Assessment of Drinking Water Quality and its Impact on Residents Health in Bahawalpur City

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Abstract

Present study aimed to assess and compare the ground water quality with WHO standards and its related diseases in Bahawalpur city. Three sample areas Satellite town, Shahdrah and Islamic colony were chosen and two water samples have been taken from each area. Data collection based on the questionnaire and laboratory analysis of water samples. Certain physical and chemical parameters like total dissolved solids (TDS), electrical conductivity (EC), pH, hardness, alkalinity (Alk) etc. was examined to find out quality of ground water. Findings reveal that groundwater quality in Bahawalpur is deteriorating. Situation was much worse in Islamic colony where 48%, 55% and 41% residents have diluted, brackish and water with slight smell respectively. Laboratory analysis of water parameters also disclosed the fact of significant contamination in ground water. EC, TDS, hardness, pH etc. were considerably high from WHO permissible limits. Such poor quality of water reasoned severe waterborne diseases like diarrhea, cholera etc. In Islamic colony, about 36% residents have been facing serious diseases. To save local residents study suggests; regular monitoring of water quality should be practiced; more water filtration plants should be installed by local govt. to provide safe drinking water etc.

Key Words: Water quality parameters, Bahawalpur city, WHO standards, Waterborne diseases.

1. Introduction

Water is most vital liquid for maintaining the life on the earth. About 97% water is exists in oceans that is not suitable for drinking and only 3% is fresh water wherein 2.97% is comprised by glaciers and ice caps and remaining little portion of 0.3% is available as a surface and ground water for human use (Miller, 1997). Safe drinking water is a basic need for good health and it is also a basic right of humans. Fresh water is already a limiting resource in many parts of the world. In the next century, it will become even more limiting due to increased population, urbanization and climate change (Jackson et al., 2001). Unfortunately, in developing countries (i.e. Pakistan) the drinking quality of water is continuously being contaminated and hazardous for human use due to high growth of population, expansion in industries, throwing away of waste water and chemical effluents into canals and other water sources. According to recent estimates, the quantity of available water in developing regions of South Asia, Middle East and Africa is decreasing sharply while quality of water is deteriorating rapidly due to fast urbanization, deforestation, land degradation etc.

Therefore, many cities in Asia facing increase in organic and nutrient material in drinking water due to the discharge of untreated domestic and industrial waste water into these resources (Annachhatre, 2006). Situation is more aggravated in South Asia, where more than 0.5 million deaths of infants happened per year with additional health threats due to poor water quality and bad sanitation. For instance, in West Bengal (India) and some areas of Bangladesh, groundwater is contaminated with arsenic at levels as much as 70 times higher than the national drinking water standard of 0.05mg/l (UNEP, 1999). Worldwide, more people are dying from 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 outcome from contagious diseases caused by pathogenic bacteria (WHO, 2002; UNEP GEMS/ Water Programme, 2008). Lack of access to safe and clean water created waterborne diseases excessively by the residents of slums in India (Lal et al., 1996). Diarrhea, a waterborne disease is reported as the leading cause of death in infants and children in the country while every fifth citizen suffers from illness and disease caused by the polluted water (Khalown et al., 2006).

Although, the issue of drinking water quality has a rising concern in developed world but little debated in developing countries. Pakistan is ranked a water stress country with the availability of about 1,200 m^3 per capita that is rapidly declining. 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 a little amount of 3% that is brought under treatment. About 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 majority of the Pakistani citizens have inadequate access to safe drinking water with poor water supply lines and faulty drainage system (Farrukh et al., 2004). Resultantly, this caused many diseases among people (Tanwir et al., 2003). Particularly, biological diseases caused high child mortality rate of 128/ 1000 per year (UNICEF and Meta-Meta, 2009). It is estimated that, in Pakistan, 30% of all diseases and 40% of all deaths are caused by bad quality of water (Global Water Partnership, 2000). Therefore, various studies have been conducted to examine and evaluate the quality of drinking water in Pakistan. For instance, a study conducted by Pakistan Council of Research in Water Resources (PCRWR) in all four provinces of Pakistan conclude that majority of the taken samples of water found insecure for drinking purposes. High arsenic found in major industrial cities of Punjab due to industrial and chemical waste discharge, high iron concentration is found in Khyber Pakhtunkhwa (KPK) while high turbidity level is observed in Sindh (Soomro et al., 2011). In Islamabad, to determine microbiological quality, water and food items were collected from different schools and colleges. Results show that out of 30 water and 10 food samples, 20 water samples and 7 food samples were highly toxic and not safe for human use (Saddozai et al., 2009).

Similarly, during a study conducted in Pakistan's biggest city Karachi, out of hundreds of samples of water no one was found safe for drinking purposes (Ihsanullah, 2009). Another study conducted in district Kohat (KPK) analyzed 18 samples collected from different sites to test the physiochemical parameters i.e. pH, TDS, Alkalinity, Electrical conductivity etc. Results indicate that most of the samples were contaminated (Ahmad et al., 2012). Similarly a study conducted by Khan et al. (2012) in Kohat (KPK) indicates most of the samples taken from wells, tube wells, hand pumps, streams and tanks were contaminated particularly in Shakardrara, Lachi and Ara Khail storage and wells were highly polluted whereas tube well water found safe for human use. It is summarize in a study conducted in district Charsadda (KPK) that drinking water of the study areas was contaminated with SO_4, NO_3 and heavy metals such as Pb, Cd, Fe, Ni, Zn and coliform bacteria.

Therefore, majority of the inhabitants of study area have been facing various health issues. Improper disposal of solid waste, sewage water, and too much use of fertilizers were the main reasons of water contamination (Khan et al., 2012). In a study to determine the effects of polluted water used for irrigation on ground water quality and causing health problems in Jamber, district Qasur (Pakistan) results indicate that use of polluted water enhance the value of conductivity, total dissolved solids (TDS) and sodium absorption ratio etc. in ground water and exceeds the national standards (Ashraf et al., 2010). It is proved that there is a keen relationship between people income and literacy of mother to water quality and health issue. More literate mothers and high income groups have the ability to prevent waterborne diseases to their family (Kausar et al., 2009). A study to analyze physiochemical parameters of water before and after monsoon period in southern Lahore shows that before monsoon the contamination of water ranges from 50-65% that risen after monsoon and reach 75%. This is possibly because of leaking of water main and sewers main found close to each other (Haydar et al., 2009). Therefore, it is clear fact that a broad range of physiochemical parameters of drinking water in Pakistan are not to meet the standards for drinking water set by WHO and Pakistan (Malana et al., 2011; Farid et al., 2012).

