Study Related to Groundwater Contamination of Sillanwali (District Sargodha) and its Health Impacts

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DEDICATION

“I fondly dedicate my dissertation to my parents who have always been a source of inspiration and courage to me”

ACKNOWLEDGEMENTS

All my humble praise is to ***ALLAH ALMIGHTY****, the creator of this universe and the greatest of all, for giving me courage, strength and determination. My modest gratitude to the* **Holy Prophet Hazrat Muhammad (S.A.W.W)** *who has taken all human beings from the darkness to the lightness, enlightened our hearts and souls, and for His countless blessings on me.*

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Adan Fatima Javed

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer	Mg	Magnesium
AF	Acre Feet	MPL	Maximum Permissible Level
APHA	American public health association	MPN	Most Probable Number
As	Arsenic	µS/cm	Micro Siemens Per Centimeter
BOD	Biological Oxygen Demand	N	Nitrate/Normal
Ca	Calcium	Na	Sodium
ND	Not Detected		
Cl	Chloride	NIH	National Institute of Health
Cfu	Colony forming unit	NO_3	Nitrate
CO_3	Carbonate	NTU	Nephelometric Turbidity Unit(s)
COD	Chemical Oxygen Demand	NWQM	National Water Quality Monitoring Program
Cr	Chromium	OECC	Overseas Environmental Cooperation
			Centre
DO	Dissolved Oxygen	PCRWR	Pakistan Council of Research in Water Resources
E.Coli	Escherichia Coliform	PO_4	Phosphate
EC	Electrical Conductivity	ppb	Parts Per Billion
EDT	Ethylene diamine Tetra acetate	ppm	Parts Per Million

	Dehydrate		
EPA	Environmental Protection Agency	PSI	Pakistan Standards Institution
F	Fluoride	RBOD	Right Bank Outfall Drain
FDA	Food Development Authority	RO	Reverse Osmosis
Fe	Iron	Sm^{-1}	Siemens Per Meter
HCO_3	Bicarbonate	SO_4	Sulphate
HDL	Highest Desirable Level	TCU	True Color Units
HRD	Human Resource Development	TDS	Total Dissolved Solids
IBW	International Bottled Water Association	UNICE	United Nations Children Fund
ICP	Inductive Coupled Plasma Spectrophotometer	UV	Ultra Violet
K	Potassium	WAPD	Water and Power Development Authority
LBOD	Left Bank Outfall Drain	WASA	Water and Sanitation Authority
M	Molar	WHO	World Health Organization
MAC*	Maximum Acceptable Concentration	WRRC	Water Resources Research Centre
MAC**	Maximum Allowable Concentration	WT	Water Table
MAF	Million Acre Feet	WQP	Water Quality Parameters

ABSTRACT

Pakistan is a country with water intensive economy as most of its farmland is irrigated through a canal system, but available resources are getting adversely affected due to issues like wastage of water, rapid population growth, deteriorating situation of dams, outdated canal system, expensive and improper ways of irrigation. On top of this, the available water which is being used for domestic purposes is contaminated by mixing of municipal sewage, industrial effluents and agricultural runoff. The core purpose of this study is to investigate presence of microbial contamination in groundwater, evaluation of different physico-chemical parameters of drinking water in an under developed area named as Sillanwali in district Sargodha and its effects on health and lifestyle of local inhabitants. In addition to this, the study would contribute for local administration to take necessary measures to protect water with contamination and provide clean and safe drinking water to people. The research work spanned for over six months and complete water quality analysis was performed including physico-chemical, microbial and heavy metals analysis. Almost 70 percent water samples collected from concerned areas were found polluted with fecal coliforms as a result of qualitative analysis done by MPN test. The samples were also sent to PCRWR for quantitative analysis based on membrane filtration method as per APHA standards and presence of coliforms was confirmed. While analyzing physico-chemical parameters and comparing them with WHO guidelines for drinking water quality, pH was found within range 7.10 to 8.14, EC ranged from 205.5 μS/cm to 1821 μS/cm, turbidity ranged from 1.22 NTU to 166.15 NTU where a decreasing trend indicated groundwater recharge, TDS ranged from 99.35 mg/L to 1897 mg/L, total chlorides had a range from 14.12 mg/L to 390 mg/ L. Most of the parameters were observed higher than the WHO guidelines, hence posing a risk to human health due to water pollution. BOD and COD was also analyzed and their values ranged from 1.36 mg/L to 16.88 mg/L and 3.28 mg/L to 32.72 mg/L respectively, which revealed mixing of waste in groundwater. The samples were also analyzed for heavy metals by ICP-OES and all the metals were found below limit of detection. Socio-demographic survey was also conducted through structured questionnaire keeping sample number as 450 and it illustrated that majority 44.8% are illiterate while 16.7% have primary education and about 50 percent population is aged between 19 and 39 years. The highest percentage income group 31.11% has monthly income of Rs. 8,000-11,000. A rising trend was found in medical cases being reported to surrounding hospitals over last 5 years due to consumption of contaminated water. The lack of hygiene and practice of open defecation is leading to the degradation of water quality, consequently the persistence of waterborne diseases in the neighborhoods of sub-rural municipalities, and there is a growing threat to the sustainability of existing water quality. The results of this study should encourage municipality policy and strategy on increasing the access to safely managed sanitation services in order to better protect surface water and groundwater sources, and limit the proliferation of epidemics to improve living standard of locals.

CHAPTER 1: **INTRODUCTION**

1.1 Background

One of the most vital components for maintaining life on the earth is water. About 97% of water exists in oceans that is not suitable for drinking out of which only 3% is fresh water. In addition to that 2.97% is comprised of glaciers and ice caps and remaining little portion of 0.3% is available as a surface water and ground water available for human use (*Miller, 1997*). On average, only 36 % Pakistani population which includes 41% urban and 32 % rural has access to safe drinking water according to a world health organization (WHO) report. Safe drinking water is considered to be a basic need for good health and it is also a right of every human being. Availability of fresh water is limited in many parts of the world. In the coming century, it will become even more limited because of increased population, urbanization and climate change (*Jackson et al., 2001*). Unfortunately, due to high growth of population, expansion in industries, throwing away of waste water and chemical effluents into canals and other water sources in developing countries like Pakistan, the drinking quality of water is continuously being contaminated and becoming hazardous for human use.

Situation is more serious in South Asia, where due to poor water quality and bad sanitation, more than 0.5 million deaths of infants take place per year with additional health threats. For instance, in some areas of Bangladesh as well as West Bengal (India), groundwater is reportedly contaminated with arsenic at levels as much as 70 times more than the national drinking water standard of 0.05 mg/L (UNEP, 1999). Worldwide, more people are dying due to poor quality of water per year than from all forms of violence including war and it is estimated that about 26% of all deaths are resulted due to contagious diseases caused by pathogenic bacteria (WHO, 2002; UNEP GEMS/ Water Program 2008). Lack of access to safe and clean water created waterborne diseases overly by the inhabitants of slums in India (*Lal et al., 1996*). Diarrhea, a waterborne disease is stated as the leading cause of death in infants and children in the India while one out of five citizen suffers from illness and disease caused by the polluted water (*Khalown et al., 2006*). Drinking water quality has a rising issue in developed world but little debated in developing Countries. Pakistan is ranked as a water stress country with the availability of about 1,200 m^3 per capita which is rapidly decreasing.

Moreover, the production of domestic and industrial wastewater is about 4 million-acre feet (MAF) per year in Pakistan that is discharging directly into water bodies except 3% of that amount which is treated. Almost 70 percent of the people in Pakistan rely on ground water for their household uses (Malik et al., 2010). Due to contamination and micro-biological impurities most of the Pakistani locals have inadequate access to safe drinking water with poor water supply lines and defective drainage system (*Farrukh et al., 2004*). As a result, this caused many diseases among people (*Tanvir et al., 2003*). Particularly, biological diseases triggered high child mortality rate of 128 out of thousand per year (UNICEF and Meta-Meta, 2009). In Pakistan, it has been estimated that 30% of all diseases and 40% of all deaths are caused by bad quality of water (Global Water Partnership, 2000). It has been proven that there is a strong relationship between people income level and literacy of mother to water quality and health issues. Relatively more literate mothers and high-income groups have the ability to prevent waterborne diseases in their family (Kausar et al., 2009). A broad range of physiochemical parameters of drinking water in Pakistan are not to meet the guidelines for drinking water established by WHO and Pakistan (*Malana et al., 2011; Farid et al., 2012*).

1.2 Socio-Economic Condition of Local Inhabitants

Since the area under consideration is a rural village and under developed as compared to urban portion of the district, most of the population is striving on agriculture related activities to earn their livelihood. Besides facing issues like lack of education and living below poverty line, local inhabitants are having health issues as well. The most serious health issue being faced by inhabitants of Sillanwali is their suffering from Hepatitis C and its cases being reported to hospitals is increasing day by day. It is opined that the main cause of this epidemic disease is consumption of contaminated water. People of Sillanwali are unaware of their water quality and unable to afford treatment of such diseases as it includes various medical tests and prolonged vaccinations. Moreover, state of the art medical facilities is also not available there.

Figure 1.2-1: Map of Sillanwali

1.3 Weather and Climate Conditions of District Sargodha

In Sargodha, the summers are sweltering, humid, and clear and the winters are short, cool, dry, and mostly clear. Over the course of the year, the temperature typically varies from 42°F to 105°F and is rarely below 37°F or above 113°F.

1.4 Justification for Selection of the Topic

The subject site is a rural area of Tehsil Sillanwali, District Sargodha. The district is located 206 km (128 miles) from Lahore, the capital of Punjab Province and 244 km (152 miles) from the capital Islamabad. The Tehsil's headquarter is situated in the town of Sillanwali. It is administratively subdivided into 16 Union Councils. Chak No. 62 SB is part of Union Council Chak No. 129. According to 1998 census, the population of district Sargodha was 2,665,979. Underground water of the tehsil has been polluted and is causing water borne diseases. Most of the people in this region are using this polluted water for drinking purpose.

Provision of safe drinking water can save people from Hepatitis and other diseases. The Drinking water contamination can be caused due to several reasons. We can categorize the drinking water quality related issues into following:

a. Likely Contaminants at the source of drinking water

i) Microorganisms and infectious diseases: virus, bacteria, parasites, etc.

ii) Natural contaminants: arsenic, barium, manganese, fluoride, radiation, etc.

iii) Anthropogenic chemicals: nitrate, pesticides, pharmaceutical and veterinary residues, personal care products, household products, antimicrobial resistance, organic compounds, etc.

iv) Algal blooms and Microcystis.

b. Contaminants due to treatment of drinking water: disinfection by-products, fluoride, by-products of flocculants or coagulants, etc.

c. Contaminants from drinking water distribution: metals (e.g., lead, copper), and other compounds released by pipes (e.g., vinyl chloride).

d. Bottled water quality

e. Mixtures of contaminants.

f. Other water parameters, e.g., hardness, minerals.

g. Interaction/balance between microorganisms and chemicals.

h. Health benefits associated with drinking water.

i. Climate change and drinking water quality.

1.5 Relevance to National Needs

In Pakistan, on drinking water quality status and contamination, which accounted sewerage water (fecal) mixing with drinking water as dominant and primary contaminant due to the poor sanitation and sewerage system. Second source of contamination is chemical pollution from toxic substances from the industrial effluents, textile dyes, pesticides, nitrogenous fertilizers, arsenic, and other chemicals. There is a need to maintain and upgrade regular inspection of already present treatment plants. Nowadays, Government of Pakistan is going to install drinking water filter all over Pakistan. The results drew attention that sewerage contamination with drinking water must be considered as an important environmental and health issue. Underground water of Sillanwali has been polluted and causing diseases.

Most of the people in village are using this polluted water for drinking purpose. Provision of safe drinking water can save people from Hepatitis and other water borne diseases. A community with better health can work better for financial improvement and high cost of disease can also be saved by this project.

1.6 Advantages

Successful outcome of the proposed research offers many advantages. Policy makers and stake holders involved in this project could benefit from the results. In order to protect the water, environment and Human health, it is important to assess the status of impacts associated with the Contamination of Water. Efforts could be made accordingly to prevent or mitigate the adverse impacts.

1.7 Areas of Application

The results from the proposed research could be used by Policy makers, environmentalists, Public health safety specialists, Social scientists and all other stakeholders and concerned citizens. Students and researchers in this field could use it as baseline study for other projects in Pakistan. This research could help understand the current situation of water, sanitation and health in the area. Future plans and recommendations could be made to combat the impacts.

1.8 Problem Statement

The most serious health issue being faced by inhabitants of Sillanwali is their suffering from Hepatitis and its cases being reported in hospitals is increasing day by day. It is opined that the main cause of this epidemic disease is consumption of contaminated water. People of Sillanwali are unaware of their water quality and unable to afford treatment of such diseases as it includes various medical tests and prolonged vaccinations. Moreover, water treatment facilities are also not available there.

1.9 Scope of Study

The overall scope of this study is to analyze the groundwater quality of Sillanwali and thereby identify, review, and critique treatment methods and technologies that we could implement to treat the ground water to an acceptable limit. The research area comprises of two parts;

i) Likely reasons for existing problem.

ii) Assessment of health damage due to contamination

iii) Short-term and immediate solution to protect people from drinking contaminated water.

iv) Long-term solution to avoid mixing of sewage into underground water and proper disposal.

1.10 Objectives of Study

- To analyse the reasons for contamination of water through structured questionnaire and interviews/ visits.
- To assess the health damage caused due to consumption of contaminated water.
- To suggest a viable solution for existing problem.

CHAPTER 2: LITERATURE REVIEW

2.1 Groundwater Status in Pakistan: A review of contamination, health risks and potential needs

The groundwater of Pakistan is highly contaminated and unsafe for drinking purposes because most of the contaminants exceed their standard limit based on the WHO and PEQS. Microbial Pathogens found in most of the samples according to studies; the same is true for organic contaminants in drinking water. All heavy metals need to be studied; however, Hg needs more attention because it has severe effects but is the least studied metal in the groundwater of Pakistan. The drinking water contamination with high concentrations of As, Cd, Cr, and Ni is alarming, while the Fe deficiency in some regions of Pakistan and excess in other areas are also critical. The concentrations of Na+, K+, F-, and NO3- exceed the safe limits in most of studies. Fluoride poses dual issues due to F- scarcity which is a risk to human health and F- supplement solutions are needed. However, its high concentration causes bone deformation and F- removal strategies are required. Human activities are the major sources of the poor groundwater quality such as the improper disposal of domestic and industrial waste.

In Pakistan, waterborne diseases are due to the presence of microbial or chemical contaminants in drinking water and the absence of proper treatment plants for safe drinking water. After a survey by the PCRWR and other individual studies, few data are available but regular surveys in various areas of the country are needed to obtain information about diseases spreading due to particular contamination in water. Under Agenda 2030, a few projects related to the water availability are in progress but have inefficient results. In addition to regulations and regulatory measures on the government level, more specific recommendations based on previous studies can help to improve and maintain the drinking water quality and provide future research opportunities.

