	493842.892		
	Total	28323716.195	23			
Chromium	Between Groups	.016	5	.003	2.187	.124
	Within Groups	.017	12	.001		
	Total	.033	17			
Potassium	Between Groups	55.688	5	11.138	3.079	.051
	Within Groups	43.413	12	3.618		
	Total	99.101	17			

Appendix XXII

One way ANOVA of test of significance of monthly variation of physico-chemical parameters at different stations of Kolpu Khola

Parameters		**Sum of Squares**	**df**	**Mean square**	**F**	**Sig.**
Temperature	Between Groups	449.250	3	149.750	37.399	.000
	Within Groups	80.083	20	4.004		
	Total	529.333	23			
Velocity	Between Groups	.420	3	.140	16.071	.000
	Within Groups	.174	20	.009		
	Total	.594	23			
pH	Between Groups	.080	3	.027	.679	.575
	Within Groups	.789	20	.039		
	Total	.869	23			
DO	Between Groups	7.865	3	2.622	4.378	.016
	Within Groups	11.976	20	.599		
	Total	19.841	23			
BOD	Between Groups	898.899	3	299.633	.203	.893
	Within Groups	29544.432	20	1477.222		
	Total	30443.331	23			
COD	Between Groups	2546.665	3	848.888	.192	.900
	Within Groups	88322.207	20	4416.110		
	Total	90868.872	23			
Free CO_2	Between Groups	91.982	3	30.661	.162	.921
	Within Groups	3782.774	20	189.139		
	Total	3874.756	23			
TA	Between Groups	5032.458	3	1677.486	2.396	.098
	Within Groups	14000.000	20	700.000		
	Total	19032.458	23			
Hardness	Between Groups	3775.380	3	1258.460	3.627	.031
	Within Groups	6940.213	20	347.011		
	Total	10715.593	23			
Ca hardness:	Between Groups	3384.085	3	1128.028	4.072	.021
	Within Groups	5540.842	20	277.042		
	Total	8924.926	23			
Ca (mg/L)	Between Groups	543.791	3	181.264	4.072	.021
	Within Groups	890.193	20	44.510		
	Total	1433.983	23			

Mg (mg/L)	Between Groups	10.496	3	3.499	1.123	.363
	Within Groups	62.283	20	3.114		
	Total	72.779	23			
Chloride	Between Groups	490.714	3	163.571	1.009	.409
	Within Groups	3240.876	20	162.044		
	Total	3731.589	23			
NO_3	Between Groups	4.327	3	1.442	5.353	.007
	Within Groups	5.388	20	.269		
	Total	9.715	23			
PO_4	Between Groups	.028	3	.009	1.257	.316
	Within Groups	.146	20	.007		
	Total	.174	23			
Iron	Between Groups	3.574	3	1.191	1.235	.323
	Within Groups	19.289	20	.964		
	Total	22.863	23			
Ammonia	Between Groups	.089	3	.030	.351	.789
	Within Groups	1.694	20	.085		
	Total	1.783	23			
Conductivity	Between Groups	18209.792	3	6069.931	4.262	.018
	Within Groups	28481.167	20	1424.058		
	Total	46690.958	23			
TDS	Between Groups	5970.754	3	1990.251	3.799	.026
	Within Groups	10477.891	20	523.895		
	Total	16448.645	23			
Transparency	Between Groups	550.792	3	183.597	5.512	.006
	Within Groups	666.167	20	33.308		
	Total	1216.958	23			
TSS	Between Groups	3248684.458	3	1082894.8	.876	.470
	Within Groups	24724140.321	20	1236207.0		
	Total	27972824.778	23			
TS	Between Groups	2978203.461	3	992734.48	.783	.517
	Within Groups	25345512.733	20	1267275.6		
	Total	28323716.195	23			
Chromium	Between Groups	.006	2	.003	1.792	.201
	Within Groups	.026	15	.002		
	Total	.033	17			
Potassium	Between Groups	34.624	2	17.312	4.027	.040
	Within Groups	64.477	15	4.298		
	Total	99.101	17			