Polluted drinking water causes many diseases as diarrhea, vomiting, gastroenteritis, dysentery, kidney problems etc. found in Thatta, Badin and Thar districts of southern Sindh, Pakistan (Memon et al., 2011). The ground water in Bahawalpur city is generally saline and brackish and not suitable for drinking purposes apart from areas lies close to canals and river Sutlej that is the main water body of the region. Majority of the inhabitants have complaints to Tehsil Municipal Administration (TMA) Bahawalpur city against the quality of water that was found colored and sediment with bacterial contamination. In addition, absence of the effective monitoring of ground water quality on regular basis being made the situation more serious. The planning and management for better water quality supply is not much efficient in Bahawalpur city (Anwar and Bureste, 2011). As a study conducted in Bahawalpur city by PCRWR indicates after treating 25 samples data, it is estimated that 24% samples were polluted with E.Coliform bactaria; 52% samples were found contaminated with Coliform bacterium: 76% possessed excess Arsenic (As) of more than 50 ppb (which is 5 times above than WHO set limits); 32% possessed excess level of Turbidity and Satellite town has extreme levels of Turbidity may be due to damaged strainer pipes; 60% samples have higher concentration of Calcium (Ca) (Govt. of Punjab & World Bank, 2006). About 75% water samples were influence by coliform bacteria in Bahawalpur city (Mehmood et al., 2012). Hence, the main objective of the study is to assess the ground water quality and its causing diseases in Bahawalpur city.

2. Study Area and Data Collection

Bahawalpur city is located in semi-arid region with dry and hot climate and less precipitation. It is lies between latitude 29°-22′ and longitude 71°-37′ approximately. In recent years, rapidly increasing population and economic and educational developments of the city brought a huge stress on natural resources including ground water, land use, farmland etc. Specifically, the quality of ground water is regularly being reported contaminated in many areas of the city by PCRWR etc. and highly threaten the health of the local inhabitants. Majority of the people have used electric pumps to extract water while few people used hand pumps.

In an order to assess the ground water quality and its related diseases, three sample areas were chosen namely Islamic colony, Satellite town and Shahdrah (Figure 1). Islamic colony is a typical slum area where majority of the residents have lower standard of life and poor housing conditions. Satellite town is a well planned scheme by government where middle and high class people are living and having all modern facilities. Standard of living is reasonably high to Islamic colony residents. In Shahdrah mix standard of living exists. People engaged in shop keeping, dairying and govt. jobs etc. Two water samples have been taken from each study area and got tested in PCRWR regional lab to find out the quality status of selected physical and chemical parameters of the water. The samples were collected from electric pumps the most common source of drinking water in Bahawalpur city. After it, the results of these parameters were compared and discussed with WHO standards. In addition, to discover the overall physical quality of water and main waterborne diseases in study areas, a field survey was conducted and data was gathered through questionnaire using random cluster sampling. Results were portrayed in graphs prepared in MS Excel. Maps of study areas were made using ArcView 3.2a software.

3. Water Quality of the Study Areas

Water quality is the physical, chemical, and biological characteristics of water in association to the set of standards. These parameters directly related to the safety of the drinking water to human use. Water quality parameters provide important information about the health of a water body. These parameters are used to find out the quality of water for drinking purpose. During field survey the following physical parameters were also investigated using questionnaire;

3.1 Color of the water

Water usually think a colorless liquid however it possesses some level of color. Colors in ground waters can originate from decomposition of organic matter and leakage through sewage. Figure 2 clears that in Shahdrah, 86% residents have clear water and very small numbers of residents have diluted and faint. Over all water quality was satisfactory in this area may be because of proximity to river Sutlej as compare to other areas. In Satellite town, 61% residents have clear water while the residents having faint and diluted water were less in number. The main reason for the change in water color was the over exploitation of water and lowing water table with passing time. In Islamic colony, 48% residents have clear water while 50% residents have diluted water. It was possibly due to suspended minerals and dead organic matter.

3.2 Taste of the Water

Various odors and tastes may be present in water. Taste is generally classified in three groups of sweet, medium and brackish. Taste in water can be traced to a number of factors including decaying organic matter, living organisms, iron, mixing industrial waste etc.

Figure 3 portrays that in Shahdrah, water condition is much better as compared to other areas. About 79% residents have sweet ground water and a small numbers have medium (16%) and brackish water (5%). Water is naturally of good quality and has sweet taste except some cases. Medium taste is because of the naturally occurring salts contents. In Satellite town, about 48% residents have accessed to sweet water while 32% and 20% residents having access to medium and brackish water respectively. Generally, quality of water is good except some patches. Major sources of changing ground water taste were observed as sewer leakage, over pumping of ground water, residential waste disposal etc. In Islamic colony water is brackish and bears a typical odor. About 55% residents have brackish water while 41% residents have accessed to sweet water. Bad taste and odor has natural origin. The poor residents of this slum area were forced to use toxic water because they were unable to afford mineral water etc.

3.3 Smell/ Odor of the Water

Smell in water in the present study was classified into three categories of slight smell, no smell, and fast smell. In Satellite town and Shahdrah water has no smell except few patches while in Islamic colony slight and fast smells were noted in water. It is analyzed that 70% residents in Satellite town have accessed to water without any smell while 20% residents have water with a slight smell (Figure 4). Smell in water may be due to the sewage leakage. In Shahdrah 84% residents have water without any smell while 14% have the problem of slight smell. In Islamic colony, 42% residents have water with no smell while a large number of residents (41%) have water with slight smell. The level of fast smell in this area is also higher as compare to other study areas.

4. Analysis of Physical and Chemical Parameters of Water

Both physical and chemical parameters of collected water samples have been tested from the regional laboratory of Pakistan Council of Research in Water Resources (PCRWR) in Bahawalpur city (Table 1.1). Important physical parameters that were tested included Total dissolved solids (TDS), Electrical conductivity (EC) and pH of water. While, important chemical parameters have been tested were Bicarbonates, chloride, sulfate, magnesium, calcium, hardness, sodium, potassium, alkalinity and nitrate. The results were then matched and discussed with WHO standards.

4.1 Total Dissolved Solids (TDS)

Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc. These minerals produced un-wanted taste and diluted color in appearance of water. There is no agreement have been developed on negative or positive effects of water that exceeds the WHO standard limit of 1,000 ppm. Total dissolved solids (TDS) in drinking water is originates many ways from sewage to urban industrial wastewater etc. Therefore, TDS test is considered a sign to determine the general quality of the water. Figure 5 clears that in Islamic colony these values were ranges from 290-595 ppm. In Satellite town TDS range is 406-694 ppm and in Shahdrah these values range from 401-429 ppm. Hence, these ranges were acceptable and concentration of TDS is not harmful.

