DRINKING WATER QUALITY OF WATER PURIFICATION PLANTS AND SOURCE TUBE WELLS AND THEIR HEALTH IMPACTS AMONG URBAN POPULATION OF RAWALPINDI

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1- Drinking water - Analysis - Standards

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2.3.11

DEDICATION

This thesis is dedicated to my loving Parents who empower me and taught me to be sincere with my studies that will surely lead me to the destiny. Without my Parent's prayers, unforgettable efforts and support since the beginning of my studies, wisdom, guidance, their deep understanding, prolonged patience, encouragement and their most of love; I would not have been able to complete my thesis. I also dedicate this thesis to my fiancé Muzaffar Hussain whose steadfast support and motivation in the completion of this thesis was greatly needed.

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ABSTRACT

The aim of the current study was to find out the coverage status of water provided by water purification plants in Rawal town, to test biological contaminants supplied by water purification plants and source tube wells, issues that resulted in bacteriological contamination and determining waterborne diseases among urban population of Rawalpindi.

Sixty water purification plants and source tube wells were selected by considering two criteria: random sampling based on statistical criteria and spatial distribution of water purification plants. Within the target area sampled water purification plants and source tube wells were selected randomly and convenient tube well and its purification plant was selected as starting point. Spatial location of purification plants were taken by Geographical Position System (GPS) Magellan Explorer 500. Forty nine samples of water purification plants and forty two samples of tube wells were analyzed for fecal contamination. Data was processed and analyzed using statistical software program excel and SPSS7. Smart draw software was used to generate diagrams for recommended design of water purification plants.

According to the estimated population of 1128316 inhabitants in Rawal Town in 2009, 60 sampled water purification plants operating for 3 average hours were providing 405000 liters water and served only 14% population and had 86% service shortfall.

Thirty eight percent water purification plants were fit, whereas, 43% water purification plants were unfit. Tube wells providing fit water were 28%, where as, 42% tube wells were providing unfit water.

The current study reveals clearly that there were faults in the existing design of water purification plants. Required contact time of chlorine was not achieved to kill all pathogenic microorganisms because it reached in granular activated carbon filter in just 18-30 seconds. One micron filter was not able to stop the spores of bacteria and viruses and resulted in the formation of bio-films on the membranes of micron filters. Ultra violet system was not properly working.

Operators of water purification plants were not trained and had no knowledge about the equipments installed. They were not provided with standard operating procedures and manuals regarding equipments. They had the duty to operate more than two purification plants as well as tube wells.

According to Holy Family hospital records for diarrheal patients during twenty years (1990-2009), 47802 people suffered from diarrhea. Benazir Bhutto hospital showed increasing trend of waterborne diseased patients by 2006 and expected to remain increasing till 2015. PHC hospital also showed that number of waterborne and water related diseased patients increased in summer season due to more consumption of drinking water.

The recommendations include increase of water purifications plant's operating hours to 3+3=6 hours to increase percentage of served population to about 29%; three alternative designs for water purification plants: install pre-chlorination tank before sand filter so that chlorine stays for 30 minutes to achieve its contact time, install ultra filter after 1 micron filter to remove all pathogens or to install both pre-chlorination tank and ultra filter; install backflow system and piping for sanitization; organize training workshops for operators, consider standard operating procedures and manuals given by manufacturers and separate operators for both water purification plants and tube wells; install and run subsidized water shops/ subsidized bottled water approach; develop regular monitoring schedule; records of waterborne diseased patients with their locations should be kept by WASA to identify areas provided with contaminated water.

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LIST OF ACRONYMS/ABBREVIATIONS

CDs	Compact Disks
DBP's	Disinfection-by-products
ER	Emergency Response
GAC	Granular Activated Carbon Filter
GPS	Graphical Positioning System
MGD	Million Gallons per Day
MPN	Most Probable Number
NTU	Nephelometric Turbidity Unit
OPD	Outpatient department
PCRWR	Pakistan Council of Research for Water Resources
PHC	Public Health Centre
RDA	Rawalpindi Development Authority
THM	Trihalomethanes
TMA	Tehsil Municipal Administration
TW	Tube Well
UC	Union Council
UCs	Union Councils
UTM	Universal Transverse Macerator
UV	Ultra Violet
WASA	Water and Sanitation Agency
WHO	World Health Organization
WPP	Water Purification Plant

CHAPTER 1

INTRODUCTION

The entire world of water is water environment. We know it and we love it. "Where does the water environment begin? It begins where a single drop of rain falls to earth. This raindrop joins with others like it to form tiny trickles. These trickles combine and run off the land to create rivulets, creeks, streams, and rivers. The small streams and mighty rivers of the world unite to produce the vast oceans and seas that surround us". (Kenneth, M.V. 2003)

In environment to sustain all forms of life, irrigate our fields and to quench our thirst; we need ample clean water. Our nature, industries, businesses, communities and homes must have clean water. There is a need of clean water today and tomorrow. We rely on clean water for drinking, cooking, bathing and in almost every aspect of our lives. We nourish our souls by counting on aesthetic values of clean water. (Kenneth, M.V. 2003)

Seventy percent of the planet is covered by water but 97% of that is salt water. Of the freshwater resources, only 0.01 percent is easily accessible for human use. This amounts to some 14 billion cubic meters. Accessible freshwater can be found in rivers, lakes and aquifers, but the vast majority remains locked in ice fields and glaciers. (Cook, G. 2003)

Both ground water and surface water have unique water quality characteristics which are influenced by natural conditions like Climate, geology, vegetation type, location of water on the earth and morphological characteristics and also by human activities in the environment. For many communities, ground water is the primary source of drinking water and secondary source for others. The main source of drinking water (World Bank, 1999) is ground water in many countries and 97% of the fresh water resources available in the world are represented by ground water except the resources locked in polar ice.

According to the Human Development Report (2006) United Nations celebrate World Water Day on 22 March each year. Millennium Development Goal 7 and target 10 to halve the number of people without having access to safe drinking water and basic sanitation has been set by member countries of United Nations, which is a great challenge. Eight hundred million people will still be without safe water in 2015 even if the targets are achieved. "The human right to water", declares the United Nations Committee on Economic, Social and Cultural Rights, "entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use" (U.N. General Comment No.15 on the right to water, 2002), (HDR, 2006)

1.1 Drinking Water and Causes of Water Pollution

Drinking water is also called as potable water that is delivered to consumer and can be used safely for drinking, cooking and washing purposes. "Potable water must meet physical, chemical, bacteriological and radionuclide parameters when supplied by an approved source, delivered to a treatment and disinfection facility of proper design, construction and operation, and in turn delivered to the consumer through a protected distribution system in sufficient quantity and pressure" (Zuane, J.D. 1997).

The total amount of water in the planet is static. Increasing demand for fresh and clean drinking water causes stress on water, affecting its quality and resulting in water pollution. Water pollution threatens the supply of clean water and makes its supply infinite on the earth. Therefore, protecting water quality is crucial. We cannot rely on clean water so heavily because there is no guarantee that it will always be available.

There are different types of water pollution, like surface water pollution, ground water pollution, oxygen depletion, nutrients and suspended matter, chemical and microbial pollution. Causes of water pollution are divided into two categories.

- First is the Direct or point source like effluent from waste water treatment plants, factories and refineries, underground storage leakages, oil pollution, sewage and waste water etc. that emit contaminants directly into urban water supplies. Every day, 2 million tons of human waste is disposed off in water courses (UNESCO, 2003).
- Second is the Indirect or non-point source including contaminants that enter water supply from atmospheric deposition in the form of acid rain, eutrophication from fertilizer runoff in storm water, global warming, metals or hydrocarbons and vehicular traffic.

Water pollution is affected by population growth, agricultural demand, energy requirements, urbanization, economic growth and industry, globalization, technological and lifestyle changes, recreation and tourism, climate changes and geopolitical changes (UNESCO, 2003).

The increase in population growth and its projection to continue until 2050 and beyond is central to the rising demand for water. Due to the increase in population the per capita availability of water is decreasing across the planet. Peter Gleick of the Pacific Institute for Studies in Development, Environment and Security, said that "approximately 1.1 billion people do not have access to clean drinking water and 2.4 billion do not have access to adequate sanitation services." Rise in population growth, rapid urbanization, industrialization, and expansion of business activities result in the depletion of aquifers and climate change. It increases the demand for fresh water. As a result, consumption patterns of water are being changed. The severe misuse of water resources causes stress on water and makes it less available. Water stress results in affecting the quality of drinking water (Reiter, L. *et al.*, 2004).

1. 2 Drinking Water Issues in Pakistan

In the list of most water-stressed countries in the world, Pakistan is already present and this stress is going to cause water scarcity (World Bank, 2005). The abundant availability of surface water resource is about 128300 million m^3 and ground water resource is about 50579 million m^3 per year in Pakistan (PNCS, 1992). With the passage of time, immense stress on the quality as well as quantity of water resources in Pakistan have been placed by urbanization, rapid population growth and unsustainable water consumption practices in the agricultural and industrial sectors (WWF - Pak, 2007).

Per capita water availability has decreased from 5,000 m^3 in 1951 to 1100 m^3 per year in Pakistan. In almost all sectors severe water shortage has been caused by the increasing gap between water demand and water supply. The principal source of drinking water for the majority in Pakistan is groundwater. In Pakistan, many major cities and rural areas rely on ground water which is thought to be the principal source of drinking water but some cities like Karachi, Islamabad, and Rawalpindi etc. have various other sources of drinking water. Punjab constitutes about 80% of fresh ground water. (Pak-SCEA, 2006)

In 2004 the population growth rate in Pakistan was stated as 1.9%. The estimated population will be 173 million in 2010 and 221 million in 2025 which shows that from 2010 onwards the per capita availability of water will be below the limits of 1000 cubic meter per year. It could create worse situation in the areas situated outside the Indus basin where per capita availability is already below 1000 cubic meter per year. (DSER, 2005)

The rapidly increasing population resulted in the rise of demand of fresh water for drinking, cooking, washing and other purposes and has eventually deteriorated the drinking water quality. Contamination of drinking water is caused by several potential sources. According to Abid & Jamil (2005); Kahlown, Tahir, & Sheikh (2004); Jehangir (2002); Sun-OK *et al.*, (2001) pipe leakages, intermittent water supply problems in sewerage system and shallow water table due to human activities are the major sources of bacteriological contamination in rural as well as urban areas throughout the country. According to Tahir (1989); Tahir & Bhatti (1994); Din *et al.*, (1997); Tahir *et al.*, (1998); Sajjad & Rahim (1998); Hussain & Mateen (1998); Sial & Mehmood (1999); Latif Akram, & Altaf (1999); Chandio (1999); and Tahir (2000), in industrial areas the major source of ground water contamination is chemical pollution which is caused by nitrogenous fertilizers, industrial effluent containing toxic substances, pesticides, textile dyes, arsenic and other chemicals. According to WHO, Government of Pakistan Ministry of Health, (2006) other causes of drinking water pollution are floods, fungicides, sewage breakdowns, excessive monsoon rains, herbicides, untreated municipal waste, oil spills and waste discharges that cause coastal water pollution.

Untreated sewage is carried by storm water drains and nullahs which ultimately discharge into irrigation canals, streams and rivers causing surface water pollution due to bacteriological and other contamination mostly in urban centres. Surface water bodies are receiving about 2000 million gallons of sewage every day (Pak-SCEA, 2006).