Appendix XXIII

Upstream surface water Quality comparison of Kolpu Khola with respect to SLFS

Parameters	Unit	WHO G.V (1993)	Upstream* (Oct,06)	Upstream** (June, 08)
1. Temperature	ºC	No value set	22	25.0
2. pH	-	6.5- 8.5	8.0	8.1
3. Electrical conductivity	µS/cm		NA	96.0
4. Odor	-		muddy	Odourless
5. Colour	Hazen		grey	<5.0
6. Turbidity	NTU	5	20	6.0
7. Dissolved Oxygen	mg/L	5	8.5	5.3
8. TSS	mg/L		67	9.0
9. BOD	mg/L	15	6.5	0.65
10. COD	mg/L	30	15.81	3.0
11. Ammonia-Nitrogen	mg/L	0.5	0.16	0.15
12. Chloride	mg/L	250	4	5.0
13. Phosphorus	mg/L	0.02	1.72	0.12
14. Lead (Pb)	mg/L	0.05	0.01	<0.01
15. Cadmium (Cd)	mg/L	0.005	<0.003	<0.002
16. Chromium (Cr)	mg/L	0.05	NA	<0.01
17. Fecal Coliform (E. Coli)	CFU/100ml	Nil	1200	60

* in ENPHO, 2007

** Water, Engineering and Training Centre (P) Ltd. (2008).

NA: Not available

G.V.: Guideline value

Appendix XXIV

Downstream surface water Quality comparison of Kolpu Khola with respect to SLFS

Parameters	Unit	WHO G.V (1993)	Downstream* (Oct,06)	Downstream** (June, 08)
Temperature	ºC	No value set	22	27.3
pH	-	6.5- 8.5	7.91	8.4
Electrical conductivity	µS/cm		NA	139.0
Odor	-		Muddy	Odourless
Colour	Hazen		Grey	5.0
Turbidity	NTU	5	240	11.0
Dissolved Oxygen	mg/L	5	8.50	5.2
TSS	mg/L		639	16.0
BOD	mg/L	15	9.50	0.8
COD	mg/L	30	31.20	13.0
Ammonia-Nitrogen	mg/L	0.5	0.64	0.21
Chloride	mg/L	250	7.0	7.9
Phosphorus	mg/L	0.02	1.77	0.21
Lead (Pb)	mg/L	0.05	0.04	<0.01
Cadmium (Cd)	mg/L	0.005	0.003	<0.002
Chromium (Cr)	mg/L	0.05	NA	<0.01
Fecal Coliform (E. Coli)	CFU/100ml	Nil	2100	75

* Source: ENPHO, 2007

** Source: Water, Engineering and Training Centre (P) Ltd. (2008)

Appendix XXV

Leachate Quality comparison of Sisdol landfill site

Parameters	Unit	Generic Standard	Leachate (Mar, 06) [a]	Leachate (Feb, 07)[b]	Leachate (June, 08)[c]	Average value*
Temperature	ºC	<40	18.0	18.0	30.6	
pH	-	5.5 – 9.0	7.78	6.98	7.8	6.9
Conductivity	µS/cm	NA	NA	NA	16055	24989
Odor	-	NA	Leachate odour	NA	Leachate odour	
Colour	Hazen	NA	Black	NA	Black	Black
Turbidity	NTU	NA	2000	<5000	252	NA
Dissolved Oxygen	mg/L	NA	0	0	0	0
TSS	mg/L	30- 200	470	2380	323	4562.46
BOD	mg/L	30- 100	12000	29750	1370	4786.19
COD	mg/L	250	21112	65500	6400	7510.00
Ammonia-Nitrogen	mg/L	50	693.6	1703.0	1757.9	243.92
Chloride	mg/L	NA	NA	NA	NA	2875.50
Phosphorus	mg/L	NA	NA	98.11	14.8	23.81
Lead (Pb)	mg/L	0.1	NA	0.19	0.26	NA
Cadmium (Cd)	mg/L	2.0	NA	0.02	0.06	NA
Chromium (Cr) VI	mg/L	0.1	NA	NA	0.19	0.445
Fecal Coliform (E. Coli)	CFU/100ml		NA	112×10^4	NA	≥2400

a: Source: ENPHO, 2007

b: Source: Water, Engineering and Training Centre (P) Ltd. (2008)

c: Source: ENPHO/CKV/East Consult (2006) (As cited in ENPHO, 2007)