4.2 Electrical Conductivity (EC)

Pure water is not a good conductor of electric current rather a good insulator. Increase in ions concentration enhances the electrical conductivity of water. Generally, the amount of dissolved solids in water determines the electrical conductivity. Electrical conductivity (EC) is actually measures the ionic process of a solution that enables it to transmit current.

According to WHO standards EC value should not exceeded 400 µS/cm. In study areas, EC value in Islamic colony was 290-595 µS/cm, 406-694 µS/cm in Satellite town and 401-429 µS/cm in Shahdrah (Figure 6). These results clearly indicate that water in study areas was considerably ionized and has the higher level of ionic concentration activity due to excessive dissolve solids. Thus, it is a fine conductor of electric current.

4.3 pH of water

The pH of pure water is refers to the measure of hydrogen ions concentration in water. It ranges from 0 to 14. In general, water with a pH of 7 is considered neutral while lower of it referred acidic and a pH greater than 7 known as basic. Normally, water pH ranges from 6 to 8.5. It is noticed that water with low pH is tend to be toxic and with high degree of pH it is turned into bitter taste. According to WHO standards pH of water should be 6.5 to 8.5. In Islamic colony, it is ranges from 7.2-7.35; in Satellite town pH was 7.4-7.5 and in Shahdrah pH values observed at 7.4-7.35 (Figure 7). Hence, in study areas the pH values were not exceeded the standard limit however these were falling in basic or alkaline range.

4.4 Bicarbonates (HCO$_3$)

Bicarbonates concentration in water relies on pH and is usually less than 500 mg/l in groundwater. It is the standard alkaline constituent found almost all surface and ground water bodies and therefore affects alkalinity and hardness of water. The weathering of rocks adds bicarbonate content in water. Mostly bicarbonates are soluble in water i.e. bicarbonate of magnesium and calcium etc. is the main causes of hardness of water. The hard water is not suitable for drinking purpose and causes the gastro diseases. The value of bicarbonates is not recommended by WHO however it is considered to be not more than 500 mg/l. Current study revealed the concentration of bicarbonates ranges from 225-320 mg/l in Islamic colony, 170-175 mg/l in Satellite town and 160 to 180 mg/l in Shahdrah and hence these were within the standard values (Figure 8).

4.5 Chloride (Cl)

Chloride is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), NaCO$_2$ and added through industrial waste, sewage, sea water etc. Surface water bodies often have low concentration of chlorides as compare to ground water. It has key importance for metabolism activity in human body and other main physiological processes. High chloride concentration damage metallic pipes and structure as well as harms growing plants. According to WHO standards concentration of chloride should not exceed 250 mg/l. In study areas the chloride value ranges from 16-66 mg/l in Islamic colony, 54-78 mg/l in Satellite town and from 51-88 mg/l in Shahdrah. Thus, all the samples have lower concentration of chloride (Figure 9).

4.6 Sulfate (SO$_4$)

Sulfate mainly derived from the dissolution of salts of sulfuric acid and abundantly found in almost all water bodies. High concentration of sulfate may be due to oxidation of pyrite and mine drainage etc. Sulfate concentration in natural water ranges from a few to a several hundred mg per liter but no major negative impact of sulfate on human health is reported. The WHO has established 250 mg/l as the highest desirable limit of sulfate in drinking water. In study areas, concentration of sulfate ranges from 33-106 mg/l in Islamic colony, 79-310 mg/l in Satellite town and 72-86 mg/l in Shahdrah (Figure 10). The results exhibit that concentration of sulfate in Satellite town was higher from standard limit and may harmful for human health.

4.7 Magnesium (Mg)

Magnesium is the 8th most abundant element on earth crust and natural constituent of water. It is an essential for proper functioning of living organisms and found in minerals like dolomite, magnesite etc. Human body contains about 25g of magnesium (60% in bones and 40% in muscles and tissues). According to WHO standards the permissible range of magnesium in water should be 150 mg/l. In study areas magnesium was ranges from 6-36 mg/l in Islamic colony, 36-56 mg/l in Satellite town and 58-84 mg/l in Shahdrah (Figure 11). The quantity of magnesium is significantly low in Islamic colony as compare to Satellite town and Shahdrah. Such a low concentration somewhat effects health of residents as it is essential for human body.

4.8 Calcium (Ca)

Calcium is 5th most abundant element on the earth crust and is very important for human cell physiology and bones. About 95% calcium in human body stored in bones and teeth. The high deficiency of calcium in humans may caused rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases. According to WHO (1996) standards its permissible range in drinking water is 75 mg/l whereas PSQCA (2002) established the limit of 200 mg/l. However, an adult requires 1,000 mg/ day to work properly. Despite others, the standards set by WHO were kept in consideration.

In study areas, results show that the concentration of calcium ranges from 26-40 mg/l in Islamic colony, 61-84 mg/l in Satellite town and 18-29 mg/l in Shahdrah (Figure 12). Calcium quantity in Satellite town was exceeded the limit by WHO and may harmful for local residents.

4.9 Hardness

Hard water is characterized with high mineral contents that are usually not harmful for humans. It is often measured as calcium carbonate ($CaCO_3$) because it consist mainly calcium and carbonates the most dissolved ions in hard water. According to World Health Organization (WHO) hardness of water should be 500 mg/l. In study areas, hardness ranges from 195-330 mg/l in Islamic colony, 190-310 mg/l in Satellite town and from 265-285 mg/l in Shahdrah (Figure 13). These results clear, that hardness of water is according to the WHO standards and it is not harmful for local inhabitants.

4.10 Sodium (Na)

Sodium is a silver white metallic element and found in less quantity in water. Proper quantity of sodium in human body prevents many fatal diseases like kidney damages, hypertension, headache etc. In most of the countries, majority of water supply bears less than 20 mg/l while in some countries the sodium quantity in water exceeded from 250 mg/l (WHO, 1984). According to WHO standards, concentration of sodium in drinking water is 200 mg/1. In study areas, finding shows that sodium concentration ranges from 36-93 mg/1 in Islamic colony, 61-140 mg/1 in Satellite town and 28-33 mg/1 in Shahdrah (Figure 14). Sodium quantity in Shahdrah is quietly low which could be harmful for the health of local inhabitants.