In Pakistan petrochemicals, food processing, paper and pulp, refineries, tanneries, sugar industries and textile are the major industrial contributors to water pollution. More than 80% of the total industrial effluents are produced by the industrial sub-sectors of paper and board, cement, sugar, polyester yarn, textile, and fertilizer. Discharge of waste water from sugarcane industries contains high concentration of pollutants and is a major cause of industrial water pollution. (World Bank, 2005; Zakaria, 2005)

1.3 Policies, Programs and Laws regarding water Issues in Pakistan

Following are the policies, framework and Laws related to water issues in Pakistan:

- Draft National Water Policy
- National Environment Policy
- Pakistan Environmental Protection Act 1997 (Regulatory Framework)
- Canal and Drainage Act (1873) related to pollution prevention of water bodies
- The law which prohibit the corrupting or fouling of canal water is Punjab Minor Canals Act (1905)
- The law which prohibits the discharge of untreated sewage and industrial waste into water is Sindh Fisheries Ordinance (1980)
- The Greater Lahore Water Supply Sewerage and Drainage Ordinance (1967)
- The government has launched nationwide clean drinking water program under two parallel phases which are the "Clean Drinking Water Initiative" (CDWI) and,
- The "Clean Drinking Water for All" (CDWA). (WWF - Pak, 2007)

1.4 The Study Area (Rawal Town)

The current study was taken to assess the water quality of water purification plants and source tube wells and their impacts on health among urban population of Rawalpindi. Mostly urban population of Rawalpindi lives in Rawal Town that is why it was selected as the research area.

Rawalpindi is the forth largest city of Pakistan. According to Rawalpindi status quality report (2006), Rawalpindi city comprises of two towns which are:

- Rawal town and
- Pothohar town

Rawal Town as the research area has a total of 46 UCs. Tehsil Municipal Administration (TMA) and Rawalpindi Water and Sanitation Agency (WASA) are providing water and sanitation facilities in the city. According to Water and Sanitation Agency, Rawalpindi is getting 10 million gallons per day (MGD) water from Rawal Lake filtration plant, 14.6 MGD water from Khanpur Dam through Sangjani filtration plant, Tomar Service reservoirs and from 272 tube wells. Out of 14.6 MGD water from Khanpur Dam only 6MGD water is available to the city because the storage capacity of the reservoir is reduced due to drought and silting. Seventy five percent of the total population is getting water in the service area from different sources and 35% of the service area is covered by piped sewerage (RSQR, 2006).

Ground water is the main source of Rawalpindi city for drinking, cooking, washing and other purposes which is being contaminated due to the recharge mechanism of nullahs and drains. Raw sewage is discharged untreated into street and drains because 60 % of the city has no sewerage system. These drains then ultimately discharge into nullahs. Piped sewerage has limited coverage in Rawalpindi city. Sewerage lines are undersized causing overflow of sewage around streets. Appurtenances and sewer lines are damaged. Overflow and chocking of sewer lines allows sewage to mix with drinking water lines. Sewerage network installed is hydraulically and technically ill planned. Another source of contamination is the blockage of drains and nullahs due to the disposal of solid waste. Waste water collection is not proper and there is no regular and constant monitoring of water quality of Rawalpindi city (Islam-ul-Haq, Cheema, W.A. 2007).

1.5 Drinking Water Contaminants and Waterborne Diseases

In developing regions, the major source of microbial pathogens (Ashbolt *et al.*, 2001; Hunter *et al.*, 2002) is drinking water. Pathogens are of faecal origin and are transmitted via drinking water. Enteric pathogens act as the indicator to assess the quality of drinking water. *Escherichia coli* (*E. coli*), which is excreted in the faeces of all warm-blooded animals and some reptiles, is the faecal indicator bacterium (Edberg *et al.*, 2000; Enriquez *et al.*, 2001). Waterborne pathogens that cause waterborne diseases and illness in developing countries are of different categories (CDC, 2009; White *et al.*, 1972):

Table 1.5.1 Categories of Waterborne Pathogens and Waterborne Diseases

WATERBORNE PATHOGENS	PRIMARY SOURCES	MAJOR WATERBORNE DISEASES
BACTERIA		
Salmonella typhi	Human faeces	Typhoid fever
Salmonella paratyphi	Human faeces	Paratyphoid fever
Other *Salmonella*	Human and animal faeces	Salmonellosis
Shigella spp.	Human faeces	Bacillary dysentery
Vibrio cholera	Human faeces	Cholera
E. coli	Human faeces	Gastroenteritis
Yersinia enterocolitica	Human and animal faeces	Gastroenteritis
Campylobacter jejuni	Human and animal faeces	Gastroenteritis
Leptospira spp.	Animal and human urine	Leptospirosis
ENTERIC VIRUSES		

Rotaviruses	Human faeces	Gastroenteritis
Adenoviruses	Human faeces	Upper respiratory and gastrointestinal illness
Hepatitis A virus	Human faeces	Infectious hepatitis
Hepatitis E virus	Human faeces	Infectious hepatitis; miscarriage and death
Polio viruses	Human faeces	Poliomyelities
PROTOZOA		
Acanthamocba castellani	Human faeces	Amoebic meningoencephalitis
Balantidium coli	Human and animal faeces	Balantidosis (dysentery)
Cryptosporidium homonis, C. parvum	Water, human and other mammal faeces	Cryptosporidiosis (gastroenteritis)
Entamoeba histolytica	Human and animal faeces	Amoebic dysentery
Giardia lamblia	Water and animal faeces	Giardiasis (gastroenteritis)

According to Pak-SCEA (2006), Pakistan Council for Research in Water Resources (PCRWR) has conducted first phase of a national water quality study in 2001 covering 21 cities. Half of the samples from 17 cities and all samples from 4 cities had bacteriological contamination. While in the second phase of the study conducted in 2004 appreciable improvement was not seen.

According to Asif, Umar, M. *et al.*, (2001), "In 1995, acute infectious diarrhoea caused more than 3 million deaths world wide in children less than 5 years of age, a death rate that has gone down from 5 million per year in 1987. Most of the deaths occur in developing countries, where two third of the world's population live". One forty million diarrhoeal cases and 80% of viral etiologies are represented by rotaviruses per year (Albert *et al.*, 1999). Children mortality rate due to waterborne diseases in developing countries is high with 870,000 deaths per year (WHO, 1997). According to WHO (2003a) and Kindhauser (2003) globally 1.1 billion people drink unsafe water and 88% of the diarrhoeal diseases are due to unsafe water and sanitation. Cholera was proved to be the waterborne disease by Dr. John Snow in 1855 (USEPA, 2000). Five hundred and seventy eight infectious disease outbreaks were verified by WHO in 132 countries from 1998 to 2001 and found that most frequent was cholera with acute diarrhoea (WHO, 2002). Worldwide, there was annual incidence of about 17 million cases of typhoid and paratyphoid fevers caused by *S. paratyphi* and *Salmonella typhi* (Kindhauser, 2003). According to WHO (2003a), 99.8% deaths related to water and sanitation and 90% children's deaths occur in developing countries.

"A study conducted by UNICEF found that 20-40% of the hospital beds in Pakistan are occupied by patients suffering from water-related diseases, such as typhoid, cholera, dysentery and hepatitis, which are responsible for one third of all deaths. Diseases such as typhoid, cholera, dysentery and hepatitis, are responsible for 33% of deaths" (Pak-SCEA, 2006).

According to HDR (1998), in developing countries 20% of the total disease burden is accounted by diarrhoea and dysentery. In the developing world diarrhoea and dysentery are produced by polluted water every year and death of 5 million people including 3 million deaths of children is caused by diarrhoeal diseases. Due to contaminated water there are 900 million cases of intestinal worms every year.

Children in poor households suffering from waterborne diseases have three to four time greater risks of death than the children in rich households. One of the world's greatest killers is diarrhoea caused by unclean water, claiming the lives of five times as many children as HIV/AIDS. The risk of a child dying by as much as 50% can be reduced by access to safe water and sanitation. "Water and sanitation are among the most powerful preventive medicines available to governments to reduce infectious diseases. Investment in this area is to killer diseases like diarrhoea what immunization is to measles—a life-saver". (HDR, 2006)

1.6 Drinking Water Treatment

Water treatment technology for the purification of water is not new and focused on improving the aesthetic values of water use for drinking. As early as 4000 BC, to improve taste and odour of drinking water different methods were recorded. Greeks and Sanskrit used water treatment methods like boiling, charcoal filters, straining and exposure to sunlight to improve the aesthetic quality of drinking water (WHO, 2003b). As early as 1500 BC, calcium alum was used by Egyptians to clarify water. Filtration of water to remove particles from it was established during 1700 BC. In Europe, slow sand filtration was started to be used regularly by the early 1800. During early 1900, drinking water treatment system design was built in U. S cities to remove microbial contamination from drinking water that cause waterborne diseases. For the primary disinfection of drinking water chlorine was used first time in 1908 in New Jersey. Safe Drinking Water Act was established in 1974. (USEPA, 2000)

Following are the approaches used for the treatment of drinking water quality.

1. Dual or combined system:

In this approach the combined water distribution network supplying domestic water is improved.

2. Separate or single line system:

   This approach involves to installing separate drinking water distribution network in addition to the combined domestic water distribution network.

3. Water Purification plants:

   In this approach, at reasonable distance from the consumer, water purification plants are installed so that consumers cover recommended maximum distance of less than 1 kilometre for fetching drinking water.

1.7 Water Purification Plants

Pakistan has adopted the approach of installing water purification plants for the treatment of drinking water, as it is cost effective, by initiating "Clean Drinking Water for All" (CDWA). According to this act, 6,579 water purification plants had to be installed throughout the country. (WWF-Pak, 2007). According to Tehsil Municipal Administration a total of 120 water purification plants were installed in Rawalpindi to treat and to provide quality water to consumers. Out of 120 water purification plants, WASA reported a total of 89 water purification plants. Aristocratic families could buy bottled water and make their families safe from the harm of poor quality water. But poor families cannot afford to buy bottled water. The only source for deprived classes for getting safe water is water purification plants; therefore TMA have installed water purification plants to facilitate and improve epidemic conditions of poor classes.

In water purification plants different treatment of water is done through different filtration processes. According to (LeChevallier, Keung, K. 2004) Water filtration can be used as an effective barrier for microbiological pathogens. Drinking water treatment can be done by various filtration processes which are as follows:

1.7.1 Granular Media Filtration

In drinking water treatment the most widely used filtration process is granular media filtration. Better removal of chlorine resistant cysts and protozoan pathogens is achieved by granular media filtration. Filter consisting of bed of granular material allows water to pass through the bed. Microbes are removed by depositing on the filter media. When both adsorption of the organic compound and filtration of particles are required, granular activated carbon is used. (LeChevallier, Keung, K. 2004). According to Yao, Habibian &. O' Melia (1971) two steps for the removal of particles by granular filtration are as follows:

- From suspension to filter medium transport of particles
- Attachment of particles to medium which is determined by the surface and solution chemistry of the system (Tobiason & O' Melia, 1998).

1.7.2 Sand Filtration

According to LeChevallier & Keung, K. (2004) slow sand filtration has the ability to remove parasites especially chlorine resistant protozoan pathogens. Slow sand filter consist of a layer of silica sand. Microbes and other substances are removed by passing water through the filter. Biological action, attachment of microbes to the sand media and physical straining are the three removal mechanisms (Weber-Shirk, M.L, Dick, R.I. 1997 a b).

1.7.3 Membrane Filtration

A thin semi permeable membrane in membrane filter is used to remove contamination from water by acting as a selective barrier. It is used for the removal of pathogens in drinking water treatment. Micro filtration and Ultra filtration are the most commonly used membrane processes (LeChevallier, Keung, K. 2004). Micro filters having the pore size of ≥ 0. 1 μm removes particles, turbidity and microbes including algae, protozoa and most bacteria. Ultra filters having the pore size of ≥ 0. 01 μm allows the removal of dissolved non-ionic solutes, microbes including algae, protozoa, most bacteria and viruses (AWWA, 1996; Taylor & Weisner 1999).

1.7.4 Disinfection Processes

Disinfection is a component of the treatment of drinking water and is important because all microbial pathogens are not removed from water by granular media filtration. Factors that affect disinfection are contact time, pH, temperature and disinfectant concentration. Different types of disinfectants are chlorine, chloramines, chlorine dioxide and ultra violet light (LeChevallier, Keung, K. 2004).