*Average of the value obtained during four months study from December, 2007 to August, 2008

Appendix XXVI

HOUSEHOLD QUESTIONNAIRE SURVEY

Date:

Name of data collector:

1. Profile of Informant/Respondent

Name of Respondent:
Sex:
Age:
Current address:
Occupation:

a) Government services b) Business c) Agriculture d) labor
e) Both b and c f) both c and d g) student

Education level

a) Illiterate b) Primary level c) Secondary level d) Intermediate
e) College f) University

Total number of family members:

Name	Sex	Age (yrs.)	Occupation	Education	Health impacts *	If yes, mention any 5 with dominant ones first

*Any health impacts after dumping started (+ce /-ce)

Water Pollution

1. Do you think the present dumping activities along the banks of river is a better way to dispose waste?
   a. Yes……………. b. No……………….

2. How was the water quality of Kolpu Khola before dumping started at Sisdol?
   a. Very good b. Good c. Bad
   d. Worse

3. Do you use the river water?
   a. Yes………… b. No…………

4. If yes, for what purpose?
   a. Irrigation b. For livestock c. Irrigation and livestock

   d. Washing, bathing, irrigation and livestock

5. Do you know what leachate is?
   a. Yes b. No

6. In your opinion how the leachate should be disposed off?
   a. No idea b. stored in pond
   c. filtered through bamboo and discharged into river
   d. treated with medicine and discharged into river
   e. discharged into the river in controlled way
   f. other (……………..)

7. What type of change have you noticed in the water quality of Kolpu Khola after operation of landfill?
   a. No change b. Degraded a little
   c. Degraded significantly d. degraded a lot (extremely)

8. How far downstream do you think does the leachate cause impacts on water quality?
   a. Up to 5 km b. Up to 10 km
   c. More than 10 km d. more than 20 km e. don't know

9. Has the degradation of water quality caused by dumping activities affected your socio-economic life?
   a. Yes……………. b. No………….

10. If yes, which aspect of your socio-economic life is affected?
    a. Agriculture b. Livestock c. Human health
    d. both a & b
    e. both b & c f. both a & c g. All of above

Impact on agriculture (If any)

13. Have you faced any change in agricultural production due to degradation in water quality?
    a. Yes……….. b. No……….

If yes, what kind of change have you faced?
a. increase in production b. decrease in production c. no change in production

Impact on Livestock health

14. Was there any death of livestock/cattle that you suspect to be caused by drinking river water?
    a. Yes b. No
    If yes, specify the number of livestock…..

Health problems

15. Have you encountered any health impacts after dumping started?
    a. Yes b. No

16. What is the frequency of getting illness?
    a. As previous   b. Increased but cannot say

17. Are there any health posts in your community?
    a. No   b. 1   c. 2   d. More than 2

18. Are they sufficient?
    a. Yes   b. No

Other related questions

19. What is the main source of income of your family?
    a. Agriculture   b. Business   c. Job   d. both a and b
    e. Both a and c

20. Income level
    a) <2500   b) 2500- 5000   c) 5000-10000   d) >10000

21. In your family, what is the main source of energy?
    a. Fuelwood   b. Electricity   c. L.P.G
    d. Fuelwood and electricity   e. Fuelwood and LPG
    f. Electricity and L.P.G.