2.2 Drinking Water Quality Standards

The basic purpose of making guidelines or standards is to provide safe drinking water to all the citizens. The World Health Organization (WHO) has given the guidelines for drinking water, which are based on scientific research and epidemiological results.

The values of various water quality parameters that are recommended by WHO are generic guidelines. That is why, different countries have set their own water quality standards to meet their national goals and priorities taking in to account their economic, technical, social, cultural, and political requirements.

The PCRWR and Pakistan Standard Institution (PSI) have already drafted drinking water quality standards for the country, however, the implementation of these standards is still a myth. This matter needs to be addressed on top priority. The WHO guidelines and standards are proposed for implementation by national agencies like PCRWR, Pakistan Standard Institution (PSI), International Bottled Water Association (IBWA), Food Development Authority (FDA), Environmental Protection Agency (EPA) and other countries

WHO defines consumption of safe drinking water having standards of Table 2.2-1 is essential for the healthy life, it does not have any health risks for the life time.

Table 2.2-1: Water quality parameters associated with their units and WHO and Pak-EPA Standards. Sources: (WHO, 2008; Pak-EPA, 2008)

Parameters	**WHO Guidelines**	**Pak Guidelines**
E. Coli/ Coliform bacteria	Not detectable in 100 ml water sample	Not detectable in 100 ml water sample
Color TCU	15	5
Odor	Unobjectionable	Unobjectionable
Turbidity NTU	5	5
T- Hardness mgL^{-1}	<500	-
pH	6.5-8.5	6.5-8.5
DO mgL^{-1}	-	-

TDS mgL^{-1}	<1000	<1000
T- Chloride mgL^{-1}	< 250	< 250
T- Nitrate mgL^{-1}	50	50
T- Phosphorus mgL^{-1}	-	-
T- Alkalinity mgL^{-1}	1000	1000
EC µs/cm	-	-
Temperature °C	25 °C	-

Table 2.2-1 also states the NEQ guidelines for Pakistan along with WHO guidelines.

As per a study conducted by *Safia et. al.* against the mentioned parameters, 84% water samples tested were contaminated and hence unsafe for drinking in 23 cities all over the country.

2.3 Assessment of Aesthetic and Physical Parameters

Sajjad and Rahim (1998) investigated chemical quality of groundwater of Rawalpindi/ Islamabad. Results of electrical conductivity analysis showed increasing trend as water moves from adjoining recharge areas of Margalla and Murree hills towards centre of the basin, which acts as discharge area for groundwater. The electrical conductivity increases from less than 400 µS/cm near the mountains to a maximum of 1200 µS/cm in the centre of the basin. *Malick et.al. (1998)* reported drinking water quality in the city of Karachi. During the study, forty samples were taken from supply lines of different locations of the city originating with waters from the Indus River and Hub sources. These samples were analyzed for physicochemical parameters such as pH, turbidity, hardness, EC, TDS, and residual chlorine. Results showed that the treated water from the treatment plants meets WHO guidelines. However, the samples taken from Kemari and Maripur area showed significant TDS increase from the original values of treated water, perhaps due to seepage of brackish water or saline water intrusion.

Standards of physical parameters mentioned above can be found in Table 2.2-1.

Kahlown and Tahir (2001) conducted a research study on quality analysis of bottled/mineral water in which a sample of 21 available bottled water brands was collected and analyzed. Aesthetic and physical quality of most brands was found to be acceptable, whereas many famous selling brands of mineral water were found to be bacteriologically contaminated.

2.4 Assessment of Chemical Parameters

Sun et al. (2001) surveyed drinking water quality of Islamabad in collaboration with National Institute of Health (NIH), Capital Development Authority (CDA) and Environmental Protection Authority (EPA). Out of 271 samples collected, 43.2% were found unsafe for drinking according to Pakistan Standard Institution (PSI) standards and 25.1% by physico-chemical parameters, 10.3% samples contained physico-chemical as well as bacteriological contaminants. Out of 196 CDA samples, 22.4% were unsafe by physico-chemical parameters while 3.6% by both physico-chemical and bacteriological contamination. *Tahir and Bhatti (1994)* carried out a survey of drinking water quality of rural areas of Rawalpindi District. All samples were found fit for physico-chemical parameters. However, in samples of Rawalpindi and Murree, the quantity of manganese was under the desirable level. Further, these samples were unsafe with respect to nitrates content.

Two samples were found unsafe with respect to chlorides and seven with respect to sodium. Six water quality parameters were found above the desirable level of World Health Organization (WHO) guidelines. *Sial and Mahmood (1999)* evaluated water pollution due to agricultural and industrial activities. They described some aspects of surface and sub-surface water pollution, best management practices and remedial measures required to minimize the environmental hazards. *Latif et al. (1999)* carried out extensive work on groundwater contamination from nitrate in the irrigated areas of Pakistan. Results showed that the nitrate concentration varied from 0.03 to 3.25 mg/L in the water samples collected from the tile-drainage area, which was below the maximum permissible limit of 10 mg/L of WHO. Whereas the nitrate concentration exceeded the permissible limit in about 15% water samples collected from outside the tile-drainage area. In general, it was concluded that there was no danger of shallow groundwater pollution by nitrate if the agriculture drainage system (Tile Drains) was functioning properly.

The groundwater pollution was observed in those areas where there is no drainage system. *Chandio (1999)* recommended proper system of monitoring and investigation on groundwater pollution and called executing public awareness and popularization programs for proper field management practices.

2.5 Assessment of Microbial Parameters

Tahir (1989) conducted a study on problems related to pollution in the water supply systems of Islamabad and Rawalpindi. It was found that 76% samples in Islamabad and 82% samples in Rawalpindi were contaminated due to bacterial presence. *Din et al. (1996)* reported the quality assessment of drinking water supplied to Islamabad. They found that the water quality of most of the CDA tube-well was satisfactory during the period of their study (September to December) except for seven tube-wells that showed high Coliform levels. Tahir et al. (1998) analyzed the drinking water quality in the rural areas of Rawalpindi. Most of the water samples were found unfit for drinking purpose due to the presence of coliform and E. coli. *Malick et al. (1998)* analyzed the drinking water quality in the city of Karachi. Results showed the presence of Coliform bacteria in the main distribution lines. It indicated that water got contaminated from the surrounding leaky sewerage pipelines. Secondly, the presence of fecal coliform in the water of branch lines feeding to consumers and stand posts, confirmed the mixing of sewage into drinking water lines making it unfit for drinking. *Hashmi and Shahab (1999)* reported that the groundwater and surface water used by rural and urban areas were heavily polluted by both sewage and industrial waste.

Another study conducted by *Odonkor et al., 2013*, “Escherichia coli as an indicator of bacteriological quality of water: an overview” states that E. coli appears to be the best indicator of bacteriological quality of water. The life span of E. coli in water is short, thus it best determines, recent contaminations. It is therefore important that there is continuous monitoring for E. coli to determine the bacteriological quality of water.

2.6 The Impact of Urban Sewers on Groundwater

Contamination of urban groundwater by sewage leakage from damaged sewers is an increasing matter of public and regulatory concern. It is estimated that in Germany several 100 million m waste water leaks every year from partly damaged sewerage systems into soil and groundwater. In many cities damaged sewerage systems are the main sources for groundwater contamination with sulphate, chloride and nitrogen compounds. Besides the ecological aspect, faulty sewerage systems exhibit essential economic problems because groundwater can also infiltrate into the sewers. (*Markus Eiswirth, 1999*).

2.7 Groundwater Quality and Public Health

Water-related disease remains one of the major health concerns in the world. Diarrheal diseases, which are largely derived from poor water and sanitation, accounted for 1.8 million deaths in 2002 and contributed around 62 million Disability Adjusted Life Years per annum (WHO, 2004). On a global scale, this places diarrheal disease as the sixth highest cause of mortality and third in the list of morbidity and it is estimated that 3.7 % of the global disease burden is caused by poor water, sanitation and hygiene (*Prüss-Üstün et al., 2004*). This health burden is primarily borne by the populations in developing countries and by children. In 2002 it was estimated that roughly 1.1 billion people lack access to any form of improved water supply within 1 kilometer of their home, and approximately 40 % of humanity (2.6 billion people) lack access to some form of improved excreta disposal (WHO and UNICEF, 2004).

2.8 Microbial contamination of drinking water in Pakistan

Water pollution caused by pathogens is one of the serious threats to human health, particularly in developing countries. In Pakistan, water at the source, in the distribution network, and at the consumer tap is heavily polluted with coliforms and fecal coliforms all over the country. A study conducted on more than 7,000 water samples reviewed in Pakistan revealed that an average of more than 71% and 58 % samples in the country were contaminated with total coliforms and fecal coliforms, respectively. Drinking water contamination contributes 20 to 40 % of all diseases in the country, which causes loss in the national income of Rs 25–58 billion annually. (*Nabeela et al., 2014*)

2.9 Presence of fecal coliform in distribution systems

A study was carried out in Gorakhpur city to test the presence of fecal coliforms (E. coli) in ground water samples using H_2S bottles. The study was carried out in 2013 (April) and around

60 samples were collected from India and shallow depth hand pumps located in different areas of Gorakhpur city. The samples were also obtained from the hand-pumps located near water logged areas. The testing of the samples revealed the contamination of ground water by fecal coliforms in shallow depth as well as India Mark-II hand-pumps. It was found that most of the samples taken from hand-pumps located near water logged areas have shown the presence of fecal coliforms (E. coli). Strict quality assurance in the installation and operation of India Mark-II hand-pumps as well as water quality surveillance by local body and government agencies with the involvement of community participation was recommended. (*Gupta et al., 2004*).

2.10 Vulnerability and impact of extreme climatic event

Aslam et al., 2017 conducted a Vulnerability and impact assessment of extreme climatic event in the Southern Punjab. They reported that increased frequency of droughts will pose a loss of USD 9 billion, droughts without adaptation will be at the cost of USD 8.5 billion and droughts with adaptation will be helpful in reducing cumulative loss up to USD 4.3 billion.

CHAPTER 3: MATERIALS AND METHODS

3.1 General

Access to safe drinking water and sanitation is a universal needs and a basic human rights. However, many of the world's population lack access to adequate and safe drinking water. Moreover, water quality and the risk to waterborne diseases are critical public health concerns in many developing countries. Today, around a billion people mostly living in the developing countries do not have access to safe and adequate water. In 2012, 1.9 billion people used either an unimproved source or an improved source with fecal contamination. Several studies have confirmed that water related diseases not only remain a leading cause of morbidity and mortality worldwide but that the spectrum of these diseases is expanding and the incidence of many water-related microbial diseases is increasing. Annually an estimated 4 billion cases of diarrhea, which represented 5.7% of the global disease burden in the year 2000 occurred.

Ensuring the safety of drinking water is a continuous process. In developing countries, drinking water regulations require the monitoring of multiple microbiological and chemical parameters. However, it is a well-established fact that the risks associated with the consumption of microbiologically contaminated water are a great concern for the occurrence of different disease like diarrhea. Hepatitis, cholera and other waterborne diseases are quite prominent. Current study indicates that the majority of the drinking water sources had coliform count beyond the WHO standard. Specifically, in Sillanwali, the majority of the drinking water sources are either of unacceptable quality or grossly polluted. The quality control mechanism is vital to ensure the safety of drinking water.

The objective of this study is therefore to determine the level of contamination of drinking water and its associated factors in district Sargodha in general and Sillanwali in particular.

3.2 Study Area

Sargodha is located 172 kilometers northwest of Lahore. It lies about 30 miles from the M-2 motorway, which connects Lahore and Islamabad. It is connected to the M-2 by several interchanges at different locations. Sargodha is roughly 94 km from Faisalabad, due southeast. Directly east connected by the M-2 motorway are Lahore and the route to Rawalpindi and Islamabad. Due east is the city of Jhang and towards the west is the city of Mianwali and the Chashma Barrage. Dera Ismail Khan is located 232 km southwest from the city. Sargodha mainly comprises of flat, fertile plains, although here are a few small hills on the Sargodha-Faisalabad Road. The River Jhelum flows on the western and northern sides, and the River Chenab lies on the eastern side of the city.

Sargodha District is administratively divided into following Seven Tehsils.

1. Bhalwal
2. Sahiwal
3. Sargodha
4. Bhera
5. Kot momin
6. Shahpur
7. Sillanwali

Sillanwali Tehsil is a subdivision of Sargodha District . The tehsil's headquarters is situated in the town of Sillanwali which is administratively subdivided into 16 Union Councils. According to 1998 census the population was 255,000 being mainly Muslim and Punjabi speaking.

The tehsil of Sillanwali is administratively subdivided into 16 Union Councils, which are;

- Chak No. 135/SB
- Chak NO. 163/NB
- Chak NO. 111/NB
- Chak NO. 147/148/NB
- Chak NO. 152/NB
- Chak NO. 48/SB

- Chak NO. 118/NB
- Chak NO. 126/SB
- Chak NO. 129/NB
- Chak NO. 131/NB
- Chak NO. 138/SB
- Chak NO. 49/SB
- Shah Nikdar
- Shaheenabad
- Sillanwali
- Sobhaga

Chak No. 62 SB is a rural area of Tehsil Sillanwali, District Sargodha. The district is located 206 km (128 miles) from Lahore, the capital of Punjab Province and 244 km (152 miles) from the capital Islamabad.

Figure 3.2-1: Satellite Image of the study area

3.3 Monitoring Approach

To understand the underground water quality situation in the study area, a general survey was conducted. Additionally hospital data for the past 5 years was collected. This was to identify the sources of contaminated water which were to be analyzed. 10 sampling locations were selected on this basis. Sampling Frequency was set to be 3 times divided in a 6 months period.

3.3.1 Assessment of Contaminated Water Impacts through Structured Questionnaire and Interviews

As the health of the local inhabitants was found to be poor, the survey was conducted based on a questionnaire which covered information like age group, occupation, common diseases along with their sources, treatment facilities, role of regulatory authorities and relevant information. The sample size was kept as n=450. In addition to this, the regulatory authorities and district hospital management was also inquired to better understand the public health scenario in the study area. Hospital record included information like number of patients getting affected from water borne diseases and details about their treatment.

3.3.2 Sampling and Analysis Plan

This research have four major parts as discussed below:

I. Sampling

II. In-situ testing

III. Lab testing from IESE, NUST

IV. Analysis from Government agencies (PCRWR and PINSTECH)

3.3.3 Sample Collection, Transport and Storage

Grab samples were collected from all 10 locations (2 Samples each from all locations) which were boreholes in autoclaved glass bottles for physicochemical and microbiological analysis. Samples were preserved in a cool box and transported to IESE for analysis and treatment within six hours of collection. All the sampling and preservation methods were carried out for the quality analysis in water samples were according to Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Sampling and analysis was done after every two months as the study span was 06 months. (Nov 2018 to May 2019).