Chlorine

If the turbidity of water is ≤ 1.0 nephelometric turbidity unit (NTU), chlorination effectively removes viruses. For inactivation of viruses contact time of chlorine residual is 30 minutes. Sodium hypochlorite or calcium hypochlorite is used for chlorination (LeChevallier, Keung, K. 2004). According to Baker (1926) chlorine destroys micro-organisms by combining with proteins to form N-chloro compounds. Halogenated organic compounds such as trihalomethane (THM) and chloro-phenols are formed by the reaction of chlorine with natural organic matter and causes risks to human health (USEPA, 1990a).

Chloramines

With respect to bio-film control, chloramines are most effective disinfectants as compared to chlorine and are used to control taste, odour and are more stable in distribution system than free chlorine (Kirmyer *et al.,* 1993; LeChevallier, Lowry & Lee, 1990). Lower concentrations of disinfectant-by-products (DBPs) are produced by chloramines as compared to chlorine (Symon *et al.,* 1998).

Chlorine Dioxide

Chlorine dioxide is used to reduce trihalomethane (THM), control taste and odour and oxidize iron and manganese in drinking water system (Hoehn *et al.,* 1992). Chlorine dioxide produces chlorate and chlorite ions as reaction by-products. Chlorine residual does not last long and it breaks into chlorite and therefore it is not effectively used as disinfectant in distribution system. (USEPA, 2004)

Ultra Violet Light

UV-B and UV-C ranges of the spectrum (200-310 nm) are effective for the inactivation of micro-organisms. When UV light reacts with thymine bases on deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), thymine dimmers are formed that makes organism sterile by inhabiting the transcription and replication of nucleic acid. High dosage is given in ultra violet disinfection to ensure the damage of nucleic acid. The effective disinfectant for bacteria and viruses is UV light. (LeChevallier, Keung, K. 2004)

1.8 Drinking Water Quality Guidelines and Standards

According to National Water Quality Monitoring Programme (PCRWR, 2002), to provide safe and clean drinking water to all the citizens is the basic purpose of making guidelines and standards. Guidelines for drinking water have been provided by World Health Organization (WHO) which are based on epidemiological findings and scientific research and are advisory in nature. Drinking water quality standards have already been drafted by Pakistan Standard Institution (PSI) and PCRWR but their enforcement is still pending. Different bacteriological quality guidelines and standards of drinking water are as follows:

1.8.1 WHO Guidelines for Bacteriological Qualities

Source/Organisms	Guideline Value
a. All water intended for drinking (E. Coli or thermo tolerant Coliform bacteria)	Must not be detectable in any 100 ml sample
b. Treated water entering the distribution system (E. Coli or thermo tolerant coliform and total coliform bacteria)	Must not be detectable in any 100 ml sample
c.Treated water in the distribution system (E. Coli or thermo tolerant coliform and total coliform bacteria)	Must not be detectable in any 100 ml sample
	In the case of large supplies, where sufficient samples are examined, must not be present in 95% of samples taken throughout any 12-month period.

(PCRWR, 2002)

1.8.2 Bacteriological Standards Drafted By PCRWR

Categories	Standards
A. *Piped Water Supplies*	
A-1 Treated water entering the distribution system	
· Faecal Coliform	0/100 ml
· Coliform organisms	0/100 ml
A-2 Un-treated water entering the distribution system	
· Faecal Coliform	0/100 ml
· Coliform organisms	0/100 ml
· Coliform organisms	3/100 ml
A-3 Water in the distribution system	
· Faecal Coliform	0/100 ml
· Coliform organisms	0/100 ml
· Coliform organisms	3/100 ml
B. *Un-piped Water Supplies*	
· Faecal Coliform	0/100 ml
· Coliform Organisms	10/100 ml

(PCRWR, 2002)

1.8.3 Limits for Bacteriological Contaminants by Pakistan Standard Institution

Acceptable bacterial standards for potable water supplies:	Column1
i) Standard plate count (SPC) / mls	No more than 100
ii) Presumptive test for Coliform	Negative
iii) Most probable number (MPN)	< 101 subject to the frequency of opportunity for water analysis.

(PCRWR, 2002)

1.8.4 Bacteriological Quality Standards by International Bottled Water Association

Total Plate Count/ml	CFU/ml	<200	Escherichia coli	MPN/100 ml
Coliform (MPN/100 ml)	MPN/100 ml	<2,20	Salmonella	CFU/100 ml

(PCRWR, 2002)

1.8.5 Indian Bacteriological Water Quality Standards

i) Water entering the distribution system coliform count in any sample of 100 ml should be zero.
ii) Water in the distribution system shall satisfy all the three criteria indicated below:
· E.Coli count in 100 ml of any sample should be zero;
· Coliform organisms no more than 10 per 100 ml shall be present in any sample; and
· Coliform organisms should not be detectable in 100 ml of any two consecutive samples or more than 50% of the samples collected for the year.
iii) Individual or small community supplies.

(PCRWR, 2002)

1.8.6 Bacteriological Drinking water Standards of Vietnam, Japan, China, Hong Kong, Korea and Taiwan

Sr.#	*Substances*	*Unit*	*Vietnam*	*Japan*	*China*	*H. Kong*	*Korea*	*Taiwan*
1	Total Plate Count/ml	CFU/ml	<10	-	100	-	<100	-
2	Coliform (MPN/100 ml)	MPN/100ml	-	<15.100	3	<2.2	0	-
3	Escherichia coli	MPN/100ml	2.2	-	-	-	-	0/100 ml

(PCRWR, 2002)

1.8.7 Bacteriological Drinking water Standards of Indonesia, Singapore, Malaysia, Thailand, Philippine and Brunei

Sr. #	*Substances*	Unit	*Indonesia*	*Singapor*	*Malaysia*	*Thailand*	*Philippi*	*Brunei*
1	Total Plate Count/ml	CFU/ml	Max $1x10^4$	Max.1x10	-	-	-	-
2	Coliform (MPN/100 ml)	MPN/100ml	<2.20	0/250 ml	Max.10	<2,20	<2.20	Nil
3	Escherichia coli	MPN/100ml	0	0	0	Negative	-	Nil
4	Salmonella/100 ml	CFU/100 ml	-	0	-	-	-	-
5	Staphylococcus Aureus/250 ml	CFU/250 ml	-	0	-	-	-	-
6	Pseudomonas Aeruginosa/250 ml	CFU/250 ml	0	0	-	-	-	-
7	Faecal Streptococci/20 ml	MPN/20 ml	-	-	-	-	1/100 ml	-

(PCRWR, 2002)

1.8.8 Bacteriological Drinking water Standards of Saudi Arabia, Guam, Australia, Argentina, Mexico and Canada

Sr.#	*Substances*	*Unit*	*S. Arabia*	*Guam*	*Australia*	*Argentina*	*Mexico*	*Canada*
1	Total Plate Count/ml	CFU/ml	-	-	<1	500	100	100
2	Coliform (MPN/100 ml)	MPN/100ml	-	<2.20	Max.10	3	<2	-
3	Escherichia coli	MPN/100ml	-	-	-	Negative	-	0
4	Pseudomonas Aeruginosa/250 ml	CFU/250 ml	-	-	-	Negative	-	0

(PCRWR, 2002)

Objectives of the study

The study was undertaken to accomplish following objectives

- To find out the coverage status of water provided by water purification plants in Rawal Town.
- To test the bacteriological contamination in water supplied by water purification plants and source tube wells in Rawal Town.
- To find out issues related to water purification plants resulting in bacteriological contamination.
- Determining the extent of waterborne diseases among urban population in Rawal Town.

Significance of the Study

Drinking water quality was found to be the serious problem of the study area. It has been reported continuously by the newspapers that the water purification plants installed in Rawal Town have no significant effects on improving the health of urban population. Citizens have reported bad taste and odour even in the water coming from water purification plants which clearly shows that water purification plants are not properly maintained. Inefficient maintenance of water purification plants leads to the growth of microbial contaminants that ultimately results in the wide spread of waterborne diseases among the citizens. Previously, un-satisfactory and ineffective work was done regarding water purification plants and showed no appreciable improvement in the drinking water quality.

This study was aimed to find out the coverage status of water purification plants and their effects on improving the health of general public. As LeChevallier *et al.*, (1999a) said, "Knowledge is the first line of defence towards providing safe drinking water." Therefore this study was aimed to provide additional knowledge and information about the issues regarding water purification plants that result in bacteriological contamination and poses health risks among urban population. This study identified the areas in Rawal Town (specific water purification plants and source tube wells) that are providing bacteriologically contaminated water to the urban population. This study will also help water agencies to curb the problem of drinking water quality and waterborne diseases. This research study will be published both in international/regional journals and will beneficial to decision makers, researchers and environmentalists to make new and effective policies and frameworks for improving drinking water quality of water purification plants in Rawalpindi and other cities in Pakistan.

CHAPTER 2

LITERATURE REVIEW

(NAP, 1997). It is difficult for the water systems to meet the standards for drinking water in small communities because they cannot afford qualified operators and equipment. Violations of Drinking Water Standards result in the presence of viruses, bacteria and parasites in drinking water and causes waterborne diseases. There are three elements to solve the problem of providing safe drinking water to small communities. First element is to provide affordable technologies to treat water. Second element is to create institutional structure so that water systems will financially stabilize. Third element is to start improving programs for the training of small system operators and giving them knowledge about the management and maintenance of water system.

(HDR, 1998). In developing countries sewage causes contamination in water and results in water pollution. Waterborne diseases including dysentery, intestinal worms, diarrhea and hepatitis are the result of water pollution among poor people.

(Letterman, R.D., 1999). With the realization that various diseases like cholera and typhoid had been caused by contamination of water, people learned that the quality of water could not be accurately judged by taste appearance and smell. Therefore, a law was passed in London in 1852 stating that all waters should be filtered. Public health authorities have advocated the use of best source water quality that can be obtained economically. Distribution system can be preserved and protected by water treatment. Granular activated carbon adsorption is a treatment process that control taste and odour.

(Joanne E. D., 2001). Water quality parameters determine and control the raw water for public consumption. Pollutants that affect water quality are removed by water treatment process to provide safe water for consumer's consumption. Physical water quality characteristics include taste, color, odor, turbidity, temperature and suspended solids. Biological water quality characteristics include waterborne microbes like algae, bacteria, viruses and parasitic worms. So, the presence and absence of pathogens in water is of primary importance.

(EPA, 2002). The issues related to the distribution system of drinking water were discussed. It was found that non-potable water through cross connections could be connected to potable water sources. Through installing back flow prevention devices; risks due to back flow could be mitigated. The reported contaminants that entered the distribution system through back flow were pesticides, anti-freeze, detergents, sewage and coolants.

(Rompre A. *et al.*, 2002). Coli-form group as indicator of water quality had great importance in public health protection. Different methods were proposed for coli-forms monitoring in drinking water. These methods include classical methods, molecular methods and enzymatic methods.

(USEPA, 2002). Construction and repair of water mains and their rehabilitation were found to be the sources of water contamination in the water distribution system by not following the standards and procedures. These pathogenic contaminations in the water distribution system were the cause of waterborne disease outbreaks. Illness like gastroenteritis, typhoid fever, hepatitis A, viral gastroenteritis, giardiasis and amoebiasis were associated with these outbreaks.

(Kennith, M.V., 2003). Clean water cannot be taken for granted. World's water pollution problems must be addressed as members of a greater worldwide environmental community. Most people may not know about many sources of pollution of water and may not be aware of the methods and rules and regulations to prevent and control it. The most common causes of water pollution include domestic discharges, accidental spills, storm-water runoff, industrial discharges and constructions of dams. Three processes for pollution control often categorized by water quality professionals are physical, chemical and biological. It introduced that human activities and natural conditions like geology, climate, morphology and vegetation etc influence water quality. It outlined different methods of preventing water pollution like filtration, sedimentation and biodegradation etc. Clean Water Act and Safe Drinking Water Act are the important rules and regulations of water quality.