4.11 Potassium (k)

Potassium is silver white alkali which is highly reactive with water. Potassium is necessary for living organism functioning hence found in all human and animal tissues particularly in plants cells. The total potassium amount in human body lies between 110 to 140 g. It is vital for human body functions like heart protection, regulation of blood pressure, protein dissolution, muscle contraction, nerve stimulus etc. Potassium is deficient in rare but may led to depression, muscle weakness, heart rhythm disorder etc. According to WHO standards the permissible limit of potassium is 12 mg/1. Results show that the concentration of potassium in study areas ranges from 5.2-7.5 mg/1 in Islamic colony, 5.4-7.9 mg/1 in Satellite town and 3.2-3.6 mg/1 in Shahdrah (Figure 15). These results were meet the WHO standards and may become preventive from diseases associated from potassium extreme deficiency.

4.12 Alkalinity

Alkalinity is the presence of one or more ions in water including hydroxides, carbonates and bicarbonates. It can be defined as the capacity to neutralize acid. Moderate concentration of alkalinity is desirable in most water supplies to stable the corrosive effects of acidity. However, excessive quantities may cause a number of problems. The WHO standards tell the alkalinity only in terms of total dissolved solids (TDS) of 500 mg/l. In study areas, results show that alkalinity ranges from 181-289 mg/l in Islamic colony, 171-188 mg/l in Satellite town and 277-211 mg/l in Shahdrah (Figure 16). Thus, these values were under the permissible limit of WHO standards and may not caused health related problems.

4.13 Nitrate (NO₃)

Nitrate one of the most important diseases causing parameters of water quality particularly blue baby syndrome in infants. The sources of nitrate are nitrogen cycle, industrial waste, nitrogenous fertilizers etc. The WHO allows maximum permissible limit of nitrate in drinking water is 10 mg/l. In study areas, results clear that the concentration of nitrate ranges from 4.5-6.4 mg/l in Islamic colony, 3.4-3.5 mg/l in Satellite town and 3.2-3.6 mg/l in Shahdrah (Figure 17). These results indicate that the quantity of nitrate in study sites is acceptable instead Islamic colony where the range of nitrate is exceeding in water and posing threat on the health of inhabitants.

5. Diseases caused by Poor Water Quality

Unfortunately, the intensity of waterborne diseases in under developing countries is very high due to polluted drinking water and poor hygienic conditions. Resultantly, the rate of casualties particularly in infants is alarming. It is estimated that in Pakistan, about 230,000 infants (less than five year old) have been died each year due to waterborne diseases (DigiTex, 2013). The treatment facilities of water is almost absent in rural and suburban areas and water is being contaminated through sewage, fertilizers use, decayed and leached organic matter etc.

A wide variety of fatal diseases are associated with poor water quality i.e. diarrhea, cholera, typhoid etc. In study areas, many of these diseases were being occurred by the use of infected ground water.

Table 2 and Figure 18 have proved that in Islamic colony 16.1% residents were suffered from cholera, 7.2% in diarrhea, 6.3% in typhoid, 4.4% in jaundice and 2% people in kidney stone disease. This is mainly caused by the use of contaminated water and bad sanitation condition. In Satellite town, 12.6% inhabitants were suffered in diarrhea and little portion of inhabitants suffered in kidney stone, typhoid, cholera and jaundice. This is because of the better ground water quality and healthy life style of the inhabitants of Satellite town. In Shahdrah, 15.6% residents were suffered in diarrhea, 3.8% in typhoid, 1.6% in kidney stone and 1.1% inhabitants were in cholera. It is analyzed that in Islamic colony 36.0% residents were suffered from water born diseases because they were being used to bad quality water as they cannot afford bottled and filtered water while 64.0% residents have no water caused disease. In Satellite town 81.9% residents have no water born disease and less number of people (18.1%) was suffered from water caused diseases because people can afford filtered and bottled water. In Shahdrah, 77.9% residents have no water related disease because the quality of ground water is good as compare to other study areas. Whereas, remaining 22.1% have been face various waterborne diseases.

6. Conclusion

Groundwater quality in Bahawalpur is deteriorating like in other main cities of Pakistan. The situation is much aggravated in Islamic colony where ground water quality was highly toxic. Survey results depict that in Islamic colony 48% residents have diluted water, 55% residents have brackish water and 41% residents have water with slight smell. In Satellite town, 61% residents have clear water, 48% residents have access to sweet water and 70% residents have access to water without any smell. As compare to these, situation of ground water quality is much better in Shahdrah where 79% residents have sweet water and 84% have found no smell in water. The laboratory analysis of physical and chemical parameters of collected water samples disclosed the fact of significant contamination in ground water. The findings of these parameters either were exceed the permissible values established by WHO or going below the average limits. For instance, among physical parameters, Electrical conductivity (EC) of water samples was very high from permissible limit of 400 µS/cm. Total dissolved solids (TDS) and Hardness of ground water in Islamic colony and Satellite were also increasing and caused harmful diseases. Similarly, the pH values of water samples were above the neutral (> 7) limit and falls in basic (alkaline) range. The values of sulfate (SO_4) and calcium (Ca) in Satellite town were 310 mg/l and 84 mg/l which were above the permissible limits of 250 mg/l and 75 mg/l respectively causing health related problems.

In Islamic colony, chloride (Cl) recorded 16-66 mg/l which is quite below than WHO standard of 250 mg/l. Sodium quantity in Shahdrah was 28-33 mg/1 which was also quietly lower from WHO standard limit of 200 mg/l and could be harmful for the health of local inhabitants. Other parameters also reflect significant variations to WHO standards. Due to this poor quality of water, the waterborne diseases like diarrhea, cholera, typhoid etc. were common in study areas particularly in Islamic colony about 36% residents have been facing serious diseases. While, the severity of waterborne diseases among the residents of Satellite town (18.1%) and Shahdrah (22.1%) was proportionally less as compare to the Islamic colony. Therefore, in order to rescue precious human lives from water related diseases current study suggests; regular monitoring of ground water quality should be practiced; District government should installed more water filtration plants to provide safe drinking water; Sewer drains should kept away from water supply drains to avoid waste water leaching in ground water; Sanitary conditions should be improved on urgent basis; The awareness campaign of waterborne diseases and importance of safe water for human health should be commenced by TMA etc.