3.4 Water Quality Analysis

To get an insight into the permissible limits of water quality parameters, WHO guidelines and drinking water standards of Pakistan set by EPA are illustrated below;

Table 3.4-1: Standards and guidelines for water quality in Pakistan

Parameter	**WHO Guidelines**	**Pak NEQ's**
E. Coli/ Coliform bacteria	Not detectable in 100 ml sample	Not detectable in 100 ml sample
Color TCU	15	5
Odor	Unobjectionable	Unobjectionable
Turbidity NTU	5	5
T- Hardness mg/L	<500	-
pH	6.5-8.5	6.5-8.5
TDS mg/L	<1000	<1000
T-Chlorides	<250	<250

The water quality analysis was sub-dived into following phases;

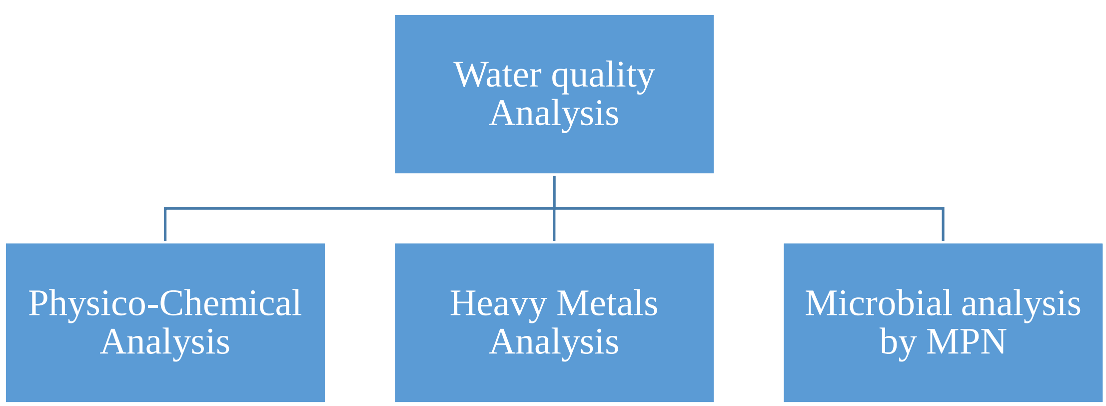

Figure 3.4-1: Types of water quality analysis

3.4.1 Physico-Chemical Analysis

Most of the parameters were analyzed in wastewater laboratory at IESE, NUST. However, a few were done onsite.

3.4.1.1 Onsite Analysis

3.4.1.1.1 Color and odor

All the samples were closely seen with naked eye and sniffed and it was observed that all the samples were colorless and odorless.

3.4.1.1.2 Temperature

It was measured onsite by using a mercury filled thermometer and the readings were recorded.

3.4.1.2 Laboratory Analysis

3.4.1.2.1 pH

The pH of all water samples was measured using pH meter (Hach) which was calibrated using a buffer with a known value of pH. Sample water's pH was evaluated by dipping the pH glass electrode. The samples were properly stirred to achieve equilibrium with electrode.

3.4.1.2.2 Electrical Conductivity

It was measured with EC meter (Hach) having conductivity probe.

3.4.1.2.3 Turbidity

It was performed using Nephelometric method by turbidimeter (Hach) 2100 N model turbidimeter. Its working principle is based on a comparison of the intensity of light scattered under the defined conditions with standard reference suspension under the same conditions.

3.4.1.2.4 Total Dissolved Solids

TDS of the water samples were measured by gravimetric method. China dish was pre-weighed and 50 ml water sample was filtered and poured in a china dish. Water sample was evaporated then china dish was dried in oven at 180 °C and weighed after drying.

The formula used is as under;

TDS (mg/L) = (A-B) ×1000 / sample volume

Where A = weight of dried residue + dish (mg) and B = weight of dish (mg)

3.4.1.2.5 Total Hardness

It was measured as magnesium ions consumed in complex formation by using EDTA-titrimetric method. The indicator used for analysis was Eriochrome Black T in 50 ml of buffered sample. 50ml water sample with 1ml buffer solution was taken in a beaker and few drops of EBT were poured, then it was titrated against the EDTA titrant. End point was purple to blue color.

Total Hardness mg/L= A× B ×1000 / sample volume (ml), where A = titrant, B = 1

3.4.1.2.6 Total Chlorides

It was analyzed by argentometric method. 100ml water sample was taken in a flask and 1ml indicator was added and titrated against 0.05 N $AgNO_3$ titrant. The end point was Pink color.

Total Chlorides mg/L= (A - B) ×N×35450 / ml sample

Where, A = ml titrant used for sample, B = ml titrant used for blank, N = normality of $AgNO_3$

3.4.1.2.7 Biochemical Oxygen Demand

It is the amount of oxygen used by microorganisms (e.g., aerobic bacteria) in the oxidation of the organic matter. Reagents and dilution media was prepared in lab following the experimental procedure elucidated in manual book. Glass bottles having 300 mL capacity having ground-glass stopper and a flared mouth were used for experiment. Three groups were prepared having three bottles each filled half with dilution media so that no air gets mixed with the media for DO test. 2 ml sample was added in each of the three bottles marked as first group, 5 ml in each bottle of 2nd group and 10 ml in each bottle of the 3rd group. All the bottles were completely filled with dilution media and stopper was placed to prevent entrapping of air bubbles. One bottle from each set was taken to estimate its DO and named as initial DO. Two more bottles with blank dilution media were prepared and DO from one bottle was found for comparison. Remaining six bottles with water samples and one bottle for blank was placed in the incubator at 20^0C. After 5 days, DO was calculated in all bottles.

The formula used is;

DO, mg/ L = (Mean volume of the titrant used *N * Equal weight of Oxygen *1000) / (Volume of the sample used *F)

Where,

F= (Volume of the BOD bottle – Volume of the chemical added) / (Volume of the BOD bottle)

BOD5= (DO depleted) / (mL of sample added)

DO depleted, mgL /L = (DO at zero day) - (DO after 5 days)

3.4.1.2.8 Chemical Oxygen Demand

It is the amount of oxygen required for chemical oxidation of organic matter using a strong chemical oxidant, such as, potassium dichromate. This test is widely used to determine the degree of pollution in water bodies. Closed Reflux Titrimetric Method is commonly used in laboratory to determine COD of samples in which VOC's are completely oxidized in a closed system. The reagents prepared were Standard Potassium Dichromate ($K_2Cr_2O_7$), Digestion Solution, 0.1 N (Eq. Wt. 49.03g) and Standard Ferrous Ammonium Sulfate Titrant (FAS). Culture tubes were properly washed with distilled water before using to prevent contamination. 2.5ml of sample, 1.5 ml $K_2Cr_2O_7$ digestion solution and 3.5 ml sulphuric acid reagent were added and the tubes were tightly capped. Tubes were placed in block digester preheated to 150°C and reflux for 2 h. These were then allowed to cool to room temperature and vessels were placed in test tube rack. 2 drops of Ferroin indicator were added and stirred rapidly and then titrated against standardized FAS. The end point was a sharp color change from blue-green to reddish brown. To avoid any errors, 5 mL FAS was taken and diluted by adding 15 mL distilled water and then culture tubes were titrated against this diluted FAS.

The formula used is;

COD (mg/ L) = [(A-B) × N ×8000) / (V sample)

Where,

A=volume of FAS used for blank (mL)

B=volume of FAS used for sample (mL)

N=Normality of FAS

8000 = milli equivalent weight of oxygen (8) ×1000 mL/L

3.4.2 Heavy Metals Analysis

The water samples collected during 1st sampling were sent to PINSTECH (Pakistan Institute of Nuclear Science & Technology), Islamabad for elemental analysis. The parameters tested included the following;

I. Arsenic (As)
II. Cadmium (Cd)
III. Chromium (Cr)
IV. Copper (Cu)
V. Iron (Fe)
VI. Mercury (Hg)
VII. Iodine (I)
VIII. Manganese (Mn)
IX. Nickel (Ni)
X. Lead (Pb)

The technique used for this analysis was ICP-OES (Inductively coupled plasma) and all the metals were found below limit of detection. Hence, the heavy metal analysis was discontinued for 2nd and 3rd sampling and only physico-chemical and microbial analysis were performed.

3.4.3 Microbial Analysis

The “Most probable number” MPN test was performed for all samples as discussed in the sampling plan. It is a method used to estimate the concentration of viable microorganisms in a sample by means of replicate liquid broth growth in ten-fold dilutions. It is mostly commonly applied for quality testing of water and to determine whether water is safe for consumption or not.

For preparation of media, the double strength medium in 10 tubes (10 ml in each tube) and single strength medium in 5 tubes (10 ml in each tube) was dispensed and a durham tube was added in inverted position in such position that the inner vial is full of liquid with no air bubbles. The same were sterilized by autoclaving at 15 lbs pressure (121°C) for 15 minutes.

The test procedure is as follows;

- 5 tubes of double strength and 10 tubes of single strength were taken for each water sample to be tested.
- 10 ml of water to 5 tubes containing 10 ml double strength medium was added with a sterile pipette.
- 1 ml of water to 5 tubes containing 10 ml double strength medium and 0.1 ml water to remaining 5 tubes containing 10 ml double strength medium was added.
- All the tubes were incubated at 37°C for 24 hrs. For those which did not appear positive, were re-incubated up to 48 hrs.
- The number of tubes giving positive reaction were compared to a standard chart to record the number of bacteria present in it.
- For example: a water sample tested shows a result of 3–2–1 (3 × 10 ml positive, 2 × 1 ml positive, 1 × 0.1 ml positive) gives an MPN value of 17, i.e. the water sample contains an estimated 17 coliforms per 100 ml.
- The chart used to calculate MPN/ 100 mL in consonance with the positive tubes is as follows,

Table 3.4-2: Five-tube MPN (95 percent confidence of limits) undiluted sample, 10 mL per tube

Positive Tubes	**MPN/ 100 mL**
0	<2.2
1	2.2

2	5.1
3	9.2
4	16.0
5	>16.0

By following above Table 3.4-2, MPN was calculated for all samples and in order to validate the results, 5 No samples were sent to PCRWR for microbial testing following APHA standards and membrane filtration method, out of which 02 No were detected with total coliforms.

3.5 Methods

3.5.1 Study Design and Area

A community-based study was designed in Tehsil Sillanwali, Sargodha. According to the data obtained from Health Department, the total population was found out to be 255,000. The majority of the population reside in rural areas. Different Chaks/ Union Councils have already been mentioned above. According to the report of the Health Department, most of the medical cases being reported belonged to water borne diseases. The study population was randomly selected from different Chaks/ Union councils of Sillanwali.

3.5.2 Sample Size and Sampling Technique

Statistical software Epi info version 7.1 was used to calculate the sample size based on an assumption that 60% of households had fecal contaminated drinking water sources with marginal error of 5%, 95% confidence interval, design effect of 2, accounted for two-stage sampling and non-response rate of 10%. Accordingly, the total sample size included in the study was 450 households.

3.5.3 Data Collection Procedures and Tools

Water samples for bacteriological analysis were collected from the household’s drinking water sources. The method of water sample collection from each household water sources was done according to the World Health Organization (WHO) guidelines for drinking water quality assessment. Water quality testing was done in terms of physic-chemical, elemental and microbial analysis. All samples were analyzed for fecal coliform count within 4 hours of sample collection using the MPN technique (Most probable number), which indicates presence of microbes. Fecal coliforms (FC) enumeration was carried out using membrane filtration techniques in which 100ml of water sample was filtered through the membrane filter (Millipore 45µm). Membrane lauryl sulfate medium that was dispensed on to the absorbent pad was used for bacterial growth medium. Then, the membrane filter with Millipore 45µm through which water sample filtered was placed on membrane lauryl sulfate medium in aluminum petri dish and was incubated at 44±0.5°C for 18-24 hours. The yellow colonies were counted as coliforms under microscope. This analysis was carried out at PCRWR.

A survey was conducted from local inhabitants in form of a structured questionnaires in order to collect socio- economic and behavioral characteristics. Observations related to sanitary survey was an integral part of the questionnaire being conducted to assess the risk of contamination of the drinking water sources.

3.5.4 Data Quality Control

Water samples from each household water source were collected in sterilized glass bottles. All water samples were collected by according to APHA 2005 standards for examination of water and wastewater. All sampling bottles were appropriately labeled before the collection of samples. The collected water samples were kept in icebox during transportation at 4 ^{o}c before analysis in the laboratory. Before analysis, sterilization of required laboratorial equipment was carried out. Moreover, to ensure the validity of the analysis, blank samples were analyzed following the same procedure and two samples were collected from each source, average of both was considered to get a precise value.

3.5.5 Ethical Considerations

After thoroughly discussing the ultimate purpose and method of the study, an Ethical clearance was obtained from National University of Science and Technology Islamabad.

Then, community consent was obtained from the respective Municipal members. The privacy and confidentiality were maintained during interview. The participants in the study that were not willing to take part in the study had full right not to participate.

3.5.6 Data Processing and Analysis

Data was entered using Epi-Info version 7.1 and analyzed using SPSS statistical package for windows, version 20.0. A, P-value of less than 5% was used to declare association between factors and the dependent variable.

3.6 Demographic Characteristics of the Study Area

3.6.1 Types of Accommodation

Almost in all the villages of the Study Area, majority of the houses had ordinary construction, with moderate standard buildings made of cement and bricks. Housing characteristics is one of the major indicators for the assessment of the living standards of the population. Approximately 58% houses are Pacca and 35.5% are Semi-Pacca while rest are the Katcha house made of mud bricks or mud. Types of housing structures in the area are given below;

Table 3.6-1: State of Accommodation (Sample number n=450)

Sr. No.	Types	Number	Percentage (%)
1	Pacca	262	58.22
2	Semi Pacca	160	35.55
3	Katcha	28	6.22
	Total	450	100

Source: Field work

Majority of the respondents have 1-2 rooms in their houses, whereas few of them are having 3 or more rooms. Types of the toilets used by the household indicates the living conditions and are significantly related to the health and hygiene of the household members. Around 70% people have latrine while only 30% were using open types. The sanitation facilities were found is very poor in the Study Area due to lack of proper sewerage system and solid waste management.

3.6.2 Sources of Drinking Water

Groundwater is being used for drinking purpose pumped through electric motors and hand pumps as shown in below Table 3.6-2. Groundwater is available at 100 to 150 ft depth. There is no proper water supply scheme in the Study Area. As per survey reports of Sillanwali at most places the quality of drinking water is poor as it exceeds the allowable limits of water quality standards.

Table 3.6-2: Sources of Drinking Water (Sample number n=450)

Sr. No.	Sources	Number	Percentage (%)
1	Hand Pump	203	45.11
2	Electric Motor	198	44
3	Both	49	10.88
	Total	450	100.0

Source: Field work

3.6.3 Income Sources and Expenditure

The income is an indicator for assessing the livelihood/well-being of the household. The highest percentage income group 31.11% has monthly income of Rs. 8,000-11,000, followed by group having an income of Rs. 5,001-8,000, only 5.34% people earn more than Rs. 20,000 per month, as illustrated in table below;

Table 3.6-3: Monthly Income (Sample number n=450)

Sr. No.	Income (Rs.)	Number	Percentage (%)
1	Up to 5,000	66	14.67

2	5,000-8,000	84	18.66
3	8,000-11,000	140	31.11
4	11,000-14,000	75	16.67
5	14,000-20,000	61	13.56
6	20,001 plus	24	5.34
	Total	450	100.0

Source; Field work

3.6.4 Population Characteristics

Based on the social survey, the maximum population of the Study Area falls under the age groups as shown in below table. The household size of the Study Area is about 7 persons. Based on the socio-economic survey of the selected households the population is presented in table below;

Table 3.6-4: Population Characteristics

Sr. No.	Age Group	Population	
		Number	Percentage (%)
1	0-4	50	11.11
2	5-9	44	9.78
3	10-19	111	24.67
4	20-39	128	28.45
5	40-49	61	13.56

6	50-59	36	8
7	60 and above	20	4.5
	Total	450	100.0

Source; Field work

3.6.5 Literacy

Educational distribution of the respondents in the Study Area is shown in table below which indicates that majority 44.8% are illiterate while 16.7% have primary education. The percentage of intermediates, graduates and post graduates is very low as compared to those who have done middle and matric.