(Reiter, L. *et al.*, 2004). It focuses on whether safe drinking water is being adequately provided by science and technology and the risks carried by drinking water. It introduced the assessment and management practices for source water protection and their health impacts. Ground water, surface water and atmospheric deposition are connected by hydrological cycle that is why for studying source of contamination it is an emerging area. It also outlined the global water issues and their implications at the water and human health.

(Ashbolt, N.J., 2004). In developing regions drinking water is the major source of pathogens. 1.7 million Deaths per year are due to poor water quality, sanitation and hygiene. *Rotavirus, Campylobacter jejuni, enterotoxigenic Escherichia coli, Shigella spp.* and *Vibrio cholera* are the major enteric pathogens among children.

(WHO, 2004). These guidelines focused on general consideration and principles, roles and responsibilities in drinking water safety management. It also gives the framework for safe and clean drinking water. Health based targets and water safety plans were discussed. These guidelines also explained the chemical and microbial aspects.

(LeChevallier, W. and Keung, K., 2004). Various disinfection processes for the treatment of drinking water to inactivate micro-organisms and pathogens were discussed. It was found that drinking water was treated by different processes like sand filtration, Granular Activated Carbon filtration, micron filtration and UV filtration. It was found that multiple barriers, adequate design and operation to ensure performance should be included in control programs.

(Ahmed, T. *et al.*, 2004). After chlorination coli-forms growth was observed in water samples taken from the filtration plant of Rawal dam. There was no coli-form growth after chlorination in the water samples of Simly dam. Samples collected from the storage of Khanpur dam even after filtration and chlorination contains microbial growth. So it was found that the quality of water used for drinking and other purposes supplied to the citizens of Islamabad and Rawalpindi was poor even after chlorination and filtration.

(Pak-EPA, 2005). The geographical location of filtration plants were recorded by using geographical Positioning System. Water sampling was preformed according to standard sampling method. There were total 5 filtration plants in Islamabad. There was no chemical contamination in those filter plants while 3 filter plants have bacteriological contamination. Total numbers of inefficient filter plants were 3 so there was 60% inefficient water filter plants in Islamabad. While in Rawalpindi there were total 26 filter plants out of which 2 filter plants have chemical contamination and 14 filter plants have bacteriological contamination. Total 16 filter plants were inefficient. 61% inefficient water filter plants were installed in Rawalpindi. It was concluded that water supply form these inefficient filter plants are unsafe for consumption of human beings.

(Omelchenko, A. *et al.,* 2005). To give protection against water related health risks various activities should be implemented including water management systems development, continuous monitoring and control of water, environmental protection and improved standards and regulations. Chloramination, ultra violet radiations, ozonation and chloride dioxide disinfection are the disinfection processes for microbiological contamination.

(NRC, 2005). Installation, repair and rehabilitation of water mains cause microbial contamination in the drinking water which has significant health impacts. Distribution system operators should receive adequate training as they are responsible for ensuring that conveyance of the water does not allow degradation of water quality.

(PMU-WASA, 2006). Population of Rawalpindi is rapidly increasing and results in the little or no access to clean drinking water and sanitation facilities, the serious environmental issues. WASA/RDA and RCB are the two independent agencies responsible for the administration of Rawalpindi Water Supply System. Tube wells are the ground water sources covering about 60% of city's water demand and about 40% from the surface water sources i.e. Khanpur dam and Rawal Lake. Drinking water supplies to Rawalpindi is of poor quality and has bacteriological contamination and is not according to the WHO guidelines. Therefore, periodic water quality monitoring and testing program is required to launch by dividing city into various zones under REIP package-B.

(HDR, 2006). The most powerful drivers for human development are clean water and sanitation. Urbanization, population growth, industrial development and agriculture needs have driven up the demand for water which is the finite resource. Water purification has broken the link between the dirty water and infectious disease and has reduced about half of the mortality.

(Fitchner GmbH & Co, 2006). Tehsil municipal administration and water and sanitation agency provides water and sanitation facilities in Rawalpindi city. The population of Rawalpindi city is increasing at a rate of 4.29% per year. In Rawalpindi city 35% of the service area is covered by piped sewerage and there is no treatment of collected sewerage. Raw water quality is monitored daily at source i.e. from Rawal Lake. Raw water quality at sangjiani filtration plant is also monitored and reported on regular daily basis.

(WHO, 2006). Research based standard and guidelines for quality drinking water must be available to monitoring agencies to ensure that quality water is being received by consumers through out the country.

(Islam-ul-Haq., and Cheema, W.A., 2007). It was found that Rawalpindi WASA was collecting only 35% of the total waste water while 65% remaining waste water was being disposed off into open drains and these drains ultimately drain off into Nullah Lai. 220 tube wells were producing bacteriological contaminated water. Ground water sources of Rawalpindi could be protected by constructing the box channel to intercept the dry weather flow and by proper lining of streams and Nullah Lai that would terminate the infiltration and seepage of contaminated water.

(USEPA, 2007). It was found that by inactivating pathogenic microbes in the distribution system, indicating the upset of distribution system and by controlling the growth of bio-film; integrity of distribution system could be maintained. It introduces the guidelines and requirements of existing disinfectant residuals and it was discussed that secondary disinfectant must be made on system by system basis.

(Kunikane, S., 2007). Key steps in developing a water safety plan include the assemblage of team to prepare the plan, documentation and description of a system, risk characterization, hazard assessment, identification and monitoring of control measures, verification of water safety plan by establishing procedures. Water safety plan should meet the health based targets. Supporting programs should be developed and procedures for management and communication should be prepared.

(WWF-Pak, 2007). Urbanization, rapid population growth and unsustainable consumption practices placed stress on the quality of water. Per capita availability of water has been decreased from 5000 cubic meter to 1100 cubic meter. Sugar industries, petrochemicals, food industries, paper and pulp are the major industrial contributors in Pakistan.

(Hafeez, A., 2008). The process of water purification reduces the concentration of viruses, bacteria, fungi, parasites, algae and suspended particles etc. Pre-treatment of water includes pumping and containment, screening, storage and pre-conditioning. The last step in purification of drinking water is disinfection which can be done by adding disinfectants like chlorine, chlorine dioxide, chloramines and hydrogen peroxide, ozonation and ultra violet radiation is also used to disinfect water. It also introduces the drawbacks of chlorination and health issues about chlorinated drinking water.

(Doria, M.F. *et al.*, 2009). Drinking water supplied to consumers must have the trust of consumers. Public perception of drinking water quality and risks were identified. Satisfaction with organoleptic properties especially flavour influenced the perception of water quality. Past health problems, organoleptic, trust in water suppliers and perceived water chemicals influenced the perception of risk of water quality.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

To study "drinking water quality of water purification plants and source tube wells and their health impacts among urban population of Rawalpindi" 60 water purification plants and their source tube wells were selected. Rawalpindi city is divided into Rawal town and Pothohar town. Most of the urban population of Rawalpindi lives in Rawal town that is why it was selected as the experimental area.

3.2 Water purification Plant Sampling Strategy

Urban population of Rawal town according to 1998 census report included of 781927 inhabitants. TMA (Tehsil Municipal Administration) have installed a total of 120 water purification plants, out of them WASA (Water and Sanitation Agency) has reported 89 water purification plants.

Sample size was taken by considering two criteria:

1. Random sampling based on statistical criteria
2. Spatial distribution of water purification plants

$$n = \frac{\left(\frac{P[1-P]}{\frac{A^2}{Z^2} + \frac{P[1-P]}{N}} \right)}{R}$$

(Blalock, Hurbert M., 1972)

Using standard statistical formula for sample size collection from a total of 89 water purification plants operated by Water and Sanitation Agency (WASA) Rawalpindi, considering variance (P) as 90% - 10% = 0.1, error ratio or precision desired (A) as 5%, confidence level (Z) as 1.96 for 95% and response level as 100%; n=54. So the sample size required came out to be 54, but considering spatial distribution of water purification plants, sample size was increased to 60 for further accuracy and to elaborate the status of clean water supply through water purification plants.

Spatial locations of the water purification plants were recorded using Geographical Positioning System (GPS) Magellan Explorer 500 by locating geographic coordinates.

Water purification plants and source tube wells were selected by stratified random sampling. The possible convenient source tube well and water purification plant was selected as a starting point which was a time saving method. Otherwise it was difficult to find pre selected water purification plants and source tube wells. A guide map of Rawal town was taken from Water and Sanitation Agency (WASA) containing all information about source tube wells; which made it easy to find out the water purification plants in study area.

3.3 Sampled Water Purification Plants

All 60 sampled water purification plants, their source tube well numbers and their Union Councils are as follows:

Table 3.3.1 Sampled Water Purification Plants

PP no	UC	PURIFICATION PLANT ADDRESS	TUBE WELL NO
PP#1	1	Union Council# 1, Ratta Amral Chungi Millad Nagar	74A
PP#2	1	Jamiya Masjid Mai Sharfan, Ratta Amral	74B
PP#3	1	Imam Bargah Road Milad Nagar, Ratta Amral	76A
PP#4	1	Bhoosa Bazar, Dhoke Ratta	75
PP#5	2	Water Purification Plant, Tohidi Road	78
PP#6	6	Mohallah Gulshan Data, Dhoke Hassu	86
PP#7	10	Union Council# 10, Khayaban-e -Sir Syed, Sector 2	160
PP#8	10	Union Council # 10, Khayaban-e-Sir Syed	168
PP#9	11	Muhammadi chowke Khayaban-e-Sir Syed	166
PP#10	11	Union Council # 11, Khayaban-e-Sir Syed	162A
PP#11	13	Union Council # 13, Khayaban-e-Sir Syed, Dhoke Najju	105
PP#12	13	Union Council # 13, Noor Pariyan, New Katariyan	169
PP#13	13	Union Council # 13, F Block, New Katariyan	2
PP#14	13	Quaid-i-Azam Park, Satellite Town F Block	4
PP#15	13	New katariya market	1
PP#16	17	Mutton Market, Pindora	10
PP#17	17	Nawaz Shrif Park, Dhoke Babu Irfan	8
PP#18	19	D Block New Town, Commercial Market	117
PP#19	20	B Block, Commercial Market	129A
PP#20	20	High School, Mohallah Muslim	125
PP#21	21	Water Purification Plant, Dhoke Kala Khan	15
PP#22	23	Water Purification Plant, Data Ganj Baksh Road	7
PP#23	23	Union Council # 23, Dhoke Kashmiriyan	175A
PP#24	24	Union Council # 24, Mohallah Aliabad	17B
PP#25	25	Water Purification Plant, 6 Road, A Block	21
PP#26	26	Water Purification Plant, Satellite Town, C Block	36
PP#27	27	Water Purification Plant, Raheem Town	28
PP#28	27	Water Purification Plant, UC Nazim Town Muslimabad	28A

PP#29	28	Union Council # 28, Muslim Town	31
PP#30	28	Water Purification Plant, Service Road, Muslim Town	30
PP#31	29	Water Purification Plant, Behari Colony	32
PP#32	30	Union Council # 30, Graveyard Road Qasimabad	48
PP#33	31	Water Purification Plant, Haq Nawaz Road, Qasimabad	45A
PP#34	31	Union Council # 31, Water Purification Plant	45
PP#35	31	Water Purification Plant, Behria Town, Sultanpura	37
PP#36	33	Water Purification Plant, Bunni Chock	133
PP#37	33	Union Council # 33, Kohati Bazar	132
PP#38	33	Union Council # 33, Kartarpura	131
PP#39	33	Water Purification Plant, Mohallah Feroze Pura	131A
PP#40	34	Union Council #34, Bunni Thana	148
PP#41	34	Union Council # 34, Private Filter	148A
PP#42	34	Water Purification Plant, Bunni Mohallah	149
PP#43	35	Union Council # 35, Water Purification Plant	154
PP#44	36	Water Purification Plant, Lai Pull, Dhoke Ratta	74
PP#45	36	Union Council # 36, College, Mohanpura	72A
PP#46	36	Union Council # 36, Dispensory Road, Mohanpura	71
PP#47	37	Water Purification Plant, Peerwadahi Pul	144
PP#48	38	Water Purificaion Plant, Tire Bazar, Ganj mandi	140A
PP#49	39	Water Purificaion Plant, Chittian Hattian	136A
PP#50	41	Water Purificaion Plant, Pull Shah Nazar, Jamiya Masjid Road	150
PP#51	42	Union Council # 42, Near committee Chowk, Dhoke Elahi	52
PP#52	42	Opposite Committee Chock, Millat Colony	46
PP#53	42	Mohallah Qasimabad, Talab Taliyan	48A
PP#54	43	Union Council # 43, Water Purification Plant	47
PP#55	43	Water Purification Plant, Dhoke khabba	51
PP#56	45	Union Council # 45, Water Purification Plant	58B
PP#57	46	Near TMA Office, Liaqat Road	64
PP#58	46	Water Purification Plant, Chaman Zar Colony	60B
PP#59	46	Water Purification Plant, DAV College Road	64A
PP#60	46	Water Purification Plant, Fawara chock	70

PP no= Water purification plant number

3.4 Data Collection (Interviews/Questionnaires)

Data regarding various aspects of present study were gathered from different sources that include:

Statistical officers of population census organization

Statistical officers of census department were asked about the data regarding union councils and their respective population in Rawal town. As a result, booklets and CDs (Compact Disks) were received containing all information about Rawal town.