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Table 1: Laboratory Analysis of Physical and Chemical Parameters of Study Areas and WHO Standards

Sample		Parameters and Permissible Limit set by WHO												
	Location	TDS (1000 ppm)	EC (400 $\mu S/cm$)	pH (6.5-8.5)	HCO_3 (500 mg/l)	Cl (250 mg/l)	SO_4 (250 mg/l)	Mg (150 mg/l)	Ca (75 mg/l)	Hardness (500 mg/l)	Na (200 mg/l)	K (12 mg/l)	Alk (500 mg/l)	NO_3 (10 mg/l)
1	Islamic Colony	290	467	7.2	225	16	33	36	26	195	36	7.5	181	4.5
2	Islamic Colony	595	930	7.3	320	66	106	66	40	330	93	5.2	289	6.4
3	Satellite Town	406	635	7.4	170	54	79	36	84	190	61	5.4	171	3.4
4	Satellite Town	694	1085	7.5	175	78	310	56	61	310	140	7.9	188	3.5
5	Shahdrah	401	627	7.4	180	51	72	58	29	265	33	5.5	277	3.6
6	Shahdrah	429	670	7.3	160	88	86	84	18	285	28	5.2	211	3.2

Source: Laboratory Analysis of Water Samples (2013)

Figure 1: Location of Study Areas in Bahawalpur City
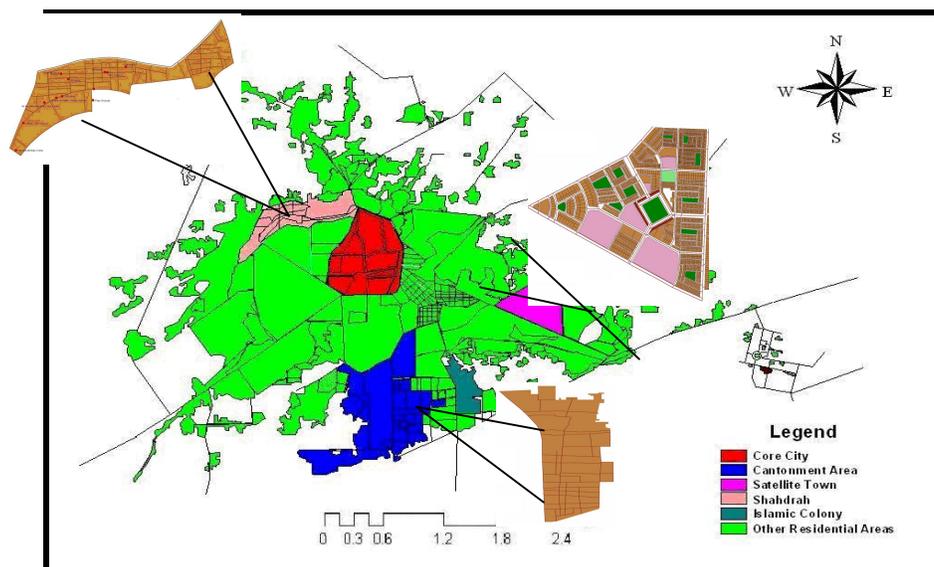
Source: Author (2013)

Table 2: Waterborne Diseases in Study Areas

Types of Diseases	Islamic Colony	Satellite Town	Shahdrah
Diarrhea	7.2%	12.4%	15.6%
Jaundice	4.4%	0.9%	0.0%
Typhoid	6.3%	1.6%	3.8%
Cholera	16.1%	0.9%	1.1%
Kidney stone	2.0%	2.3%	1.6%
No disease	64.0%	81.9%	77.9%
Total	100%	100%	100%

Source: Field Survey (2013)

Figure 2: Color of the water
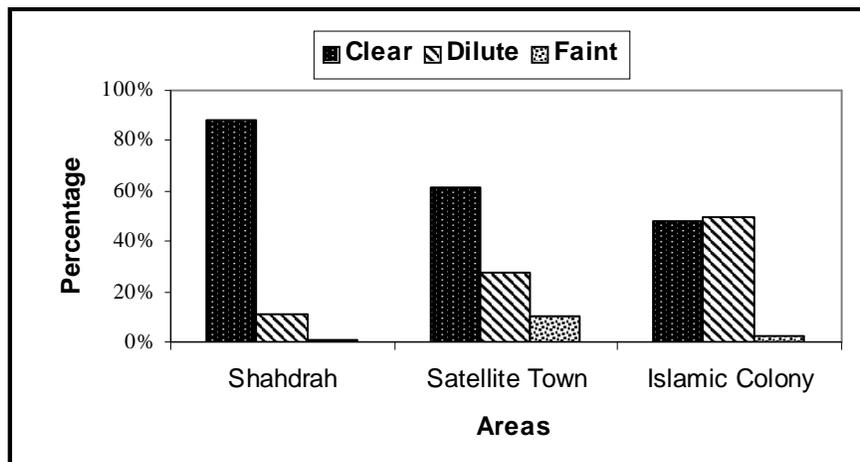
Source: Field Survey (2013)

Figure 3: Taste of water
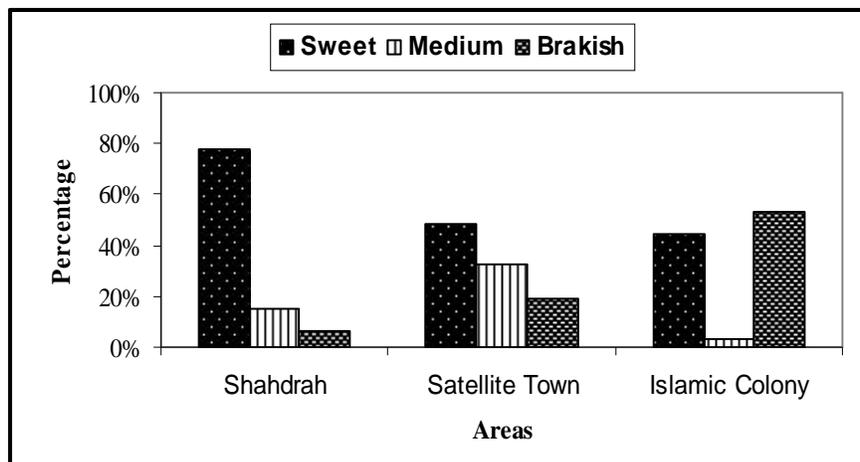
Source: Field Survey (2013)