22. Have you got any subsidies/incentives by SWMRMC?
    a) Yes   b) No   c) Not informed

23. In your opinion, what can be done to this landfill site in the future (after its closure)?
    a. No idea   b. Greenery   c. Play ground
    d. Source of methane gas   e. both b & c

PHOTO DISPLAY

Plate 1: Sampling station 1 (S_1) of Kolpu Khola

Plate 2: Thulo Khola mixing into the Kolpu Khola just before Sisdol landfill

Plate 3: Leakage of leachate from SLF into Kolpu Khola

Plate 4: View of sampling station 3 (S_3) of Kolpu Khola towards Dhading

Plate 5: View of sampling station 3 (S_3) of Kolpu towards Nuwakot

Plate 6: Muddy water seen at Kolpu Khola Khola (between S_3 and S_4) on August

Plate 7: Muddy water at station S_4 on February

Plate 8: Muddy water at station S_5 on February

Plate 9: Private well about 150 m NE from SLF

Plate 10: Bore hole-2 made for monitoring groundwater quality near leachate tank of valley 2

Plate 11: Leachate tank 2 made for collection of leachate from valley 2

Plate 12: Researcher taking water sample in a vial for faecal coliform test

Plate 13: Series of volumetric of flasks made ready to take absorbance for iron

Plate 14: Series of nutrient agar and Mckonkey's broth tube made for completed test

Plate 15: Green metallic sheen on the EMB agar showing presence of faecal coliform

Plate 16: Researcher doing titration in the field

Plate 17: Researcher doing titration for determination of COD

Plate 18: Researcher sterilizing the inoculating loop to perform MPN test for faecal coliform

Plate 19: Researcher taking an interview with EPH teacher of Mukundeshwari Secondary School at Chauthe

Plate 20: Researcher taking questionnaire with Ex- president of Chauthe VDC

Plate 21: Mukundeshwori Secondary School of Chauthe

Plate 22: School building of Mahakali Kishan Secondary School of Chhatredeurali-9

Sisdol Sanitary Landfill

– Okharpauwa, Nuwakot –

Landfill Type	Semi-aerobic Type Sanitary Landfill	
Total Site Area		15 ha
-Landfill Area		2 ha
-Other Infrastructures (Building, On-site road, Leachate Pond, etc.)		1 ha
-Site Protection Area (Buffer zone, Greenery/ forest, Access road, etc.)		12 ha
Expected Landfill Capacity	Valley 1	169,000 cum
(Total: 275,000 cum)	Valley 2	106,000 cum
Expected Landfill Life		3 year

Leachate Treatment System (aeration and recirculation system)			
Section	Leachate Pond	Aerator	Recirculation Pump
Valley 1	350 cum	10 hp x 1unit	5.5 kw x 1 unit
Valley 2	375 cum	15 hp x 1unit	5.5 kw x 1 unit

Commencement day of Operation	June 5, 2005
Development Agency	Solid Waste Management & Resource Mobilization Center
Operation Municipality	Kathmandu Metropolitan City Lalitpur Sub-Metropolitan City
Local Coordination	Okharpauwa Sanitary Landfill Site Main Coordination Committee
Technical Cooperation	Japan International Cooperation Agency

Valley 2 is proposed plan and to add a charcoal treatment system

Note:
Valley 1 was developed in cooperation with the JICA CKV (Clean Kathmandu Valley) Study as the Pilot Project for a first landfill with semi-aerobic system in Nepal.

CKV -Sapha Sahar Hamro Rahar-

Clean Kathmandu Valley Study

Plate 23: Map showing the structure of Sisdol Sanitary landfill at Okharpauwa

Plate 24: Dozers helping for unloading the waste at Sisdol Sanitary landfill

Plate 25: Waste scrappers collecting plastic at Sisdol Sanitary landfill

Plate 26: Soil extraction for using as cover material at the Sisdol Sanitary landfill

Plate 27: Temporary landfill site under construction at Aletar, Okharpauwa

Plate 28: Bancharedanda, the future landfill site at Okharpauwa, Nuwakot