Operators of water purification plants

Interviews with operators of water purification plants were conducted using semi-structured questionnaire. The questionnaire was designed considering the study objectives. Operators were asked about the filter change frequency, presence of hypo-chlorinators in tube wells, physical maintenance of equipment in water purification plants, operator training, use of operating standard or manuals provided by manufacturers, sanitization mechanism, backwash system and number of water purification plants under their supervision.

Consumers fetching water from water purification plants

Consumers were interviewed using semi-structured questionnaire. Consumers were asked about the travelling distance, frequency of fetching water, containers used, problems faced during water collection and quality of water fetched.

Doctors, nurses and statistical department of different hospitals

Holy family hospital, Benazir Bhutto hospital and PHC hospital were visited for the collection of data regarding waterborne diseases. Doctors, nurses and statistical officers of these hospitals were verbally interviewed and asked about the frequency of waterborne diseases among urban population of Rawalpindi. They information was furnished from primary record sheets of hospitals regarding waterborne diseases.

3.5 Microbiological Analysis

Water samples were taken from water purification plants and source tube wells to test water quality. Water quality tests were conducted through 'Water Check' kits developed by Merck and some tests were conducted at PCRWR (Pakistan Council of Research in Water Resources). Major indicators for microbiological contaminants include *Escherichia Coli (E. coli)* and *Total Coli-forms* that cause waterborne diseases. So tests for *Total Coli-forms* and *E. coli* were analyzed by using most probable number (MPN) at PCRWR (Pakistan Council of Research in Water Resources) to see the faecal contamination in drinking water.

3.6 Water Sampling Procedures for Microbiological Testing at (PCRWR)

Water sampling procedures taken into consideration for microbiological testing were:

1. Spray spirit on hands up to arms for disinfection purpose.

2. Remove any attachments from the tap such as pipes, filters etc. open the tap for 5 minutes to flush out the standing water, close the tap and clean it with tissue paper. Spray a small quantity of spirit on the surface of tap and flame it with match stick and let it cool down.
3. After flaming, open the tap again to turn the water down to a thin stream (about the width of a pencil) and let it run for one minute.
4. To avoid contamination while taking the sample, hold the bottle near the bottom with one hand, hold the cap of the tap with the other, and then unscrew the cap. Do not place the cap on the ground. Sampling will be more reliable if performed near flame.
5. Hold the bottle under the stream of water, being careful not to let the bottle touch the sample tap. Fill the bottle to the neck (leave 1" from the top) but do not allow it to overflow. Remove the bottle from the water flow and replace the cap.
6. Label the bottle with permanent marker and keep in insulated ice box having sterilized coolants (under controlled condition of 4°C). Sample should be delivered to laboratory as soon as possible.

3.7 'Water Check' Kits

Merck has developed "Water Check" kit to check faecal / sewerage contamination in drinking water. It can either be municipal source, bottled form, cane water or water coming out from filters used to clean drinking water at home.

Contents

1. Blister pack for 50 ml of water sample
2. Sterile container

Procedures

1. Open the screw cap of container and pour 50 ml of water (bottled, cane, tap, filter) into it up to the given red line mark.
2. Take out blister pack; shortly tap to ensure the granules settled down at the bottom. Break it at the neck with hands.
3. Add the contents of the blister pack to the given container having water close to the mouth with the cap and shake to completely dissolve the granules.
4. Put it at room temperature, away from children's reach. Check the colour of water after 48 hours. Colour change of water to any shade of green and blue shows sewerage contamination which means that water is not fit for drinking.
5. No change in colour or to yellow, off-white, brownish shade means no faecal or sewerage contamination, water can be used for drinking.

3.8 Data Processing, Analyzing and interpretation

For statistical analysis of data collected MS-excel 2007 and SPSS7 were used. Data gathered were organized and then graphs and tables were generated after analysis through above mentioned software. Smart Draw software was used to generate diagrams for design of water purification plants.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter describes all the results after analysis of the data collected. As water is the primary requisite for the survival of humans or animals, therefore provision of safe and clean drinking water is necessary for their lives. Rawal Town is facing many water quality problems. TMA and WASA/RDA are the agencies which are providing water to the urban population of Rawal Town for drinking, cooking, washing and other purposes. Water purification plants were installed by TMA to provide safe drinking water and Water and Sanitation Agency Rawalpindi is managing these water purification plants.

4.1 Coverage Status of Water Provided By Water Purification Plants in Rawal Town

Rawal Town as the research area has total 46 UCs (Union Councils). Table 4.1.1 shows the names of all 46 UCs (Union Councils), population of UCs (Union Councils) in 1998 according to the census report and estimated population in 2009.

Table 4.1.1 UCs & Estimated Populations in Rawal Town

UC NAME	UC No	1998 POPULATION	2009 ESTIMATED POPULATION
Ratta Amral	UC 1	18445	26616
Dhoke Ratta	UC 2	18277	26374
Hazara Colony	UC 3	13959	20143
Dhoke Mangtaal	UC 4	20128	29045

Dhoke Hassu North	UC 5	13000	18759
Dhoke Hassu South	UC 6	12643	18244
Peer Wadhai	UC 7	17294	24955
Fauji Colony	UC 8	18155	26198
Bangash Colony	UC 9	18880	27244
Khayaban-e-Sir Syed North	UC 10	14456	20860
Khayaban-e-Sir Syed South	UC 11	15962	23033
Dhoke Najju	UC 12	17814	25705
New Katariyan	UC 13	16929	24428
Satellite F Block	UC 14	15677	22622
Saidpur Scheme	UC 15	16635	24004
Mohallah Eid Gah	UC 16	14557	21006
Dhoke Babu Irfan	UC 17	19261	27793
Pindora	UC 18	18482	26669
Satellite Town	UC 19	18242	26323
Asghar Maal Scheme	UC 20	19681	28400
Dhoke Kala Khan	UC 21	16530	23853
Qayummabad	UC 22	16318	23547
Dhoke Kashmiriyan	UC 23	17193	24809
Dhoke Ali Akbar	UC 24	16398	23662
Sadiqabad	UC 25	16931	24431
Afandi Colony	UC 26	14964	21593
Muslim Town East	UC 27	14597	21063
Muslim Town West	UC 28	17993	25964
Khurram Colony	UC 29	17185	24798
Chah Sultan	UC 30	19320	27879
Dhoke Hukam Daad	UC 31	19615	28304
Amar Pura	UC 32	18285	26385
Kartar Pura	UC 33	15961	23032
Banni	UC 34	16152	23307
Mohallah Imam Bara	UC 35	16988	24514
Mohan Pura	UC 36	17579	25366
Dhoke Dalal	UC 37	15383	22198
Ganj Mandi	UC 38	16119	23260
Waris Khan	UC 39	14184	20467
Purana Qilla	UC 40	14440	20837
Shah Chan Charagh	UC 41	13835	19964
Millat Colony	UC 42	17437	25161

Dhoke Khabba	UC 43	17914	25850
Dhoke Farman Ali	UC 44	20836	30066
Chaman Zar Colony	UC 45	22041	31805
City	UC 46	19252	27780
Total	**46**	**781927**	**1128316**

Table 4.1.1 shows that total population of Rawal Town was 781927 inhabitants according to the Census Report of 1998. But in year 2009 it increased to about 1128316 inhabitants. By applying formula F=1998 population*$(1+i)^n$, estimated population in year 2009 was calculated. Where F= future population, i= growth rate (3.39% for urban population) and n= designed period in years. This increase in population is due to one of the major factors i.e. the migration of people from adjoining areas like Taxila, Wah Cantt, Chakri and Murree for various purposes like employment, business, education and health facilities etc. This uncontrolled population growth disabled WASA/RDA (Water and Sanitation Agency/Rawapindi Development Authority) to fulfil the needs of additional people. Rise in the demand of water for different purposes like cooking, cleaning, bathing and especially for drinking deteriorate its quality.

Table 4.1.2 Union Council Wise Coverage Status of Water Purification Plants in Rawal Town

UC No	Avail-able WPP	Observed WPP Operatin-g Hrs	Water Supplie-d by WPP (@ 500g/hr)	2009 Estimated Pop	Water Demand (2.5L)	Service Short Fall	%age Short Fall	Un Served Pop	Served Pop	Serv-ed Pop (%)
UC 1	4	3	27000	26616	66540	39540	59%	15816	10800	41%
UC 2	1	4	9000	26374	65935	56935	86%	22774	3600	14%
UC 3	0	0	0	20143	50357.5	50358	100%	20143	0	0%
UC 4	0	0	0	29045	72612.5	72613	100%	29045	0	0%
UC 5	0	0	0	18759	46897.5	46898	100%	18759	0	0%