Table 3.6-5: Respondents Qualification

Sr. #	Education Status of the Respondent	Percentage (%)
1	Illiterate	44.8
2	Primary	16.7
3	Middle	13.5
4	Secondary	6.3
5	Higher Secondary	8.3
6	Graduate	7.3
7	Post Graduate	3.1
	Total	100.0

Source; Field work

CHAPTER 4: **RESULTS AND DISCUSSION**

4.1 Introduction

The study gave an insight into the physico-chemical properties and presence of various pathogenic microorganisms in drinking water. According to experimental findings, it has been observed that the drinking water quality in Pakistan in general and Sillanwali in particular, is on the road to deterioration day by day. In Sillanwali about 20% of the whole population has access to safe drinking water. The remaining 80% of population is left with no other way but to use unsafe drinking water due to the scarcity of healthy drinking water sources. The primary source of contamination is sewerage (fecal) which is extensively discharged into drinking water system supplies. Secondary source of pollution is the disposal of toxic chemicals from pesticides and fertilizers from agriculture sources into the water bodies. Anthropogenic activities cause waterborne diseases that constitute about 80% of all diseases. This review highlights the drinking water quality, contamination sources, sanitation situation, and effects of unsafe drinking water on humans. There is immediate need to take protective measures and treatment technologies to overcome unhygienic condition of drinking water supplies in different areas of Sillanwali.

4.2 Socio-demographic characteristics of respondents

From a total of 450 respondents of households who participated, nearly half, 239 (53.12%) respondents were aged between 10-39 years. The 202 (44.8%), of the participants were unable to read. Most of the respondents, 195(44.4%) were married. The majority, 275 (60%) of the respondents had family size of more than five individuals and 425 (94.5%) of the respondents had income less of than Rs-20,000.

Table 4.2-1: Distribution of socio-demographic characteristics of respondents in Sillanwali (n=450)

Variables	Status	Percentage (%)
Sources of potable water	Piped	53.8
	Open well	9.3
	Protected well	20
	Open spring	9.8
	Protected spring	5.8
	River	1.3
Water shortage experience	Yes	62.6
	No	37.4
Solid waste disposal	Pits	22.8
	Open field	75.6
	Burning	1.6
Hand washing facility	Yes	51.6
	No	48.4
Animals/ Cattles in house	Yes	23.6
	No	76.4

Source; Field work

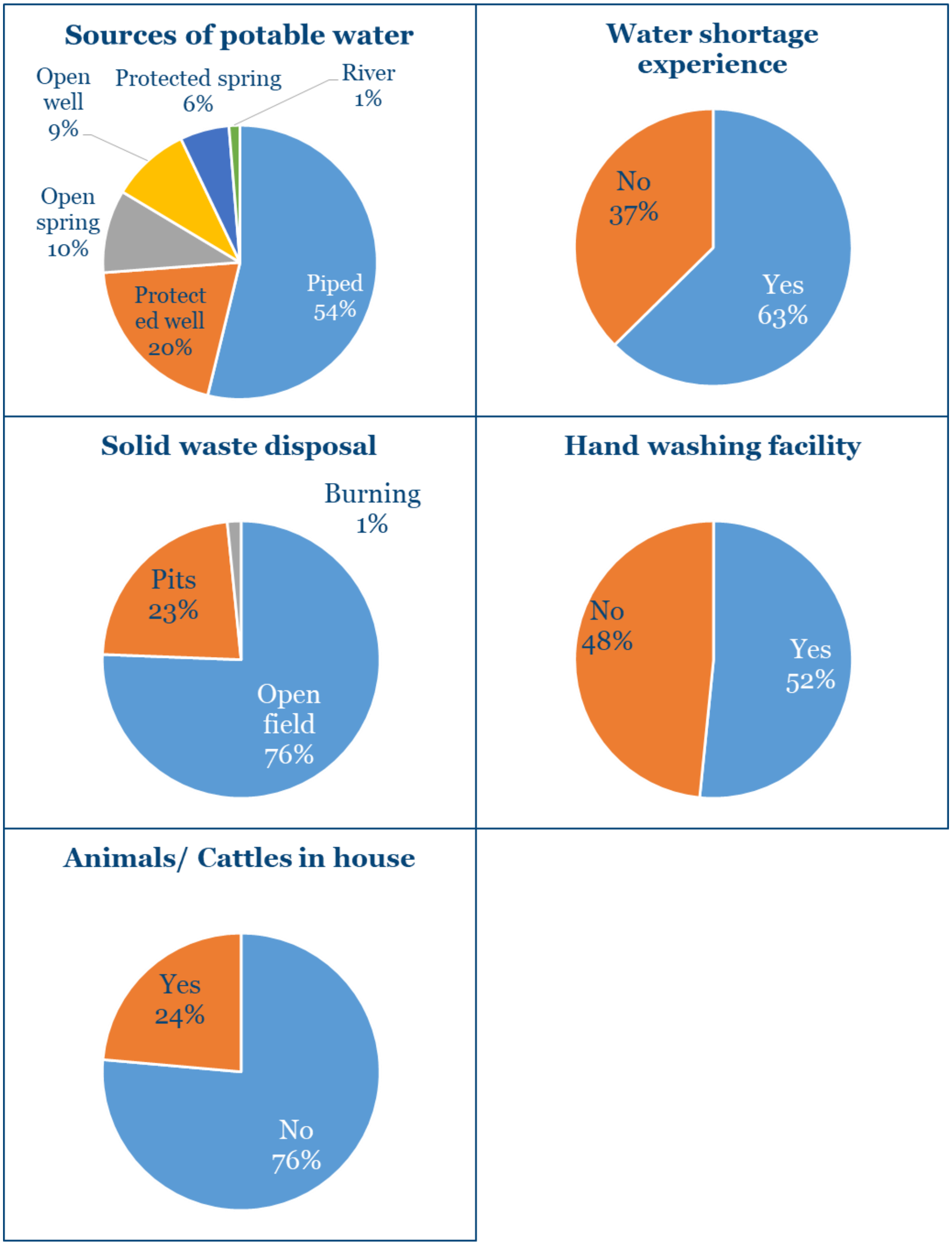

Figure 4.2-1: Distribution of socio-demographic characteristics of respondents in Sillanwali (n=450)

The majority, 242 (53.8%), of the respondents used pipe water as source of potable water, and only 232 (51.6%) of the respondents had hand washing facility. The majority, 338(75.5%) of the respondents used open field as way of disposing solid waste, and 106 (23.6%) of the participants lived with animals in the household (

Table 4.2-1).

4.3 Behavioral characteristics of respondents:

Distribution of behavioral characteristics of local inhabitants is shown in table below.

Table 4.3-1: Distribution of behavioral characteristics of respondents in Sillanwali (n=450)

Variables	Status	Percentage (%)
Type of household water treatment	Boiling	1.8
	Filtering	2.6
	Use of chemicals	1.4
	Allowing particles to settle	5.6
	No treatment	88.6
Hand washing history in last 24 Hours	Yes	100
	No	0
Time of hand washing	Before cooking	32.6
	After Eating	10.4
	After visiting washroom	24.4
	At all conditions	32.6
Materials to wash hands	With Soap	57.7
	Without Soap	42.3
Risk contamination at household storage	Low	18
	Medium	22.7
	High	56.9
	Very High	12.4
Risk contamination at source	Low	13.6
	Medium	4.9
	High	62.7
	Very High	18.8

Source; Field work

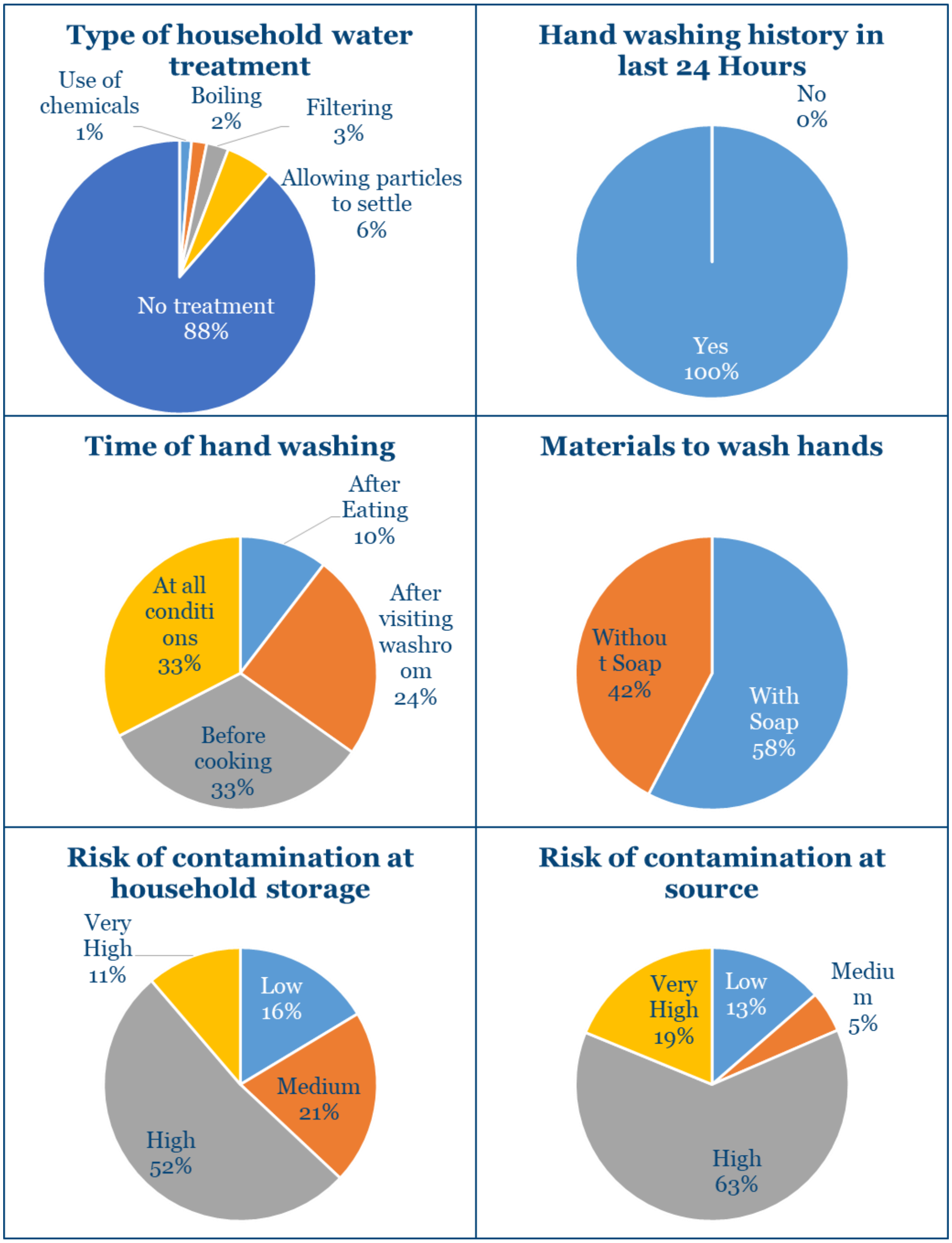

Figure 4.3-1: Distribution of behavioral characteristics of respondents in Sillanwali (n=450)

The majorly of the respondents, 399 (88.6%) do not use any type of household water treatment techniques. All respondents washed their hands in the previous 24 hours, and less than 1% of respondents washed their hands after visiting toilet. More than half, 260 (57.7%) of the participants washed their hand with soap and water, and 282 (62.7%) of water sources had high risks of contaminations.

4.4 Level of Fecal Contamination of Drinking Water Sources

The prevalence of positive fecal coliform from the water sample taken from drinking water source in Sillanwali was found to be 56.5% (n=254) with [95% CI (53- 60)]. After the bacteriological analysis, the fecal coliform load was quantitatively and qualitatively categorized to determine the risk level based on WHO classification. Factors associated with presence of fecal coliform in drinking water sources: In the invariable binary logistic regression analysis, educational status, religion, income status, place of solid waste pit, risk of contamination at the water source, presence of latrine facility, water shortage experience had a p-value less than 0.2 and further analyzed by multivariable binary logistic regression. Finally, Educational status, sanitary risk of contamination at the water source and water shortage experience had significant associations with the presence of fecal coliform in drinking water sources. Findings of study are elucidated below;

Table 4.4-1: Level of fecal contamination of drinking water sources

Risk cfu/100ml	Percentage (%)
No risk (0)	4.7
Low (1-10)	10.9
Intermediate (11-100)	15.6
High (101-1000)	56.5
Very high (1000+)	12.3

Source: Field work

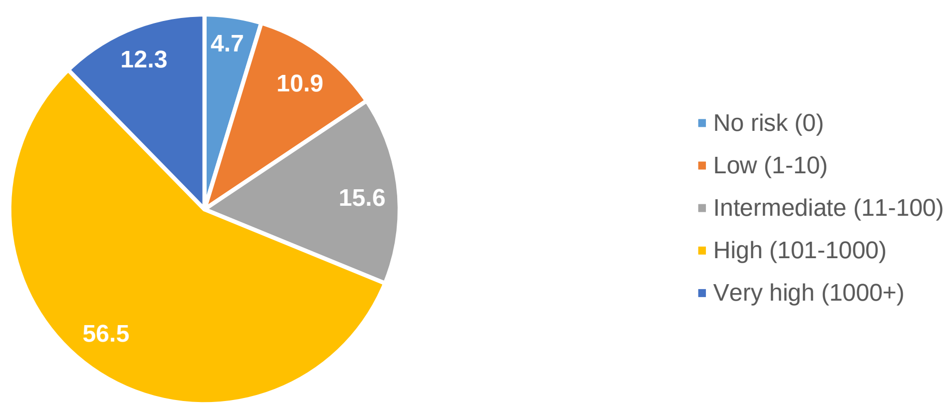

Figure 4.4-1: Level of fecal contamination of drinking water sources

Respondents whose educational status was above grade 12th had lower chance of fecal coliform contamination in drinking water sources than illiterate respondents. Water sources which had high risk of contamination in sanitary survey had higher odds of fecal coliform contamination in drinking water sources than water source which had low risk of contamination in sanitary survey. Moreover, water source which had medium risk of contamination in sanitary survey had higher odds of fecal coliform contamination in drinking water sources than low risk of contamination in sanitary survey. Detailed information is illustrated below;

Table 4.4-2: Multivariable analysis of factors affecting the presence of fecal coliform in drinking water sources (n=450)