Figure 4: Smell of water
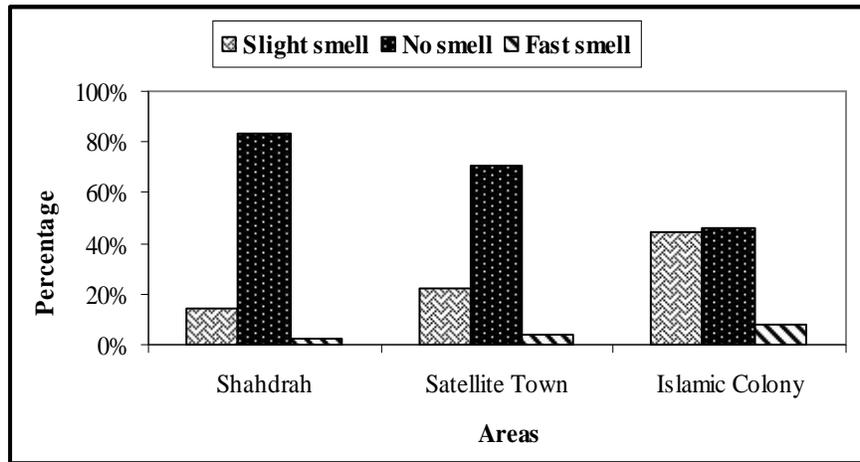
Source: Field Survey (2013)

Figure 5: Values of Total Dissolved Solids (TDS) in Study Areas
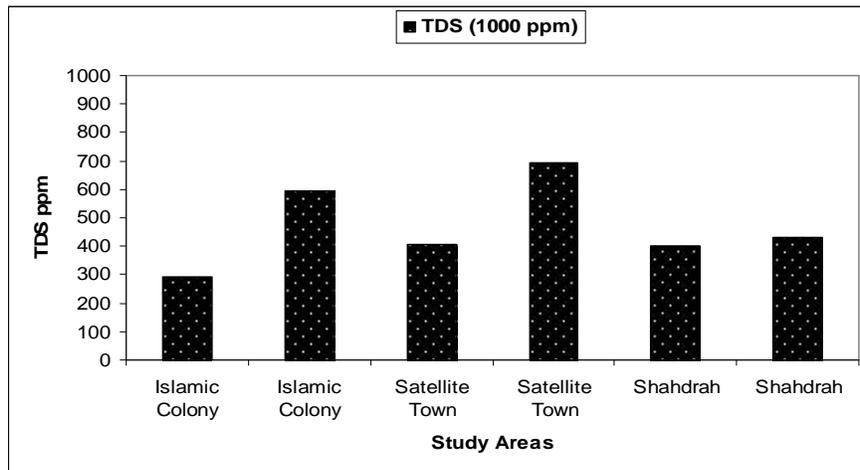
Source: Laboratory Analysis

Figure 6: Values of Electrical Conductivity (EC) in Study Areas
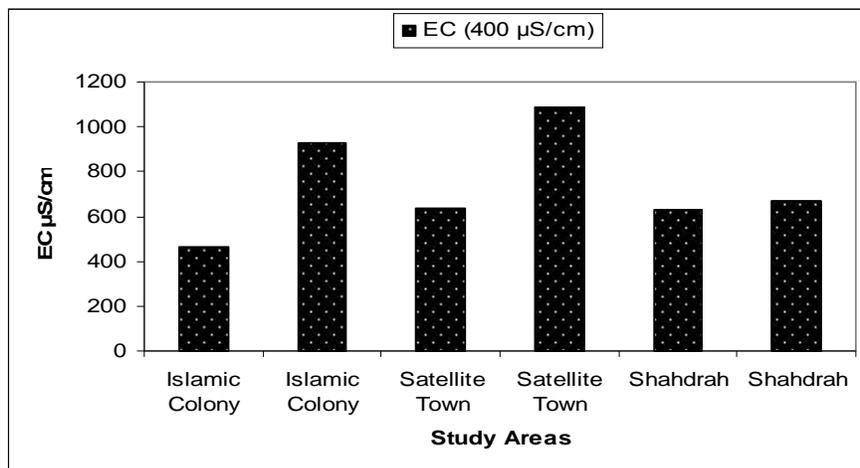
Source: Laboratory Analysis

Figure 7: Values of pH in Study Areas
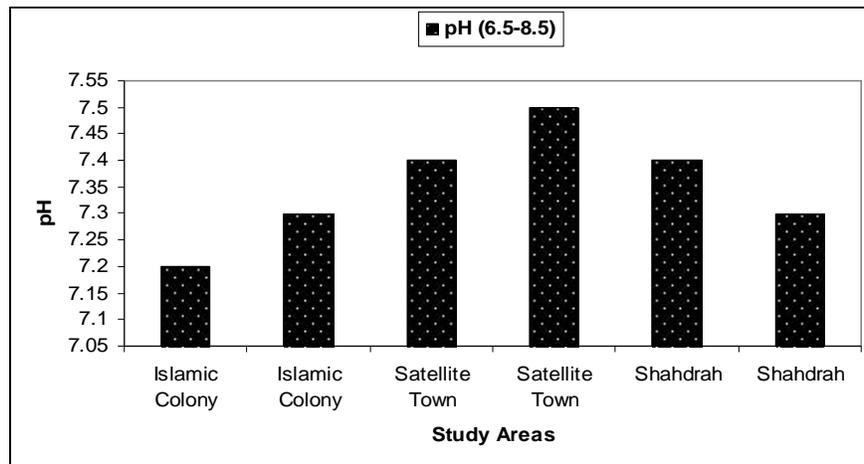
Source: Laboratory Analysis

**Figure 8: Values of Bicarbonates (HCO₃) in Study Areas**
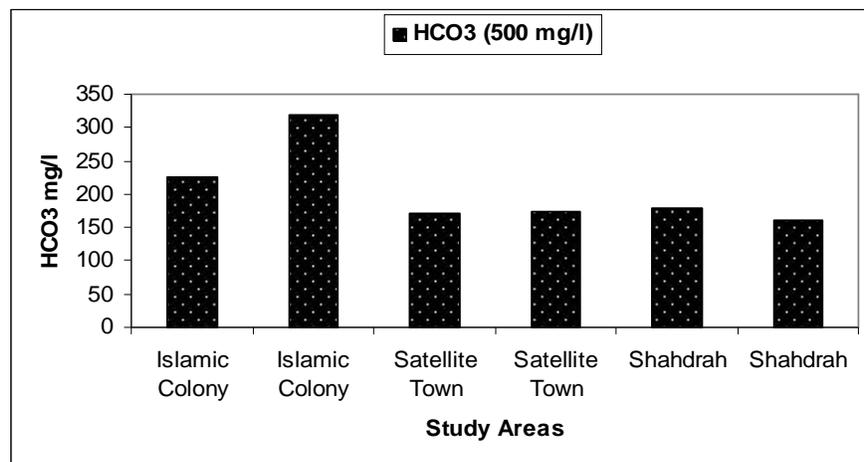
Source: Laboratory Analysis