UC 6	1	4	9000	18244	45610	36610	80%	14644	3600	20%
UC 7	0	0	0	24955	62387.5	62388	100%	24955	0	0%
UC 8	0	0	0	26198	65495	65495	100%	26198	0	0%
UC 9	0	0	0	27244	68110	68110	100%	27244	0	0%
UC 10	2	2	9000	20860	52150	43150	83%	17260	3600	17%
UC 11	2	8	36000	23033	57582.5	21583	37%	8633	14400	63%
UC 12	0	0	0	25705	64262.5	64263	100%	25705	0	0%
UC 13	5	5	56250	24428	61070	4820	8%	1928	22500	92%
UC 14	0	0	0	22622	56555	56555	100%	22622	0	0%
UC 15	0	0	0	24004	60010	60010	100%	24004	0	0%
UC 16	0	0	0	21006	52515	52515	100%	21006	0	0%
UC 17	2	4	18000	27793	69482.5	51483	74%	20593	7200	26%
UC 18	0	0	0	26669	66672.5	66673	100%	26669	0	0%
UC 19	1	6	13500	26323	65807.5	52308	79%	20923	5400	21%
UC 20	2	4	18000	28400	71000	53000	75%	21200	7200	25%
UC 21	1	4	9000	23853	59632.5	50633	85%	20253	3600	15%
UC 22	0	0	0	23547	58867.5	58868	100%	23547	0	0%
UC 23	2	6	27000	24809	62022.5	35023	56%	14009	10800	44%
UC 24	1	4	9000	23662	59155	50155	85%	20062	3600	15%
UC 25	1	5	11250	24431	61077.5	49828	82%	19931	4500	18%
UC 26	1	6	13500	21593	53982.5	40483	75%	16193	5400	25%
UC 27	2	3	13500	21063	52657.5	39158	74%	15663	5400	26%
UC 28	2	4	18000	25964	64910	46910	72%	18764	7200	28%
UC 29	1	4	9000	24798	61995	52995	85%	21198	3600	15%
UC 30	1	4	9000	27879	69697.5	60698	87%	24279	3600	13%
UC 31	3	6	40500	28304	70760	30260	43%	12104	16200	57%
UC 32	0	0	0	26385	65962.5	65963	100%	26385	0	0%
UC 33	4	5	45000	23032	57580	12580	22%	5032	18000	78%
UC 34	3	4	27000	23307	58267.5	31268	54%	12507	10800	46%
UC 35	1	4	9000	24514	61285	52285	85%	20914	3600	15%
UC 36	3	3	20250	25366	63415	43165	68%	17266	8100	32%
UC 37	1	4	9000	22198	55495	46495	84%	18598	3600	16%
UC 38	1	3	6750	23260	58150	51400	88%	20560	2700	12%
UC 39	1	4	9000	20467	51167.5	42168	82%	16867	3600	18%
UC 40	0	0	0	20837	52092.5	52093	100%	20837	0	0%
UC 41	1	4	9000	19964	49910	40910	82%	16364	3600	18%
UC 42	3	8	54000	25161	62902.5	8902.5	14%	3561	21600	86%
UC 43	2	4	18000	25850	64625	46625	72%	18650	7200	28%

UC 44	0	0	0	30066	75165	75165	100%	30066	0	0%
UC 45	1	3	6750	31805	79512.5	72763	92%	29105	2700	8%
UC 46	4	6	54000	27780	69450	15450	22%	6180	21600	78%

Table 4.1.2 exhibits the coverage status of water purification plants located in Rawal Town. In this table Union Councils are mentioned with available water purification plants in these UCs. Then observed operating hours of water purification plants are discussed. Water supplied by water purification plant at the rate of 500 g/hr is calculated for each UC. According to the estimated population in 2009, water demand at the rate of 2.5 L/person/day is found. By considering water supplied by water purification plant at 500 g/hr and the water demand at 2.5 L/person/day, service short fall is calculated. Un-served population is found by considering percentage short fall and estimated population in 2009. Population served by water purification plants, is calculated according to the estimated population in 2009 and un-served population. At the end percentage of served population is also calculated.

Table 4.1.3 Average, Minimum and Maximum Water Coverage Status

	Available WPP	Water Supplied by WPP (@ 500g/hr)	2009 Estimated Pop	Water Demand (2.5L)	Service Short Fall	%age ShortFall	Un Served Pop	Served Pop	Served Pop (%)
Minimum	0	0	18244	45610	4820	8%	1928	0	0%
Average	1	13549	24529	61321.522	47773	78%	19109	5420	22%
Maximum	5	56250	31805	79512.5	75165	100%	30066	22500	92%

Table 4.1.3 shows the minimum, maximum and average water coverage status in Rawal town. As an Average, 1 water purification plant was available in each Union council operating at an average of 3 working hours per day. Average estimated population found in each UC was 24529 inhabitants having average water demand of

about 61322 litres. Average short fall percentage was found to be 78% and average served percentage was 22%.

Table 4.1.4 Whole Coverage Status of Water Provided By Water Purification Plants in Rawal Town

Year	Total Ucs	1998 Pop	2009 Estimated Pop	Available WPP	Observed WPP Operating Hrs	Water Supplied by WPP (@500g/hr)	Water Demand (2.5L)	Service Short Fall	%age Short Fall	Un Served Pop	Served Pop	% Served Pop
2009	46	781927	1128316	60	3	405000	2820790	2415790	86%	970352	157964	14%

Table 4.1.4 clearly shows that in year 1998 the total population of 46 UCs was 781927 inhabitants and in year 2009 it grew to 1128316 inhabitants. Total available water purification plants in all 46 UCs are 60 which are working for an average of 3 hours per day. As the average size of purification plant is 500 g/hr, 405000 L water is supplied per day. But the total water demand at 2.5 L/person/day is 2820790 L. So the service short fall was 2415790 L (86%) in 2009. Population Served was only 157964 (14%) inhabitants, where as un-served population is 970352 (86%) inhabitants in the same year.

Table 4.1.5 Regression Model: Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	AOH(a)	.	Enter

a. All requested variables entered.
b. Dependent Variable: SSF

In table 4.1.5, the variable SSF (service short fall) is regressed on the variable AOH (average operating hours). The regression model in this case is $y=\alpha+\beta x+\epsilon$. Where variable 'y' is service short fall and variable 'x' is average operating hours, 'α' is that value of 'y' (service short fall) when 'x' (average operating hours) is equal to zero and called y-Intercept and 'β' is the stop coefficient of the independent "variable average operating hours".

Table 4.1.6 ANOVA

Mode l		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2424964337.7	1	2424964337.74	14.669	.001(a)
	Residual	4794182629.5	29	165316642.4		
	Total	7219146967.3	30			

a. Predictors: (Constant), AOH
b. Dependent Variable: SSF

In table 4.1.6, the value of F = 14.669 and P value = .001 which shows that the variable "average operating hours" plays a significant role to estimate the value of dependent variable "service short fall". The lesser the AOH (average operating hours) of the water purification plants, the more would be the SSF (service short fall) of drinking water provided by these water purification plants in each UC and vice versa.

Table 4.1.7 Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	70141.4	7882.413		8.898	.000
	AOH	-6484.101	1692.994	-.580	-3.830	.001

a. Dependent Variable: SSF

In table 4.1.7, the coefficient of the variable "average operating hours" of water purification plants is tested by applying t-test. The value of coefficient AOH (average operating hours) is equal to −.580, which shows that when "average operating hours" is increased by one unit, the dependent variable SSF (service short fall) will decrease by

0.580. The high value of t= −3.830 and p-value = .001 implies that the coefficient of variable AOH is not equal to zero.

Table 4.1.8 Regression Model: Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	AOH(a)	.	Enter

a. All requested variables entered.
b. Dependent Variable: WS

In table 4.1.8, the variable WS (water supplied) is regressed on the variable AOH (average operating hours). The regression model in this case is $y=\alpha+\beta x+\epsilon$. Where variable 'y' is "water supplied" by water purification plants and variable 'x' is "average operating hours", 'α' is that value of 'y' (water supplied) when 'x' (average operating hours) is equal to zero and called y-Intercept and 'β' is the stop coefficient of the independent variable "average operating hours".

Table 4.1.9 ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2715856526.7	1	2715856526.7	18.490	.000(a)
	Residual	4259615247.4	29	146883284.3		
	Total	6975471774.1	30			

a. Predictors: (Constant), AOH
b. Dependent Variable: WS

In table 4.1.9, the value of F = 18.490 and P value = .000 which shows that the variable "average operating hours" plays a significant role to estimate the value of dependent variable "water supplied". The more the AOH (average operating hours) of the water purification plants, the more would be the WS (water supplied) by these water purification plants in each UC and vice versa.

Table 4.1.10 Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-10442.114	7429.970		-1.405	.171
	AOH	6861.997	1595.818	.624	4.300	.000

a. Dependent Variable: WS

In table 4.1.10, the coefficient of the variable average operating hours of water purification plants is tested by applying t-test. The value of coefficient AOH (average operating hours) is equal to .624, which shows that when variable "average operating hours" is increased by one unit, the dependent variable WS (water supplied) by water purification plants will increase by .624.

Figure 4.1.11 Spatial distribution of sampled water purification plants coverage area in Rawal Town

Figure 4.1.11 exhibits spatial distribution of water purification plants by locating UTM Coordinates for East and North of these purification plants on Google Earth Map.

Table 4.1.10 Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-10442.114	7429.970		-1.405	.171
	AOH	6861.997	1595.818	.624	4.300	.000

a. Dependent Variable: WS

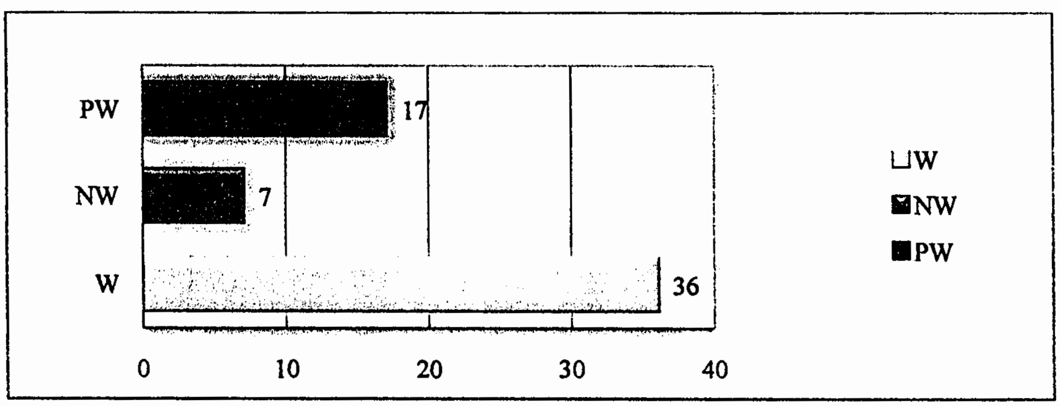
In table 4.1.10, the coefficient of the variable average operating hours of water purification plants is tested by applying t-test. The value of coefficient AOH (average operating hours) is equal to .624, which shows that when variable "average operating hours" is increased by one unit, the dependent variable WS (water supplied) by water purification plants will increase by .624.

Figure 4.1.11 Spatial distribution of sampled water purification plants coverage area in Rawal Town

Figure 4.1.11 exhibits spatial distribution of water purification plants by locating UTM Coordinates for East and North of these purification plants on Google Earth Map.

We have taken ½ Km return distance from user to purification plant. Going of a person to the purification plant and coming back to his house is called round trip. 1 Km round trip will make ½ Km radial distance. It also shows that the water fetching distance from user to purification plant is high for most of the users. Half Km return distance is convenient for user; he can even go by walk. But, if the distance exceeds he may use bicycle, motor-cycle, car and bus for fetching water from purification plants. We can also see from the figure above that water purification plants are unevenly distributed. If we are taking purification plants working at 100% quality, even then the coverage area of safe and clean drinking water is not sufficient for the citizens of Rawal Town.

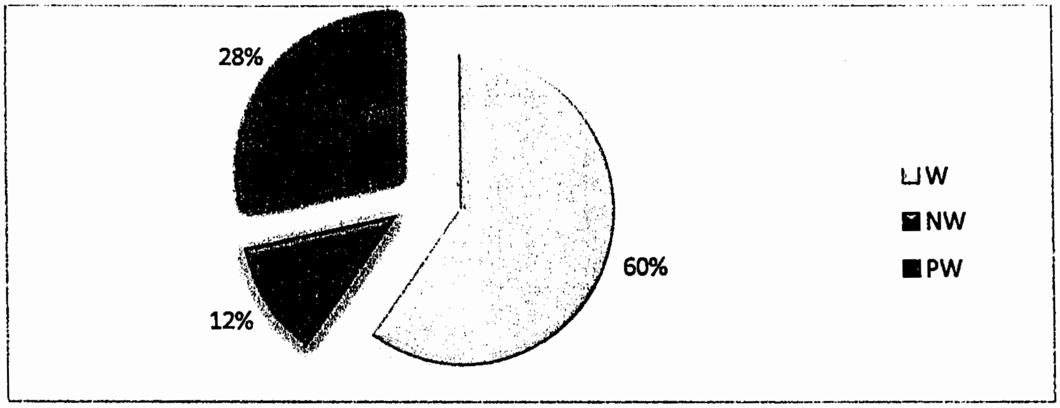
4.2 Water Purification Plants and Their Operational Status in Rawal Town



W= Working NW= Not Working PW= Partially Working

Figure 4.2.1 Operating status of water purification plants

Figure 4.2.1 illustrates that total 36 water purification plants were working during the study period, where as total 7 water purification plants were not operating. Seventeen water purification plants were those which were operating but with limitations. It is a good sign that most of the water purification plants were operating.