Variables	**Status**	**Presence of coliform at source**	
		Yes	**No**
Educational	Illiterate	69.2%	37.1%
	Read and write	29.7%	70.3%
	1-12th grade	15.3%	84.7%
	Above 12th grade	4.0%	96.0%
Income	Up to Rs. 8,000	63.5%	36.5%
	Rs. 8,000- Rs. 20,000	52.1%	47.9%
	Above Rs. 20,000	27.6%	72.4%
Risk of contamination at the water source	Low risk	9.2%	90.8%
	Medium risk	88.5%	11.5%
	High risk	93.6%	6.4%
Presence of Washroom facility	Yes	62.9%	37.1%
	No	44.5%	55.5%
Water shortage experience	Yes	64.6%	35.4%
	No	42.9%	57.1%

Source: Field work

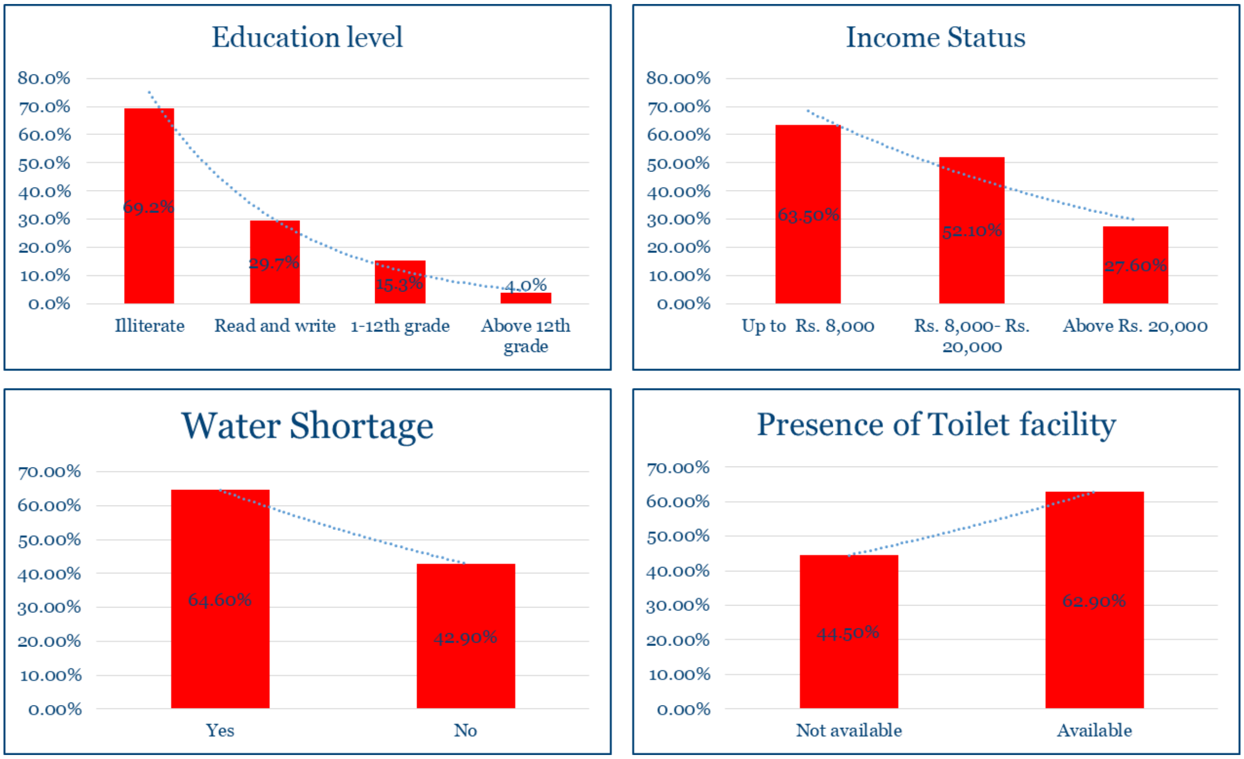

Figure 4.4-2: Multivariable analysis of factors affecting the presence of fecal coliform in drinking water sources (n=450)

4.5 Water Quality Status

The physico-chemical and microbiological properties of drinking water have great importance because a minor fluctuation in these parameters affects the human health. The pH is also a crucial factor that greatly affects water quality and pollution in water bodies. To evaluate the drinking water quality of Sillanwali, drinking water samples were collected from different places. Analysis showed that 20 samples out of 30 were contaminated with fecal microbes and not fit for drinking purposes. Microbial contamination is the most common and widespread risk associated with drinking water. The water supply lines were highly contaminated and even samples collected from different water sources throughout Sillanwali and surrounding Chaks were found that more than half of the samples were contaminated.

Geographic Information System and Water Quality Index study of bore wells and open wells of Sillanwali revealed that more than half of samples were poor in quality for drinking due to over exploitation of groundwater resource, agricultural impact, and direct release of contaminants. Drinking water contamination with E. coli and fecal coliforms is a clear indication of human and animal waste intervention. In Sillanwali, water distribution channels were also found highly affected with bacterial contamination.

4.6 Sources of Contamination

4.6.1 Microbiological Contaminants

In Pakistan, microbial pollution has been discovered as one of the most serious problems in rural as well as urban areas. This is due to the leakage of pipes, pollution from sewage lines intrusion into drinking water supplies been found in Sillanwali water samples.

4.6.2 Chemical Contaminants.

Chemical contaminants come from industries, soil sediments, and runoff from agriculture i-e pesticides and fertilizers, and enters into water resources. The chemicals commonly include insecticides, leach into ground water resources by mixing with irrigated and rain water. Another issue of significant importance is high concentration of salts, which is mainly due to irrigation, soil salts dissolution and chemical industries. Effluent from domestics waste contains high concentration of coliform and arsenic that is becoming a severe problem.

4.6.3 Complete Picture of Drinking Water Quality of Sillanwali

4.6.3.1 Temperature (C)

It was recorded that the temperature ranged from 16.24 C to 18.5 C. Temperature is important because it helps in accelerating microbial growth. In this case as the water is being pumped from a depth of 100 to 150 feet, no significant variation was observed depending on winter and summer season.

Table 4.6-1: Sample Temperatures

Sr. No	Location	Depth of borehole (Ft)	Sample 1 16^{th} of Nov, 2018	Sample 2 $18^{th}$of Feb, 2018	Sample 3 16^{th} of May, 2019
1	Chak 129	120	17.36	16.85	17.88

2	Filter plant	100	18.50	17.45	17.82
3	Chak 95	125	16.40	16.48	17.20
4	Chak 27	125	18.40	17.84	17.46
5	Chak 79	130	17.24	16.48	16.88
6	Chak 108 Home	125	16.45	16.24	16.72
7	Petrol Pump	150	16.25	17.47	16.32
8	Chak 27 (Canal)	-	18	17.44	17.24
9	Chak 116	100	17.50	17.24	17.21
10	Chak 118	130	17.20	16.88	16.84

Source: Field work and lab experiments

4.6.3.2 Most Probable Number (MPN)

Samples obtained from locations "Chak 95" and "Chak 118" have been found more contaminated with fecal coliforms throughout the study period. However, results analyzed from other locations have marginal contamination. But, presence of fecal coliforms in groundwater indicates possibility of sewerage mixing in groundwater due to damaged/ leaked pipes.

Table 4.6-2: MPN Results

Sr. No	Location	Depth of borehole (Ft)	Sample 1 16 Nov 2018	Sample 2 18 Feb 2018	Sample 3 16 May 2019
1	Chak 129	120	<2.2	<2.2	5.1
2	Filter plant	100	5.1	<2.2	<2.2

3	Chak 95	125	>16.0	>16.0	9.2
4	Chak 27	125	<2.2	<2.2	<2.2
5	Chak 79	130	>16.0	<2.2	<2.2
6	Chak 108 Home	125	16	5.1	5.1
7	Petrol Pump	150	<2.2	5.1	>16
8	Chak 27 (Canal)	-	>16.0	9.2	5.1
9	Chak 116	100	5.1	5.1	<2.2
10	Chak 118	130	>16.0	9.2	>16

Source: Field work and lab experiments

WHO Guidelines/ Pak NEQ's: Not detectable in 100 mL water sample

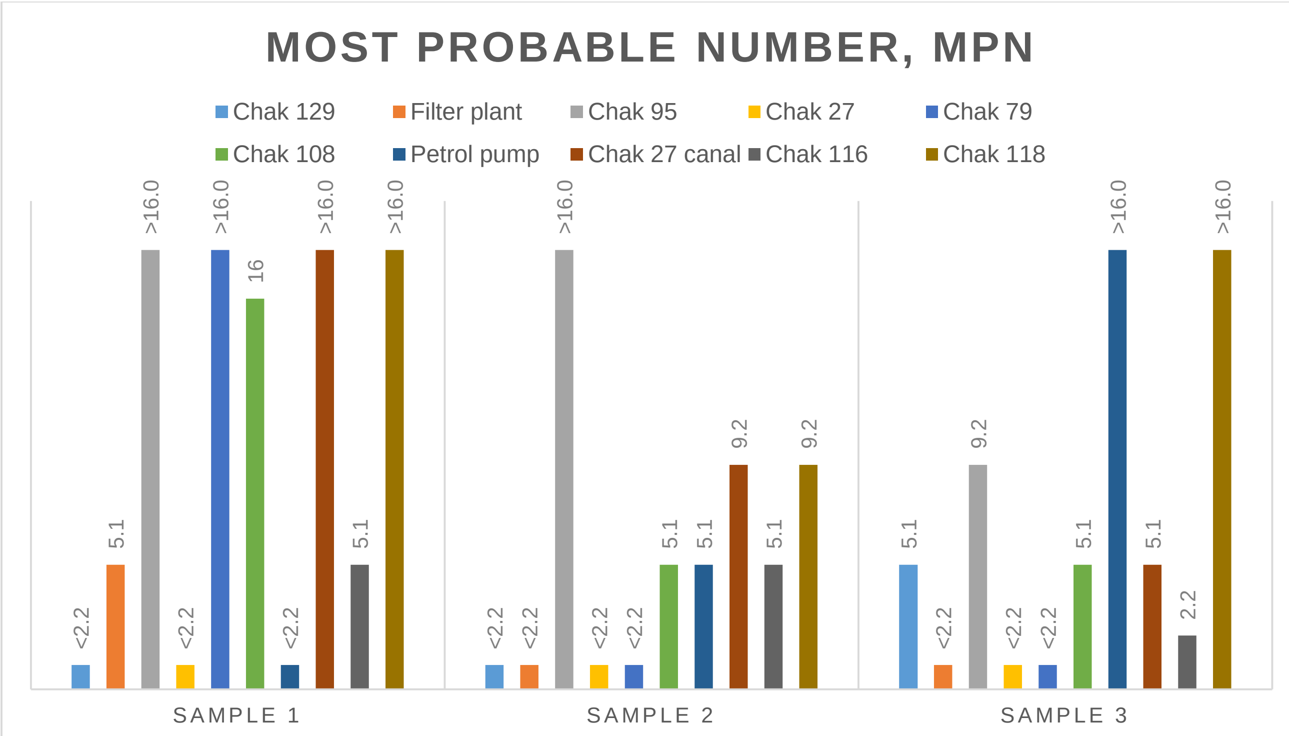

Figure 4.6-1: MPN Results

4.6.3.3 pH

In this study, pH value ranged from 7.10 to 8.14 which is within the range specified in WHO guidelines and Pak EPA standards as 6.5 – 8.5.

Table 4.6-3: pH Results

Sr. No	Location	Depth of borehole (Ft)	Sample 1 16 Nov 2018	Sample 2 18 Feb 2018	Sample 3 16 May 2019	WHO/ Pak NEQ's
1	Chak 129	120	7.85	7.95	7.60	6.5-8.5
2	Filter plant	100	7.52	7.18	7.31	6.5-8.5
3	Chak 95	125	7.97	7.88	7.10	6.5-8.5
4	Chak 27	125	7.73	8.14	7.64	6.5-8.5

5	Chak 79	130	7.77	7.19	7.98	6.5-8.5
6	Chak 108 Home	125	7.59	7.18	7.20	6.5-8.5
7	Petrol Pump	150	7.12	7.56	7.44	6.5-8.5
8	Chak 27 (Canal)	-	7.91	7.49	7.60	6.5-8.5
9	Chak 116	100	7.56	7.78	7.20	6.5-8.5
10	Chak 118	130	7.83	7.92	7.38	6.5-8.5

Source: Field work and lab experiments

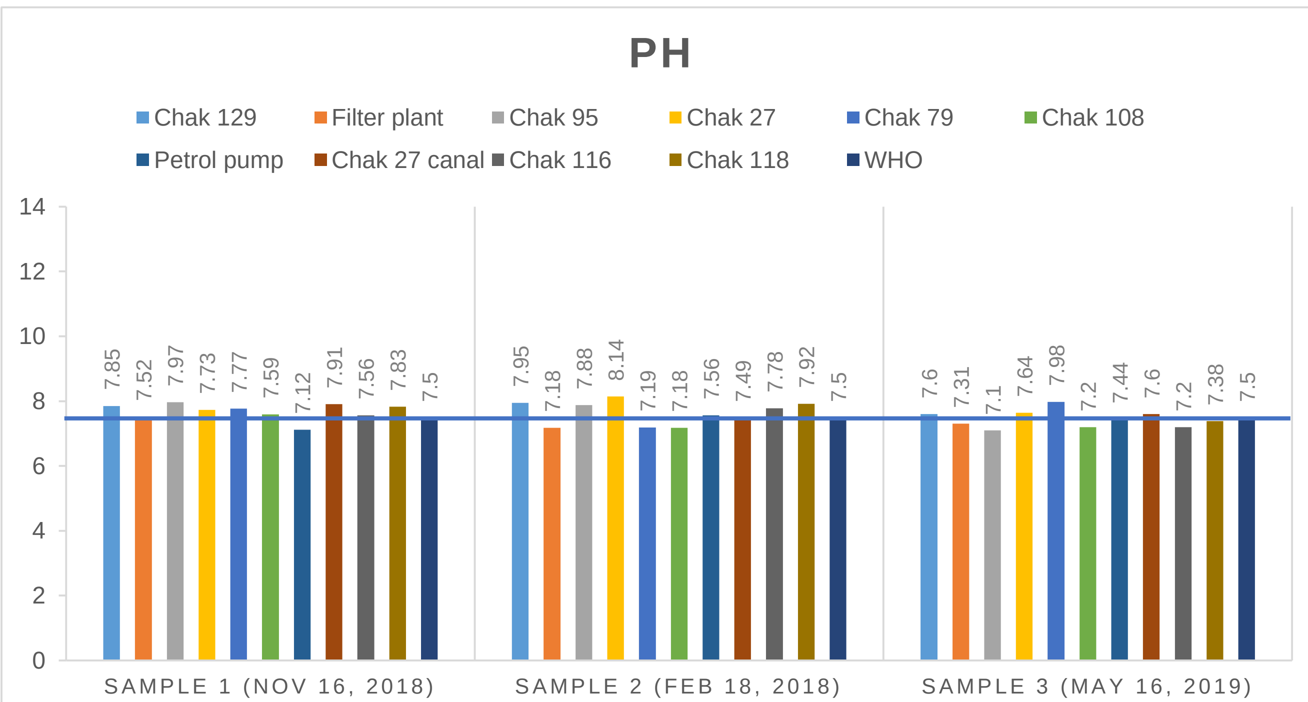

Figure 4.6-2: pH Results

4.6.3.4 Electrical Conductivity (EC, µS/cm)

EC of the samples ranged from 205.50 µS/cm to 1821 µS/cm. Samples obtained from “Chak 95”, “Chak 108”and “Chak 79” result in higher values. However, a decreasing trend was found when the results were compared with each other based on study span. Lower value of EC on same location after a period of three or six months shows possibility of ground water recharge.