Figure 9: Values of Chloride (Cl) in Study Areas
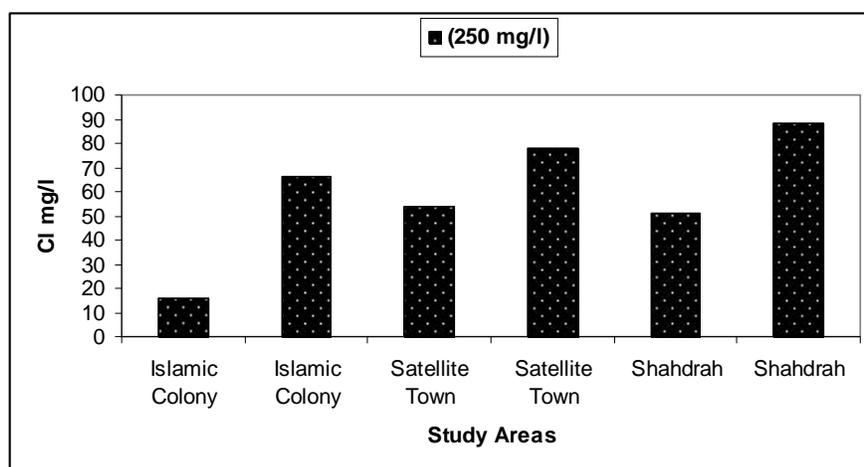
Source: Laboratory Analysis

Figure 10: Values of Sulfate (SO₄) in Study Areas
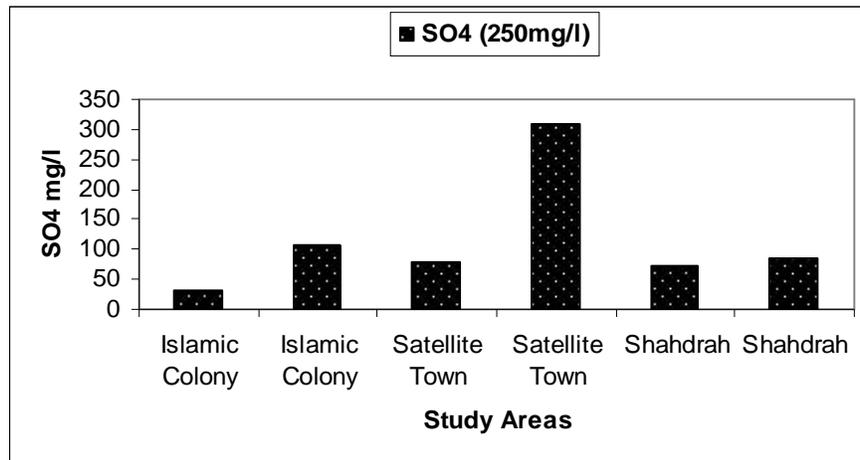
Source: Laboratory Analysis

Figure 11: Values of Magnesium (Mg) in Study Areas
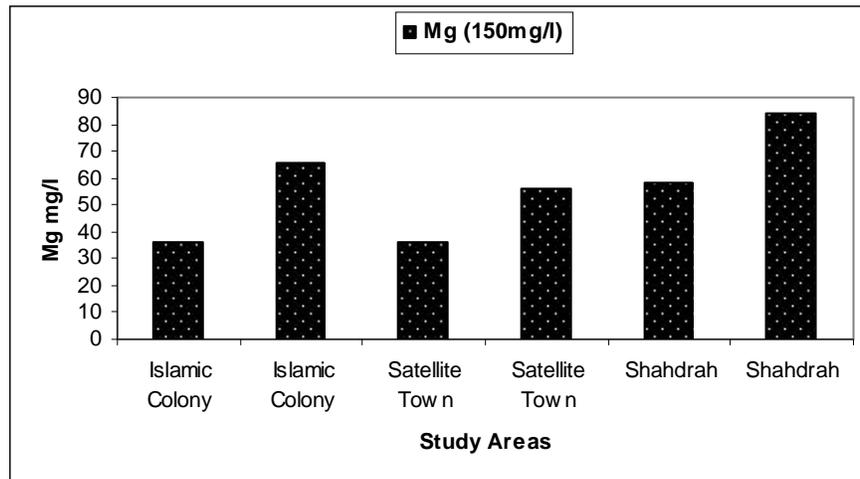
Source: Laboratory Analysis

Figure 12: Values of Calcium (Ca) in Study Areas
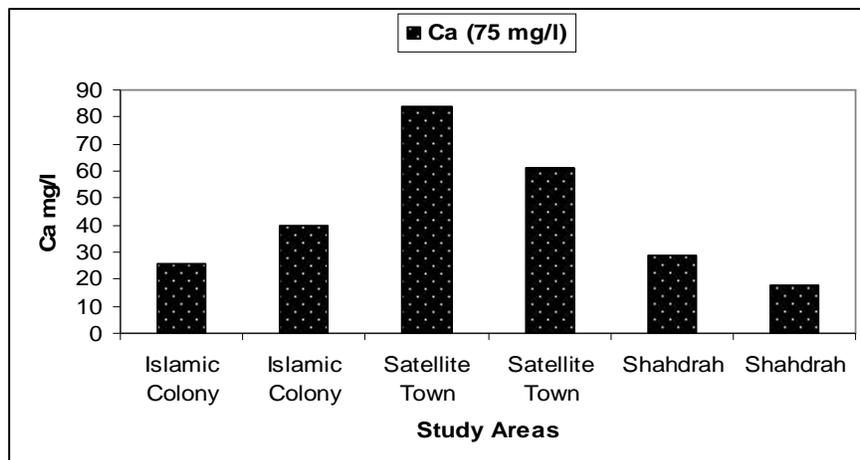
Source: Laboratory Analysis