W= Working; NW= Not Working; PW= Partially Working

Figure 4.2.2 Percentage of water purification plants operational status

Figure 4.2.2 describes the total percentage of the working status of water purification plants during the research. Sixty percent were those water purification plants which were working, 12% water purification plants were out of order and were not operational. Water purification plants working with some limitation or with some issues were 28%.

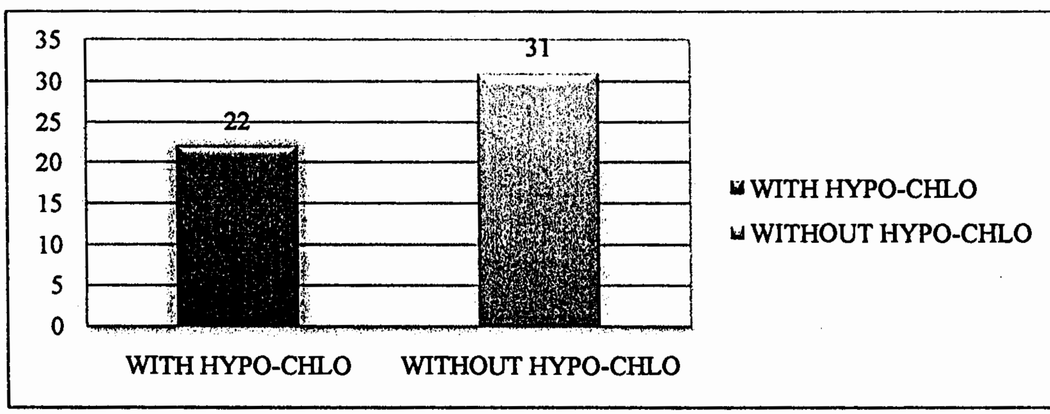


Figure 4.2.3 Water purification plants operating with and without hypo-chlorinators

Figure 4.2.3 shows the presence and absence of hypo-chlorinators in the operational water purification plants. Twenty two water purification plants were working with hypo-chlorinators attached with their source tube wells while 31 water purification plants were operating without hypo-chlorinators attached with their source tube wells.

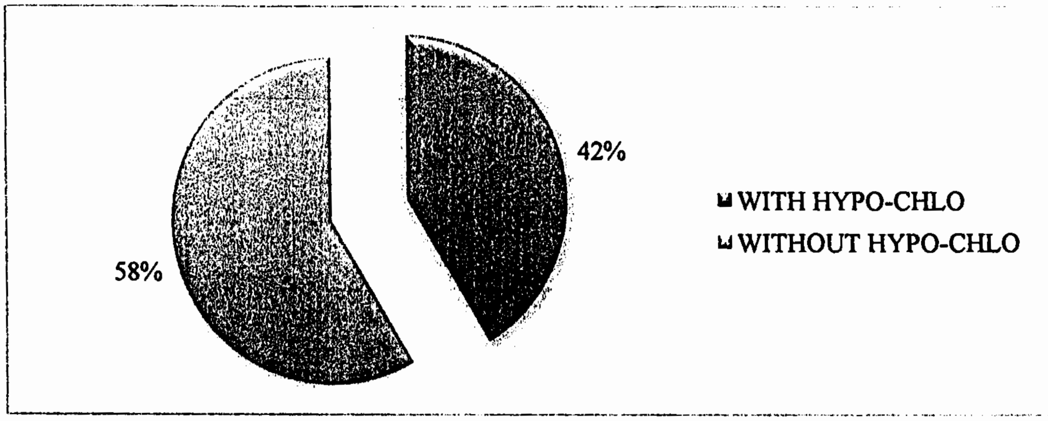
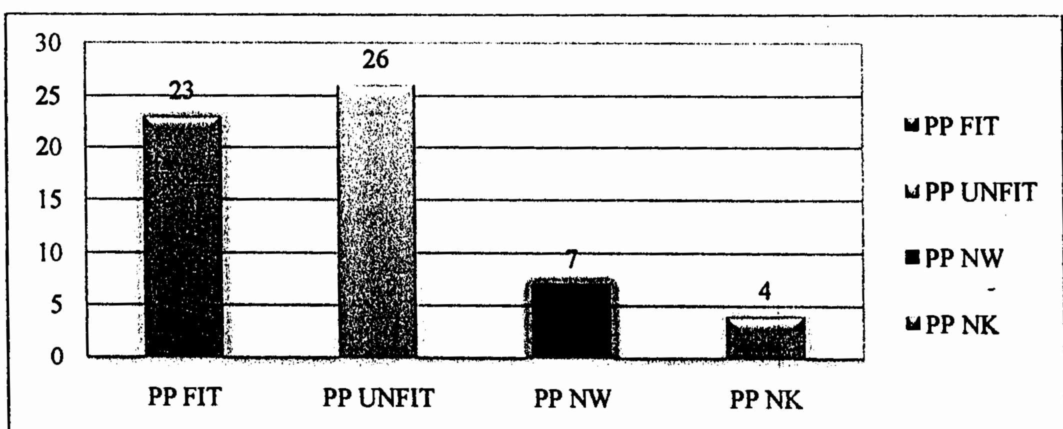


Figure 4.2.4 Percentage of water purification plants operating with and without hypo-chlorinators

Figure 4.2.4 illustrates the percentage of water purification plants working with and without hypo-chlorinators attached in the source tube wells. So, total 42% water purification plants were operating with hypo-chlorinators while 58% water purification plants were working without hypo-chlorinators. It shows that most of the water purification plants were treating water which was not pre-chlorinated. The tube wells, in which chlorine disinfection was done, were giving high doze of chlorine which causes bad odour in water and makes water unfit for drinking.

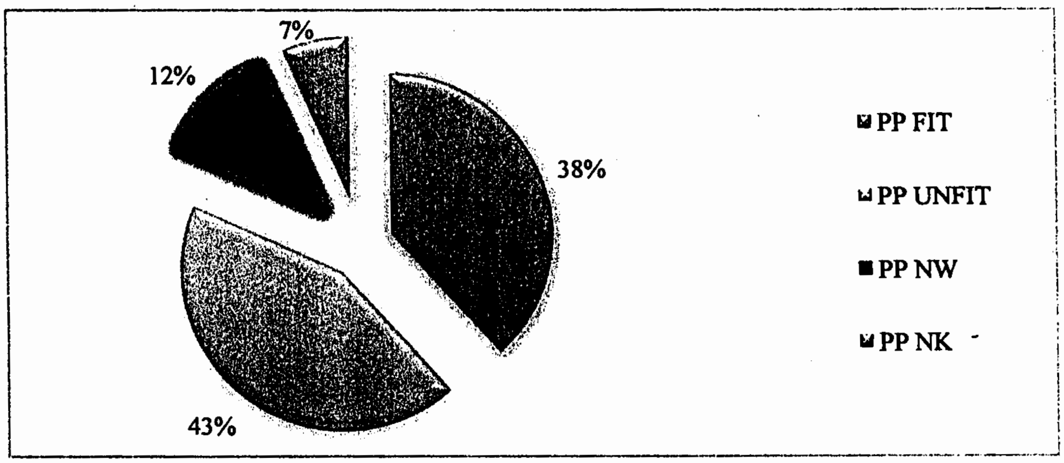
4.3 Water Quality of Water Purification Plants and Source Tube Wells



PP= Purification Plant; NW= Not Working; NK= Not Known

Figure 4.3.1 Faecal contamination status in water purification plants

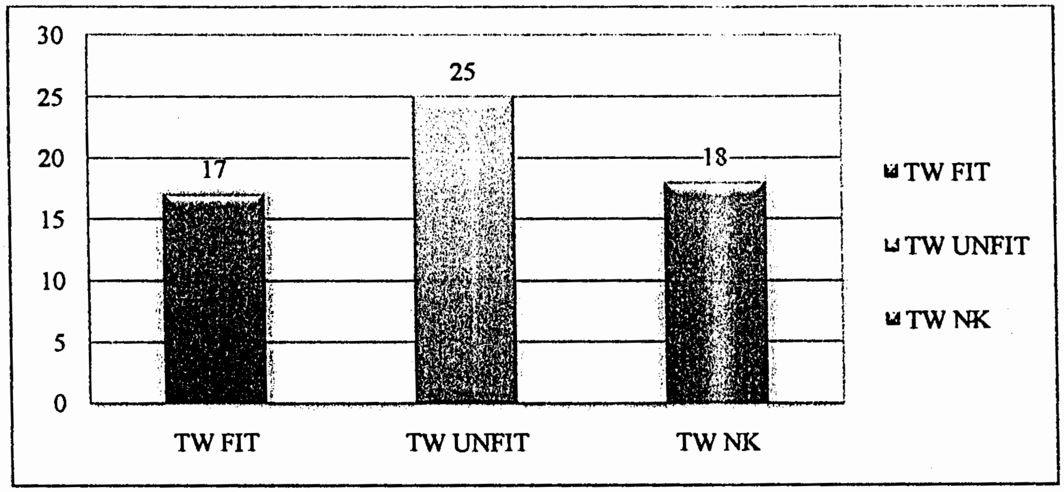
Figure 4.3.1 explains the status of faecal contamination in water purification plants. This figure clearly shows that 23 water purification plants were safe and fit. There was no faecal contamination in them. While 26 water purification plants were contaminated. So it was found that more purification plants were operating but with faecal contamination. Seven water purification plants were not working during the study period while 4 water purification plants were closed and therefore water samples were not taken for faecal contamination test.



PP= Purification Plant; NW= Not Working; NK= Not Known

Figure 4.3.2 Percentage faecal contamination status in water purification plants

Figure 4.3.2 shows the percentage of faecal contamination status in water purification plants that were operating during the study period. Thirty eight percent water purification plants were giving safe and fit water, whereas 43% water purification plants were unfit and had faecal contamination. So it was found that most of the citizens of Rawal Town are getting contaminated water from water purification plants. Twelve percent water purifications plants were not working whereas from 7% water purification plants water samples were not taken for test.



TW= Tube well; NK= Not Known

Figure 4.3.3 Feacal contamination status in tubewells

Figure 4.3.3 shows the faecal contamination status in source tube wells of these water purification plants. A total of 17 source tube wells were fit where as 25 tube wells had faecal contamination. Eighteen tube wells were those whose faecal contamination tests were not conducted. They were closed at that time.