Table 4.6-4: Electrical Conductivity Results

Sr. No	Location	Depth of borehole (Ft)	Sample 1 16th of Nov, 2018	Sample 2 18th of Feb, 2018	Sample 3 16th of May, 2019	WHO/ Pak NEQ's
1	Chak 129	120	381	383.50	355.50	Not defined
2	Filter plant	100	799.5	800	781	-
3	Chak 95	125	1013.5	1013	980.50	-
4	Chak 27	125	250	249	226	-
5	Chak 79	130	1821	1629	1478.50	-
6	Chak 108 Home	125	1016.5	1022	988	-
7	Petrol Pump	150	624.5	639	637.50	-
8	Chak 27 (Canal)	-	229.5	238	225.50	-
9	Chak 116	100	243	253	205.50	-
10	Chak 118	130	935.5	930	913.50	-

Source: Field work and lab experiment

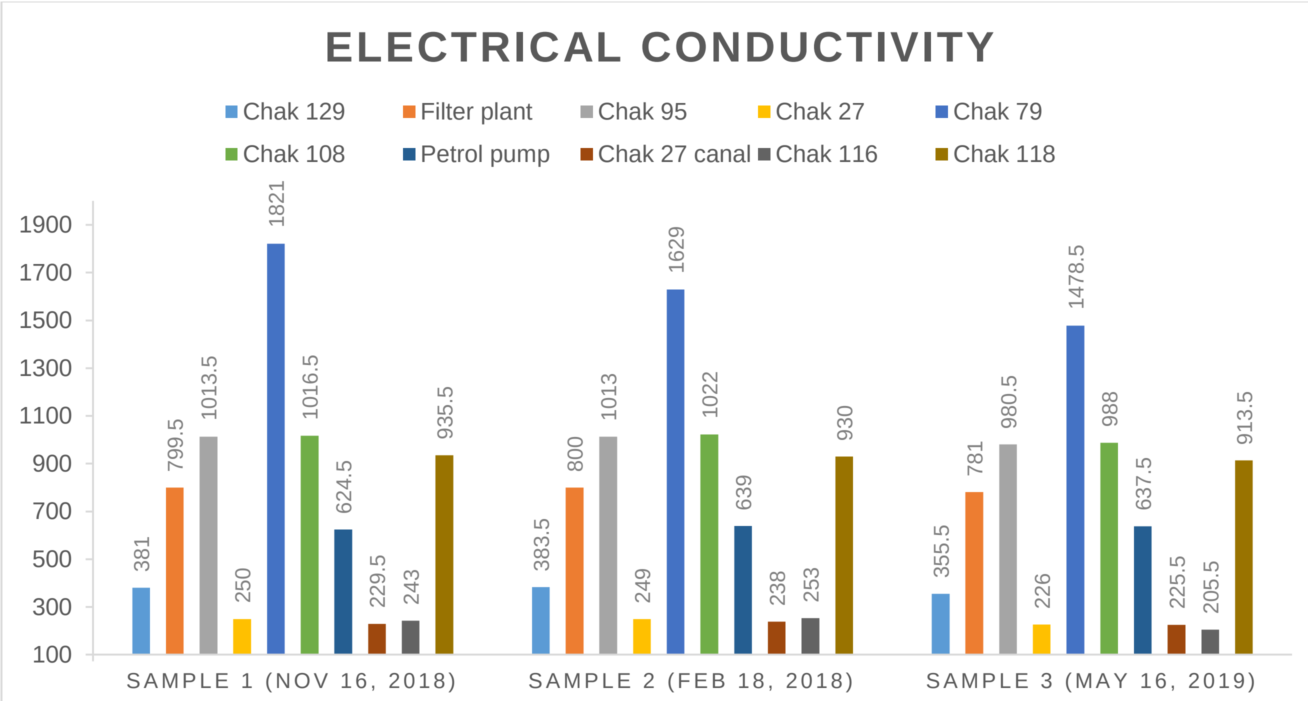

Figure 4.6-3: Electrical Conductivity Results

4.6.3.5 Turbidity (NTU)

Turbidity of the samples ranged from 1.22 NTU to 166.15 NTU. Most of the values were within the WHO/ Pak EPA standards except max value calculated from Canal whose trend was decreasing but still very turbid. The reason mixing of waste in canal from other sources but for all groundwater samples, the values were within permissible limits.

Table 4.6-5: Turbidity Results

Sr. No	Location	Depth of borehole (Ft)	Sample 1 16th of Nov, 2018	Sample 2 18thof Feb, 2018	Sample 3 16th of May, 2019	WHO/ Pak NEQ's
1	Chak 129	120	1.91	1.76	1.87	5
2	Filter plant	100	1.8	1.39	2.90	5
3	Chak 95	125	1.22	1.57	2.96	5

4	Chak 27	125	1.305	1.50	1.90	5
5	Chak 79	130	1.115	1.785	2.925	5
6	Chak 108 Home	125	1.25	1.43	2.89	5
7	Petrol Pump	150	1.84	1.92	2.82	5
8	Chak 27 (Canal)	-	166.15	154	143.62	5
9	Chak 116	100	1.915	2.23	66.25	5
10	Chak 118	130	2.9	2.135	2.51	5

Source: Field work and lab experiments

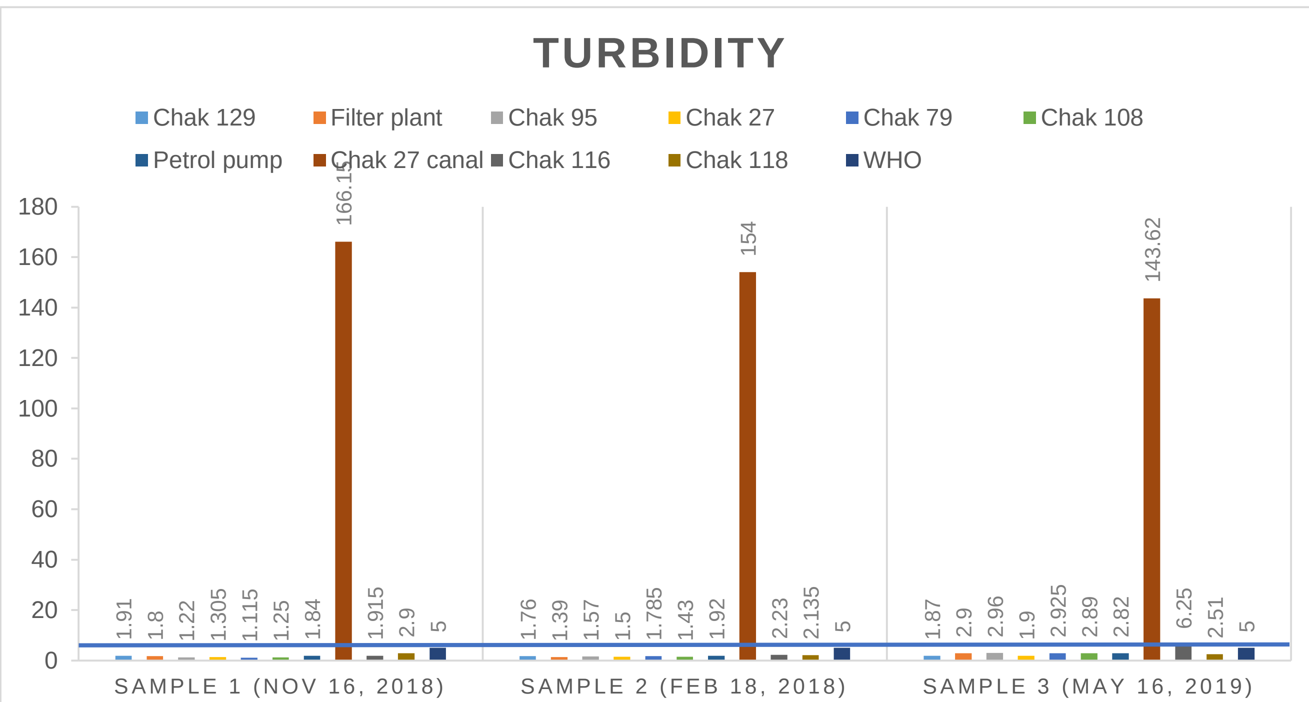

Figure 4.6-4: Turbidity Results

4.6.3.6 Total dissolved solids (TDS, mg/L)

There is a relationship between TDS and conductivity. As the dissolved salts (usually salts of sodium, calcium and magnesium, bicarbonate, chloride, and sulphate) increases in water, electrical conductivity increases (Kelin et al., 2005). The TDS ranged from 99.35 mg/L to 1897 mg/L. Higher values were observed at locations "Chak 79", "Chak 95" and "Chak 108". The WHO permissible limit for consumption in terms of TDS is 1000 mg/L. The higher values indicate possibility of less dilution and increment of salts and dissolved ionic species.

Table 4.6-6: TDS Results

Sr. No	Location	Depth of borehole (Ft)	Sample 1 16th of Nov, 2018	Sample 2 18thof Feb, 2018	Sample 3 16th of May, 2019	WHO/ Pak NEQ's
1	Chak 129	120	182	192.60	147.20	<1000
2	Filter plant	100	425.25	433.40	382.40	<1000
3	Chak 95	125	1217.90	1027.30	1280.345	<1000
4	Chak 27	125	125.75	132.65	113.74	<1000
5	Chak 79	130	1842.75	1897.15	1660.805	<1000
6	Chak 108 Home	125	1504.90	1533.30	1489.40	<1000
7	Petrol Pump	150	575.30	622.45	497.755	<1000
8	Chak 27 (Canal)	-	113.10	143.65	99.35	<1000
9	Chak 116	100	123.4	130.50	103.53	<1000
10	Chak 118	130	471.5	482.50	455.415	<1000

Source: Field work and lab experiments

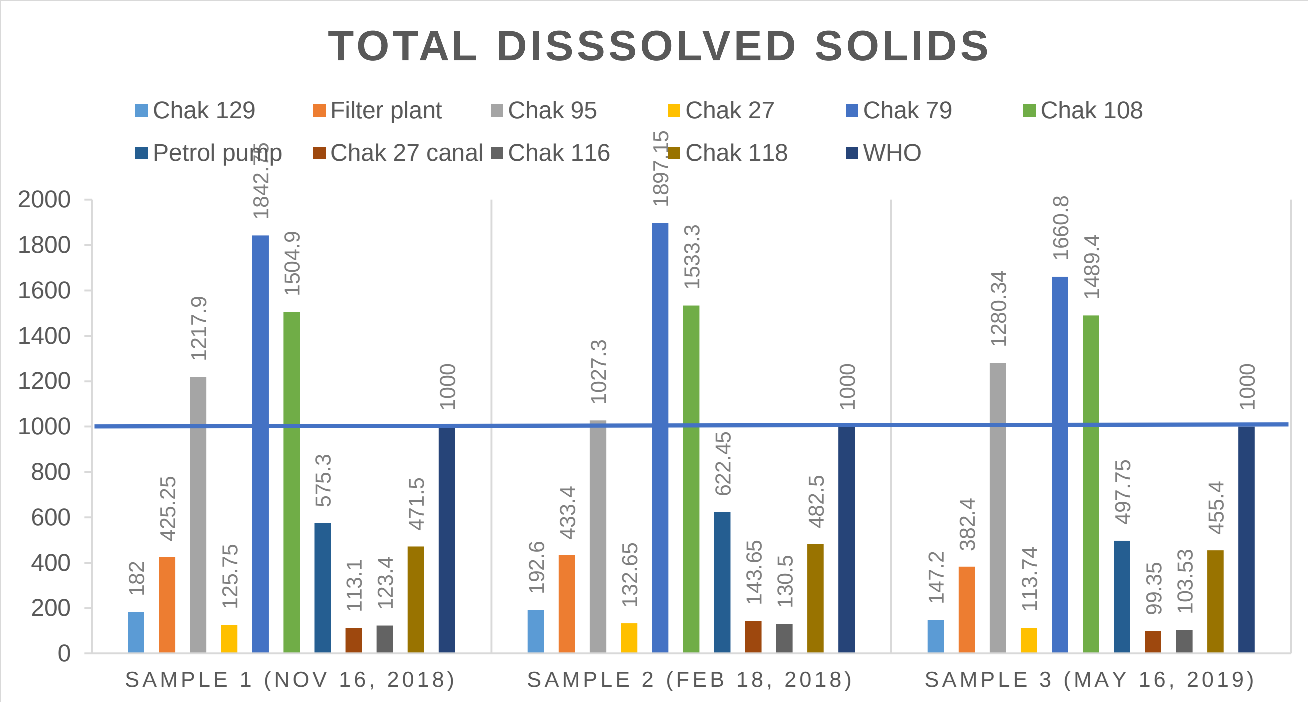

Figure 4.6-5: TDS Results

4.6.3.7 Total Hardness (mg/L)

The values obtained were found in the range of 83.25 mg/L to 649.1 mg/L. Rest of the samples were found within permissible limits of WHO which is 500 mg/L. Samples obtained from location "Chak 79" were higher than the limits. Slight increase was observed in Canal sample in summer season due to increase in temperature and evaporation.