Figure 13: Values of Hardness in Study Areas
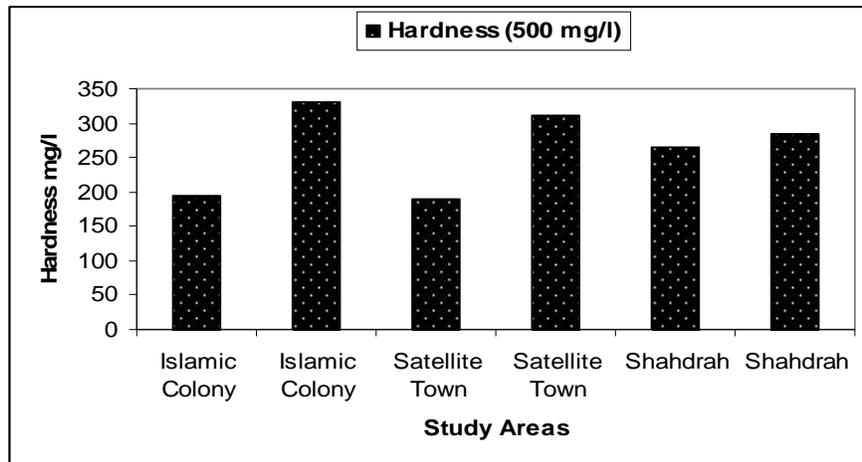
Source: Laboratory Analysis

**Figure 14: Values of Sodium (Na) in Study Areas**
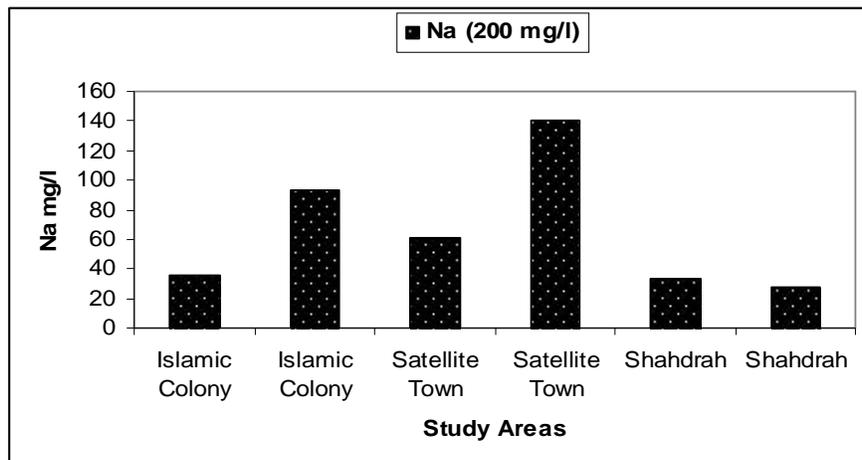
Source: Laboratory Analysis

**Figure 15: Values of Potassium (K) in Study Areas**
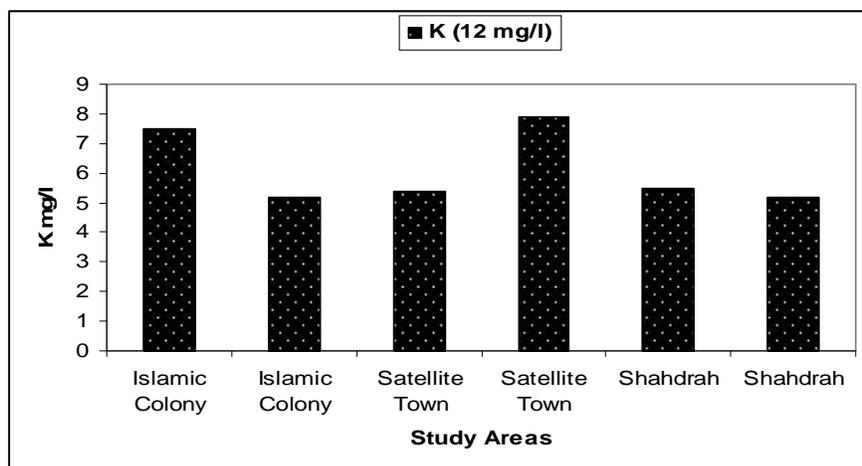
Source: Laboratory Analysis

**Figure 16: Values of Alkalinity (Alk) in Study Areas**
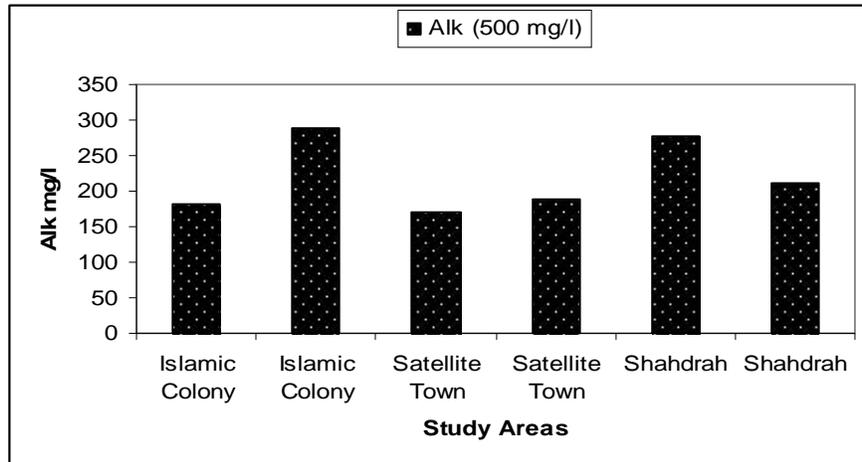
Source: Laboratory Analysis

Figure 17: Values of Nitrate (NO₃) in Study Areas
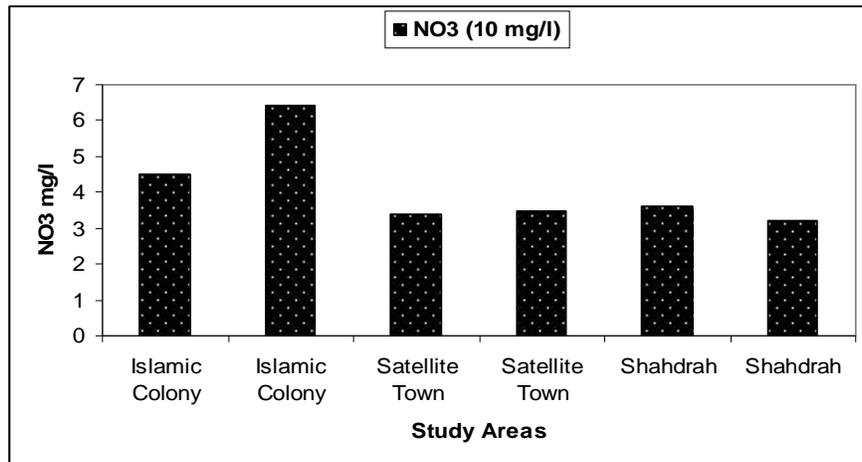
Source: Laboratory Analysis

Figure 18: Waterborne Diseases in Study Areas

Source: Field Survey (2013)