Table 4.6-7: Total Hardness Results

Sr. No	Location	Depth of borehole (Ft)	Sample 1 16th of Nov, 2018	Sample 2 18th of Feb, 2018	Sample 3 16th of May, 2019	WHO/ Pak NEQ's
1	Chak 129	120	372	385.45	338	<500
2	Filter plant	100	111.25	147.25	97	<500
3	Chak 95	125	277.90	312.82	247.75	<500

4	Chak 27	125	179.10	185.49	144.18	<500
5	Chak 79	130	649.10	574.44	640.605	<500
6	Chak 108 Home	125	407.70	428.60	348.26	<500
7	Petrol Pump	150	99.25	139.725	83.225	<500
8	Chak 27 (Canal)	-	179	174.03	224.8	<500
9	Chak 116	100	346.50	356.50	326.63	<500
10	Chak 118	130	235.50	249.505	197.73	<500

Source: Field work and lab experiments

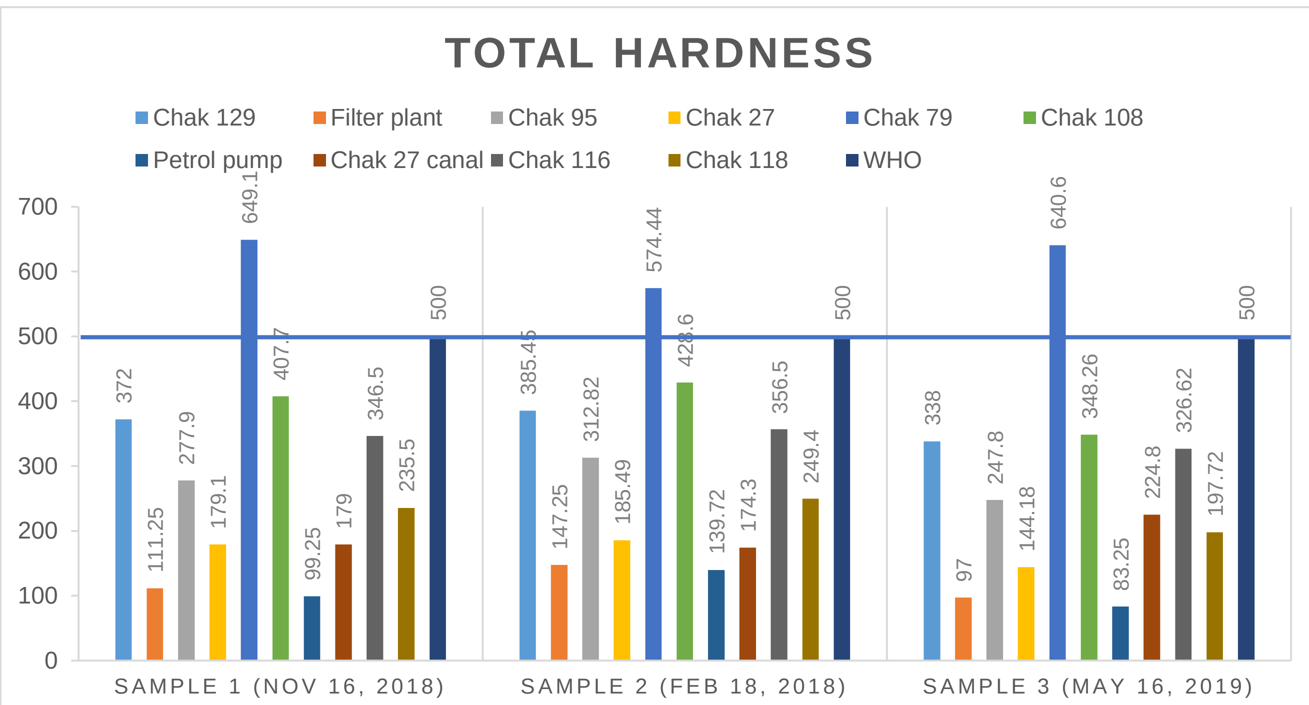

Figure 4.6-6: Total Hardness Results

4.6.3.8 Total Chlorides (mg/L)

The value of chlorides ranged from 14.12 mg/L to 390.44 mg/L. The highest value was obtained from sample of “Chak 79”. It also followed uniform trend as other parameters on the decreasing side. Despite the sample obtained from Mess, others were found within WHO permissible limits i-e 250 mg/L.

Table 4.6-8: Total Chlorides Results

Sr. No	Location	Depth of borehole (Ft)	Sample 1 16th of Nov, 2018	Sample 2 18thof Feb, 2018	Sample 3 16th of May, 2019	WHO/ Pak NEQ's
1	Chak 129	120	22.70	25.01	14.69	<250
2	Filter plant	100	32.55	33.09	24.98	<250
3	Chak 95	125	68.20	67.45	64.17	<250
4	Chak 27	125	24.18	28.23	22.79	<250
5	Chak 79	130	379.75	390.44	367.20	<250
6	Chak 108 Home	125	149.96	156.97	124.28	<250
7	Petrol Pump	150	25.28	33.72	18.17	<250
8	Chak 27 (Canal)	-	16.70	24.02	15.08	<250
9	Chak 116	100	17.25	19.52	14.12	<250
10	Chak 118	130	24.68	29.96	22.95	<250

Source: Field work and lab experiments

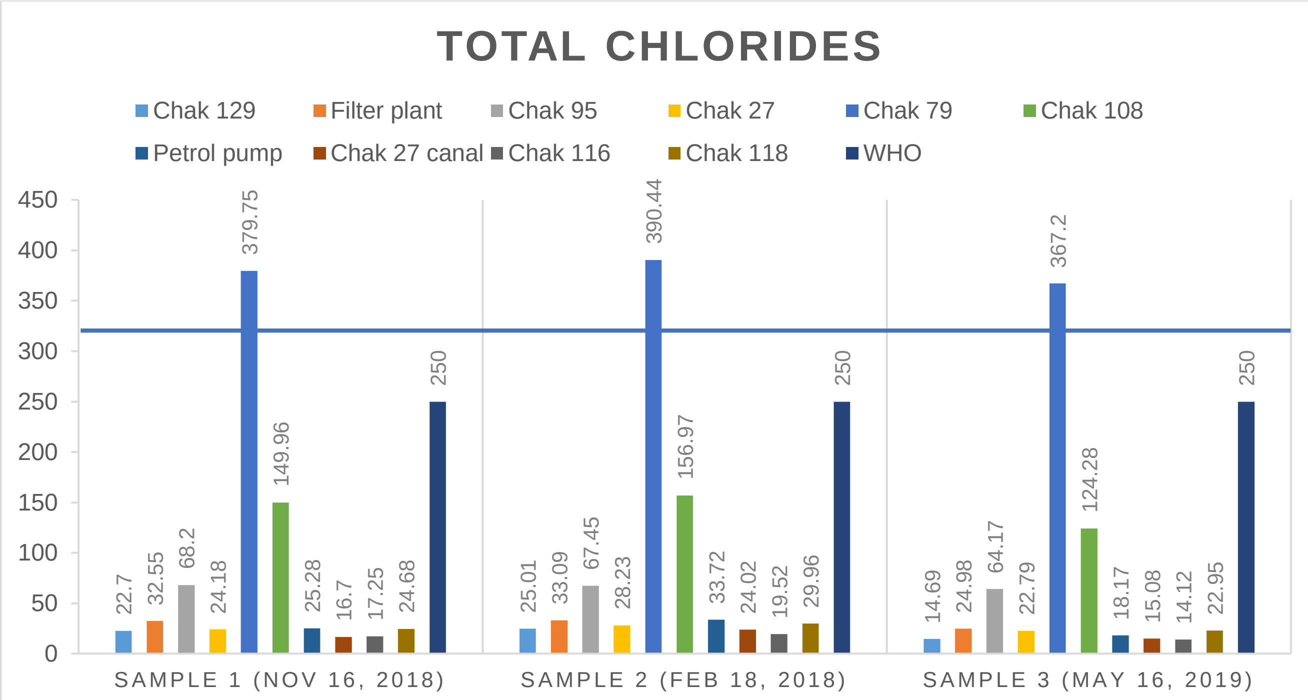

Figure 4.6-7: Total Chlorides Results

4.6.3.9 Biochemical Oxygen Demand (BOD_5 mg/L)

Almost all the samples were detected with BOD which indicates that the quality of water is not suitable for consumption. The local inhabitants are directly using this water for drinking purposes which is one of the main causes of health issues. Presence of BOD also indicates possibility of mixing sewage discharge into ground water. BOD calculated from samples obtained from "Chak 95", "Chak 108" and "Chak 27 Canal" were relatively higher as compared to other locations.

Table 4.6-9: BOD Results

Sr. No	Location	Depth of borehole (Ft)	Sample 1 16th of Nov, 2018	Sample 2 18th of Feb, 2018	Sample 3 16th of May, 2019	WHO/ Pak NEQ's
1	Chak 129	120	5.44	5.86	6.14	Not defined
2	Filter plant	100	2.18	1.36	5.17	-

3	Chak 95	125	8.71	14.12	10.12	-
4	Chak 27	125	7.22	7.81	2.94	-
5	Chak 79	130	2.83	5.21	2.18	-
6	Chak 108 Home	125	12.48	16.88	10.45	-
7	Petrol Pump	150	2.87	2.98	2.42	-
8	Chak 27 (Canal)	-	6.34	7.89	9.14	-
9	Chak 116	100	4.85	6.10	4.27	-
10	Chak 118	130	1.98	3.24	3.98	-

Source: Field work and lab experiments

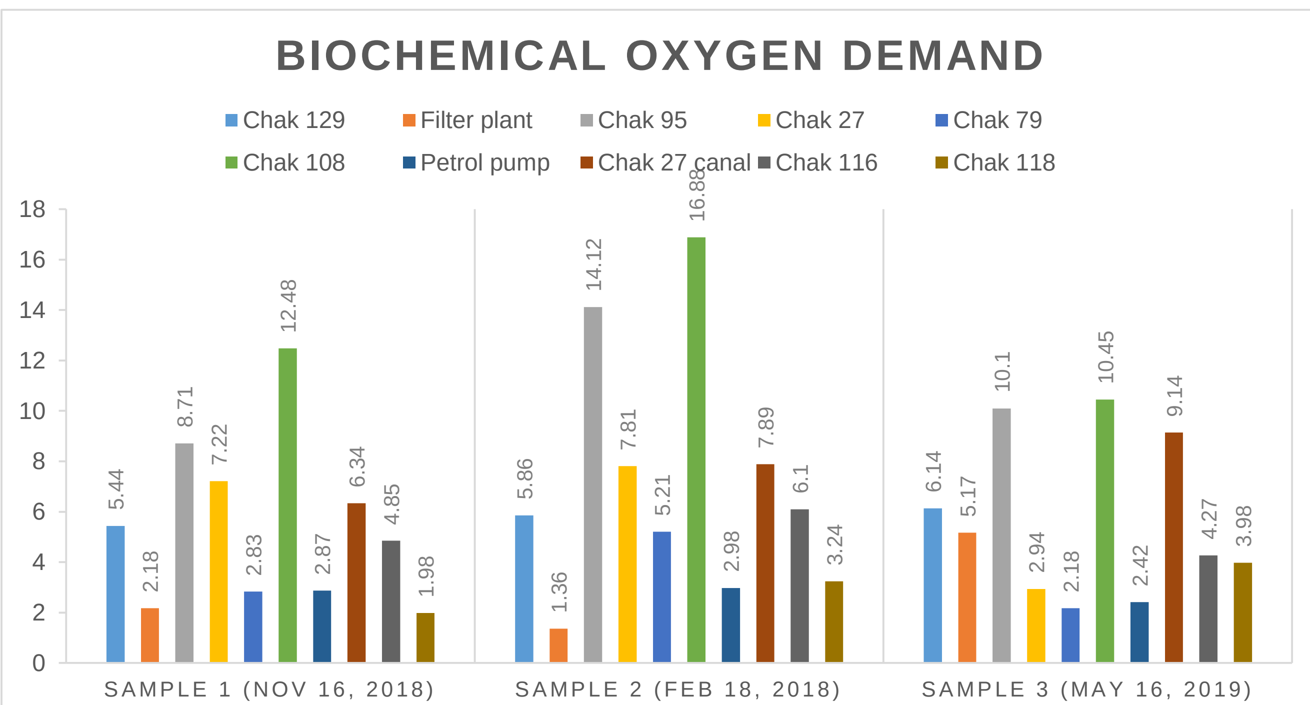

Figure 4.6-8: BOD Results

4.6.3.10 Chemical Oxygen Demand (COD, mg/L)

Ideally, COD should be negligible/ zero in drinking water just like BOD because their presence contributes to pollution presence in water due to industrial and sewage discharges into groundwater. In this study, the locations of "Chak 27, "Chak 95" and "Chak 108" resulted with higher COD levels which indicates mixing of wastes.

Table 4.6-10: COD Results

Sr. No	Location	Depth of borehole (Ft)	Sample 1 16th of Nov, 2018	Sample 2 18th of Feb, 2018	Sample 3 16th of May, 2019	WHO/ Pak NEQ's
1	Chak 129	120	11.24	12.66	10.24	Not defined
2	Filter plant	100	4.84	5.37	8.16	-
3	Chak 95	125	20.28	32.72	23.52	-
4	Chak 27	125	11.645	15.81	6.54	-
5	Chak 79	130	5.715	9.10	4.19	-
6	Chak 108 Home	125	25.41	30.41	18.24	-
7	Petrol Pump	150	4.50	4.12	5.78	-
8	Chak 27 (Canal)	-	11.16	13.52	17.55	-
9	Chak 116	100	8.25	10.92	7.39	-
10	Chak 118	130	3.28	5.22	6.62	-

Source: Field work and lab experiments-

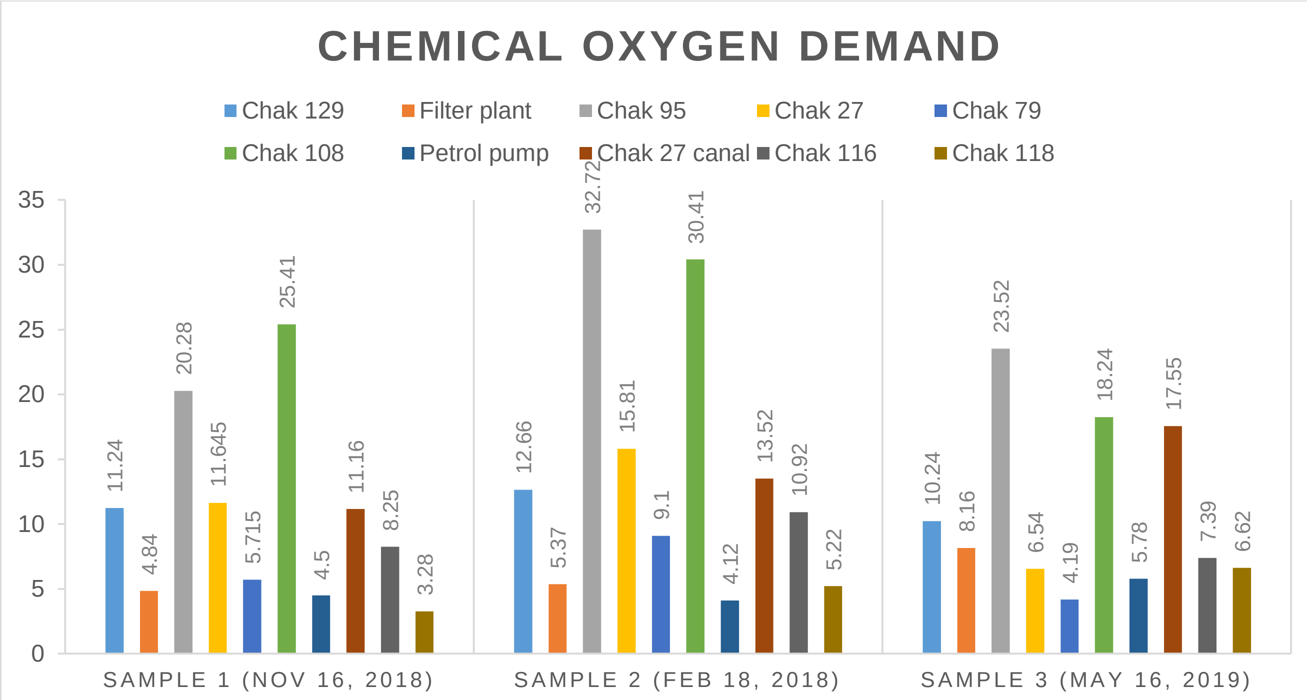

Figure 4.6-9: COD Results

4.7 Assessment of health damage caused due to consumption of contaminated water in Sillanwali and vicinity

Total coliforms are a group of bacteria commonly found in the environment, for example in soil or vegetation, as well as the intestines of mammals, including humans. Total coliform bacteria are not likely to cause illness, but their presence indicates that the water supply may be vulnerable to contamination by more harmful microorganisms. Escherichia coli (E.coli O157:H7) is the only member of the total coliform group of bacteria that is found only in the intestines of mammals, including humans. The presence of E.coli in water indicates recent fecal contamination and may indicate the possible presence of disease-causing pathogens, such as bacteria, viruses, and parasites. Although, most strains of E.coli bacteria are harmless, certain strains, such as E.coli 0157:H7 may cause illness. Total coliforms and E.coli are used as indicators to measure the degree of pollution and sanitary quality of well water, because testing for all known pathogens is a complicated and expensive process. This Study has revealed that the main source of pathogens in Sillanwali drinking water is through recent contamination from human or animal waste mainly due to;

- Improperly treated septic and sewage discharges
- Leaching of animal manure
- Storm water runoff
- Domestic animals or wildlife
- Agricultural and Industrial waste

Poor well construction or poor maintenance can increase the risk of groundwater contamination. In water, coliform bacteria (E. coli bacteria known as E. coli O157:H7) has no taste, smell, or color. The National environmental quality standards for Pakistan and WHO drinking water quality guideline for total coliforms is none detectable per 100 mL. The health effects of exposure to disease-causing bacteria, viruses, and parasites in drinking water area varied. The most common symptoms of waterborne illness include nausea, vomiting, and diarrhea. Infants, the elderly, and those with compromised immune systems may suffer more severe effects. In extreme cases some pathogens may infect the lungs, skin, eyes, nervous system, kidneys, or liver and the effects may be more severe, chronic, or even fatal. Due to the poor sanitation system, treatment, and monitoring, drinking water quality deteriorates. The presence of toxic chemicals and coliform bacteria in drinking water of Sillanwali has caused adverse effects on human health. Due to the fecal contamination maximum people have been suffering from waterborne diseases. In Sillanwali waterborne diseases like typhoid, dysentery, cholera, and hepatitis are systematically reported. However, it is very difficult to properly quantify the danger due to several reasons. They include underreporting of diseases and poor record maintenance in healthcare centers and hospitals related to diseases caused by poor water quality. Diseases such as hypertension, kidney diseases, heart problem, muscle weakness, bladder weakness, and asthma were observed.

The higher level of Fe is the likely reason of many health problems such as weakening of cardiovascular tissue, central nervous system, kidney, and liver, blood problems, vomiting, and diarrhea. Moreover the Unsafe drinking water is the major cause of the many other disease like endemic diarrhea (47%–59%), gastroenteritis (40%–50%), dysentery (38–45%), hepatitis A

(32%–38%), hepatitis B (56%–79%), and hepatitis C (36-57%) disease due to presence of in Pathogens in drinking water including many viral, bacterial, and protozoan agents.

Basing upon the water analysis, 5 years record available in health units Sillanwali and surrounding area (Chack NO. 147/148/NB, Chack NO. 152/NB, Chack NO. 48/NB, Chack NO. 49/SB,Shah Nikdar, Shaheenabad, Sillanwali, Sobhaga, Chack No. 135/NB,Chack NO. 163/NB, Chack NO. 111/NB, Chack NO. 118/NB, Chack NO. 126/NB, Chack NO. 129/NB, Chack NO. 131/NB, Chack NO. 138/SB) and survey conducted through questionnaire, following health impacts have been confirmed due to contamination of drinking water by sewer water.

Table 4.7-1: Water Contamination contributions to health effects in Sillanwali and Surrounding Areas

Diseases	**2013**	**2015**	**2016**	**2017**	**2018**
TB Suspects	61961	68712	73432	74049	76556
Suspected Malaria	80243	71495	79764	80132	85956
Suspected Meningitis	3,450	5,023	4,698	6,226	5,587
Suspected Measles	16,592	2,792	7,750	4,839	6,486
Suspected Viral Hepatitis(A,B,C)	88,658	1288,97	1355,72	1481,12	172,001
Suspected Diarrhea/Dysentery/cholera nausea/ vomiting/gastroenteritis	67000	60000	58000	65000	85000
Suspect of hypertension/heart problem/ muscle weakness/bladder weakness/asthma/cysts/reduced renal function/rapid heartbeat	4,631	5,366	8,470	4,399	1,337
Myocarditis/ paralysis/ acute hemorrhagic/ conjunctivitis	726	734	649	821	1,044
Lungs/skin/eyes/nervous system/ kidneys/ liver	1,827	3,306	3,875	9,272	19,381

Hyperkeratosis and pigmentation changes.	1,527	2,306	3,875	8,272	9,381

Source: EDO Literacy and Formal Education Sargodha and Field work

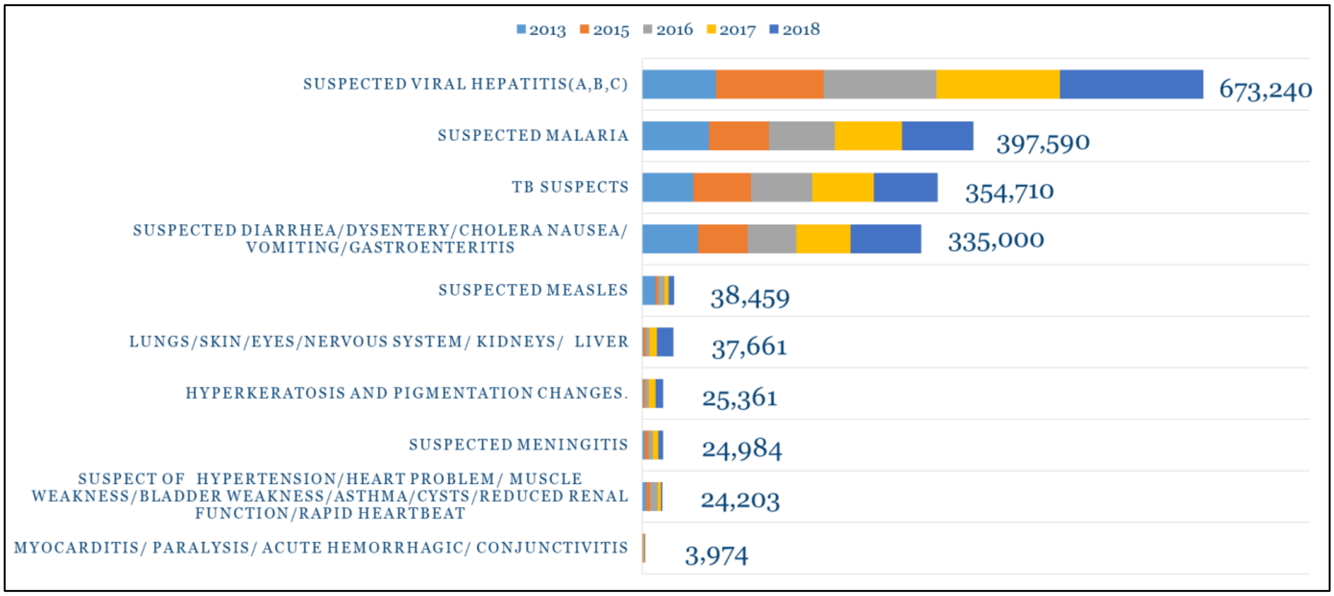

Figure 4.7-1: Water Contamination contributions to health effects in Sillanwali and Surrounding Areas

Graphical representation of the data above shows that more than 90% medical cases are infectious diseases with a high ratio of waterborne diseases.

4.8 Suggestions regarding the viable solution for existing problem

4.8.1 Adaptation of Management Strategy

District and Municipal authorities should cover protection of sources from contamination, replacement/ up gradation of old and vintage drinking water distribution lines their proper maintenance, monitoring and awareness of the people.

4.8.2 Legislative Control

There is a poor framework for the legislation of drinking water supplies. Drinking water quality standards should be provisionally established for the treatment and maintenance of drinking water distribution system. Water and Sanitation Agency (WASA) should take action with the help of private institutions to protect water resources and control pollution from its source.

A great attention is also required to stop the sewer water intrusion into the fresh ground water resources.

4.8.3 Governance

Government should take action for the maintenance, proper functioning, and handling of already present drinking water treatment plants. There is a lack of proper sampling system of the drinking water treatment plants to ensure that water is safe and fit for drinking in areas of Sillanwali. To stop the spread of waterborne diseases, there is need for proper functioning, inspection, and sampling analysis twice a year to ensure safe drinking water according to the quality standards.

4.8.4 Proper Maintenance

Water distribution system and chlorination should be done according to the law and regulations to kill pathogens. Government should provide the latest and reliable instruments and trained personals for the drinking water quality analysis.

4.8.5 Regulatory Authorities

Strict action for their industrial and Agricultural effluent disposal according to the NEQS under the 1997 Act. If anyone found to be violating the rules, should be punished with heavy fine and imprisonment.

4.8.6 General

Public awareness campaigns should be started at school, college, university, and community level to address the significance of secure drinking water. NGO's might act in this facet. Rural communities should adopt safe control methods for protecting water storage in houses and simple disinfection technologies of drinking water.

4.8.7 Punjab Government

Should be asked for the provision of funds to replacement / Separation of existing water and sewer lines. Proper disposal of waste, water treatment at source and even at quite no of places and should ensure its maintenance and regular provision of water from these water treatment plants.

4.8.8 Irrigation water

The water used for irrigation especially for seasonal vegetables and fruit should be disinfected and should have prior treatment. The pesticides used should not be leached into soil and form the part of runoff.

4.8.9 Boil your water

Either boiling prior to consumption or another source for drinking for preparing infant formulas, preparing juices and ice cubes, washing fruits and vegetables, cooking, and brushing teeth.

4.8.10 To destroy pathogens

Bring water to a rolling boil for one minute. You do not usually need to boil water for other household purposes. Those who can avoid swallowing the water may shower, bathe, and wash using the well water. Toddlers and infants should be sponge bathed. Dishes and laundry may be washed in well water either by hand or machine.

4.8.11 If E.coli is present in the water

It means there has been fecal contamination and other pathogens. Investigate the source of the bacteria and take corrective measures. If E.coli is absent, but only total coliforms are present, it could mean one of three things:

- A layer of bacteria may have developed within well or plumbing system. This layer of bacteria is called a biofilm.
- Surface/nearby pond water may be getting into well. This increases the risk of animal waste contaminating your water.
- Your well water may come from an aquifer that contains bacteria. This can happen when groundwater comes from a shallow source.

In such cases inspect the well construction and repair or rehabilitate the existing well. Check separation distances between wells and sources of contamination. Determine if there is a source of E.coli near well, such as a malfunctioning septic system, then the boiling water to kill microorganisms, one must keep water at a rolling boil for at least one minute. Water can be boiled either in a pot or kettle on a stove, in a microwave oven, or in an electric kettle without an automatic shut-off. Water to be used should be properly boiled, bottled water, or another source of water that has been tested and found to be safe for

- Drinking
- Preparing infant formula
- Preparing juices or ice cubes
- Washing fruits and vegetables
- Cooking
- Brushing teeth

4.8.12 Installing a treatment system

To treat current source of water if there is no other source of water available and rectification of the problem.

If E.coli is absent, but only total coliforms are present, solutions depend on why total coliforms are present:

If a biofilm has developed within well or plumbing system, you can disinfect your well and plumbing system.

If surface/Pond water is getting into well, identify how surface water is entering a well and prevent this from happening by help of a well specialist.

If well water comes from an aquifer that contains bacteria, which can happen when groundwater comes from a shallow source, then there are two options:

- Drill a deeper well, which may solve the problem. Be sure to meet the requisite separation distances and properly decommission old well.

- Install a treatment system.
- Compare the cost of drilling a new well to the long-term cost of buying and maintaining a treatment system

4.8.13 Treatment of Bacteria

It can't be removed water with pitcher-type carbon filters. Bacteria can be removed by keeping water at a rolling boil for at least one minute. Effective treatment methods for microbial contamination include permanent point-of-entry disinfection units, which can use

- Chlorine
- Ozone
- Ultraviolet light (UV light)
- Distillation

4.8.14 Further options;

Buy a treatment system that has been certified to meet the current NSF standards for the inactivation of bacteria.

An ultraviolet light unit purchased for the inactivation of pathogenic microorganisms must be certified to NSF Standard 55 Class A. Units without the Class A designation are only intended to be used for the reduction of non- pathogenic, nuisance organisms. Ultraviolet lights are intended for water that is visually clear (that is, not coloured, cloudy, or turbid). If the water is turbid, it should be filtered first to clarify the water.

Once installed, re-test water to ensure that the treatment system is working properly. Maintain the system according to the manufacturer's instructions to ensure a continued supply of safe drinking water. Testing should be conducted every three months for supplies that are contaminated with bacteria.

Make sure that the well casing is watertight and extends 152 millimeters (6 inches) or more above ground.

Ensure the well has a proper vermin-proof cap. Disinfect the well, pump, and plumbing after repairs. Disinfect any water placed in a well for drinking, repair, or priming of pumps. Never use water from a lake or pond in your well. Keep pumps, well pipes, and well equipment off the ground when they are being repaired – laying them on the ground can cause them to become contaminated with bacteria.

CHAPTER 5: **CONCLUSION AND RECOMMENDATIONS**

5.1 Conclusion

This research was conducted in Sillanwali on drinking water quality status and contamination, which accounted sewerage water (fecal) mixing with drinking water as dominant and primary contaminant due to the poor sanitation and sewerage system and second source of contamination is chemical pollution from toxic substances from the industrial effluents. There is a need to replace existing water supply and sewerage system, maintain and up gradation/ Installation of already present/ new treatment plants. The results drew attention that sewerage contamination with drinking water must be considered as an important environmental and health issue.

5.2 Recommendations

The report provides conclusion based on the impacts assessed during field work and following are the set of major recommendations and next steps:

- Since coliforms have been detected so repairs or modifications of the water Supply system must immediately be carried out. Boiling the water is advised until disinfection/ elimination is done.

- Installation of continuous disinfection equipment should be done. Using bottled water for drinking and food preparation.

- Waste Management plan should be implemented.

- Connecting to the regional public water system, if possible.

- Inspection of wells for defects and repairing be done.

- If possible Health and Safety Plan based on the frameworks provided in EMP should be in line.

- A missing or defective well cap - seals around pipes and where the cap meets the casing may be cracked, letting in contaminants be done.

- Contaminant seepage through the well casing - cracks or holes in the sewerage and water supply lines allow mixing .need immediate repair if not replaced.

- More water samples will be collected to find and eliminate potential contamination sources, and a system not normally disinfected will most likely be chlorinated and flushed.

- NGOs and other Educational Institutes and researchers should be allowed to see the exactly going on inside the plant.

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