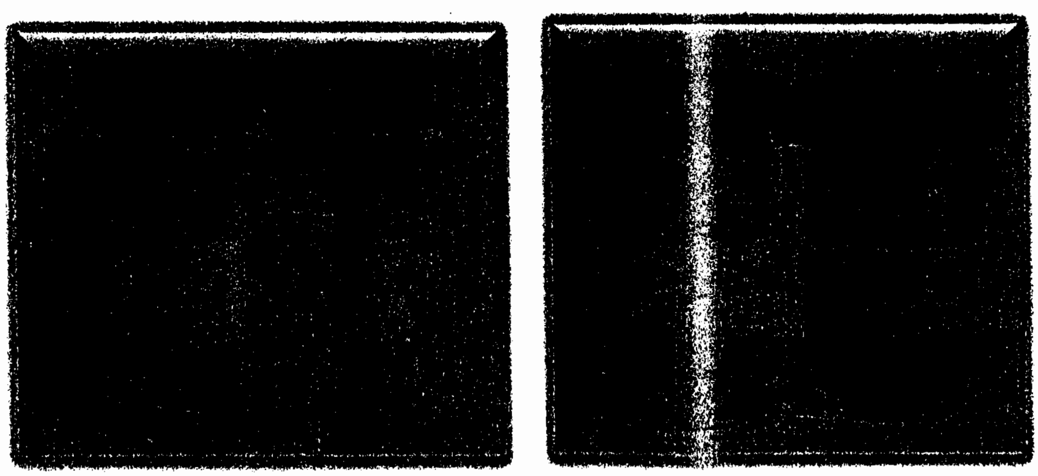
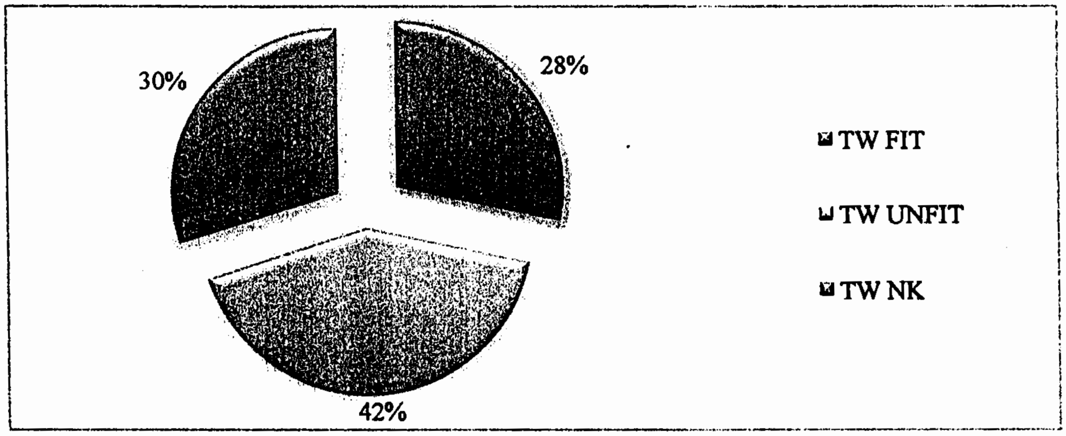


Figure 4.3.4 Water samples from fit tube wells and fit water purification plants

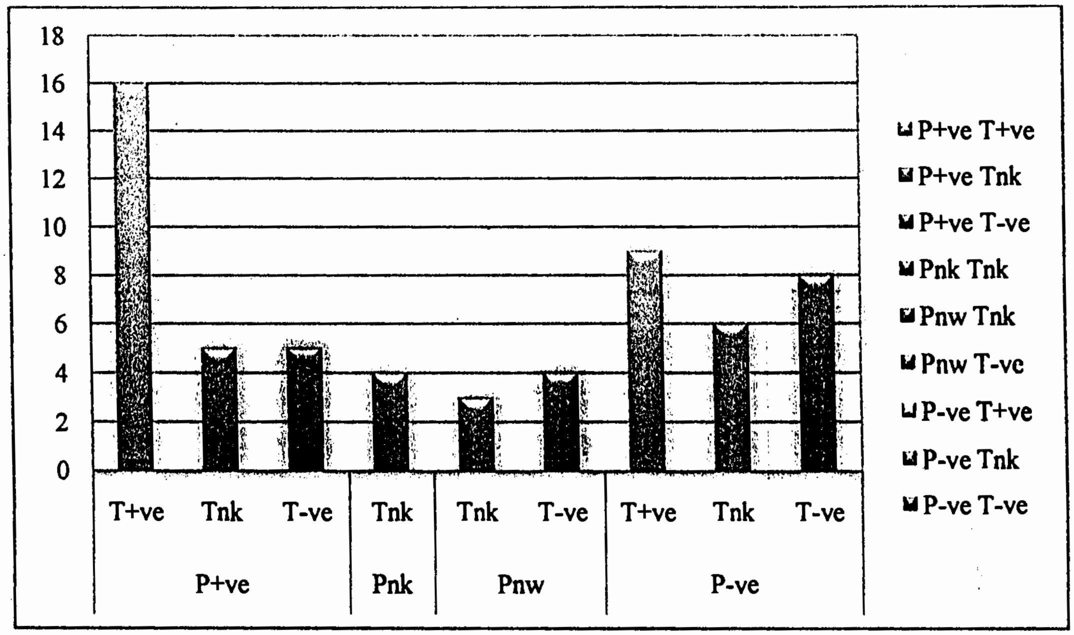


TW= Tube Well; NK= Not Known

Figure 4.3.5 Percentage fecal contamination status in tubewells

Figure 4.3.5 illustrates the frequency of faecal contamination in source tube wells. It shows that 28% tube wells were providing fit water whereas 42% tube wells were contaminated and therefore unfit. There is a huge difference between these two percentages. It has been observed that a higher number of tube wells had faecal contamination while for 30% tube wells water quality tests were not conducted for being closed.

Figure 4.3.6 Water samples from unfit tube wells and unfit water purification plants



P +ve= Purification plant unfit; T +ve= Tube well unfit; T nk= Tube well not known
T –ve= Tube well fit; P nk= Purification plant not known;
P –ve= Purification plant fit; P nw= Purification plant not working

Figure 4.3.7 Overall faecal contamination status in water purification plants and source tube wells

Figure 4.3.7 illustrates the overall status for faecal contamination in a total of 60 studied operational water purification plants and their source tube wells. In this figure, it is clearly shown that there were 26 water purification plants which were unfit. These 26 unfit (p +ve) water purification plants were working with 16 tube wells that were unfit (T +ve), 5 tube wells that were fit (T -ve) and 5 tube wells were those for which faecal contamination status was not known (T nk) because they were closed at that time. From the figure above, it is observed that 23 water purification plants were fit (p -ve), having 9 source tube wells which were unfit (T +ve) means they had faecal contamination, 8 fit (T -ve) tube wells, whereas 6 tube wells were closed at that time that is why there faecal contamination status was not known (T nk). According to the figure above, the status of faecal contamination in 4 water purification plants and their source tube wells was not known (P nk, T nk) because they were closed at the time when water samples were taken. The figure above shows that 7 water purification plants were not operational (p nw) during the study period. These 7 not working (p nw) water purification plants had 4 fit (T -ve) tube wells where as the faecal contamination status of 3 tube wells was not known (T nk). So it has been observed that the water quality status in most of the water purification plants and their source tube wells was unfit.

4.4 Existing Design of Water Purification Plant by TMA and Issues in Existing Design

According to the manufactures of these water purification plants, 500 g/hr water is supplied by the existing design of the purification plant.

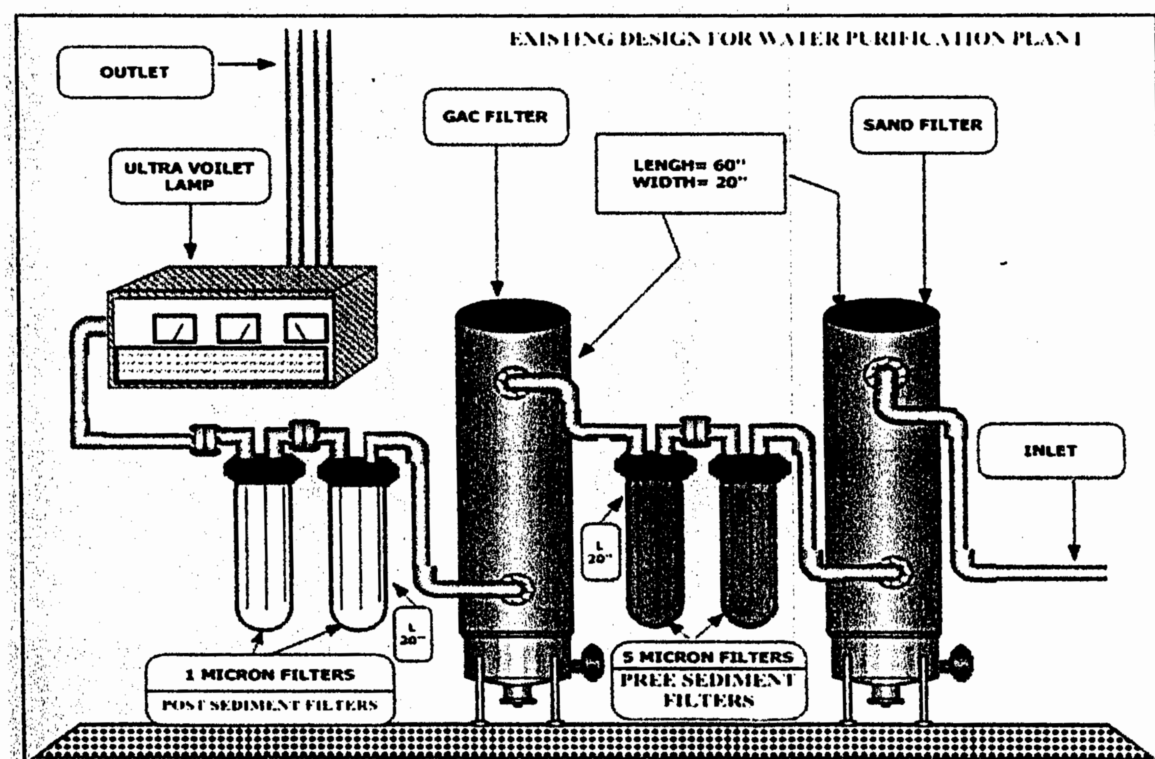


Figure 4.4.1 Existing design of water purification plants

Figure 4.4.1 shows that water purification plants installed by TMA comprises of:

One Sand Filter

It is enclosed in a vertical cylindrical steel tank which is 60 inches long and 20 inches in width. Incoming water is distributed throughout the filter with the help of a top distributor. Water is filtered under pressure through the cylindrical tank. Through filter bed raw water flows downwards. Suspended matter is retained on the silica sand surface which is the filtration media.

Issues

It was found that the cylindrical tank of sand filter was not made of stainless steel; hence result was the corrosion of cylindrical tank. Filtration media used in the sand filter was not silica sand and it was found to had different material in every water purification plant.

Two 5 Micron Filters

There are two 5 micron filters which are 20 inches in length. These consist of tightly woven cartridges and are required for pre sedimentation filtration.

Issues

Five micron filters were membrane filters consisting of woven cartridges. They were least effective for maintaining microbial water quality. Spores of bacteria and viruses were found to be able to pass through the membrane filters and cause microbial contamination.

One GAC Filter

After pre sedimentation filtration water passes through the Granular Activated Carbon filter which is same in length and width as sand filter. Activated carbon acts as an adsorbent in drinking water treatment. It removes particles and organics which react with disinfectants like chlorine and results in the formation of disinfection-by-products (DBP's).

Issues

Instead of granular activated carbon, coal was found to be present in granular activated carbon filter. Free chlorine was found in the effluent which shows the presence of coal. As activated carbon acts as an adsorbent therefore presence of coal affects the functioning of GAC filter and water is not properly de-chlorinated.

Two 1 Micron Filters

There are two 1 micron filters which are of same size as 5 micron filters. These are the most tightly woven cartridges which are used for the post sedimentation filtration.

Issues

Bio-films were found in 1 micron membrane filters because they were unable to clear and retain all spores of bacteria and viruses. Bio-films allow survival of microbiological pathogens in micron filters. Ultra filtration is necessary, after 1 micron filtration, to capture molecules and microbes which are above the specific molecular weight to clean water.

One Ultra Violet Set

After post sedimentation filtration water is exposed to the UV light rays through UV light lamp. It is used for the treatment of microbiological contaminants like bacteria, viruses, oocysts like cryptosporidium and many others.

Issues

40 watt UV lamp was used in 33 inches long container which was not sufficient to disinfect water. In some water purification plants UV filters were not operational.

Issues in Pipes

Some water purification plants had broken pipes which were the cause of microbial contamination. Piping system for sanitization mechanism is not present in the existing design.

Taps

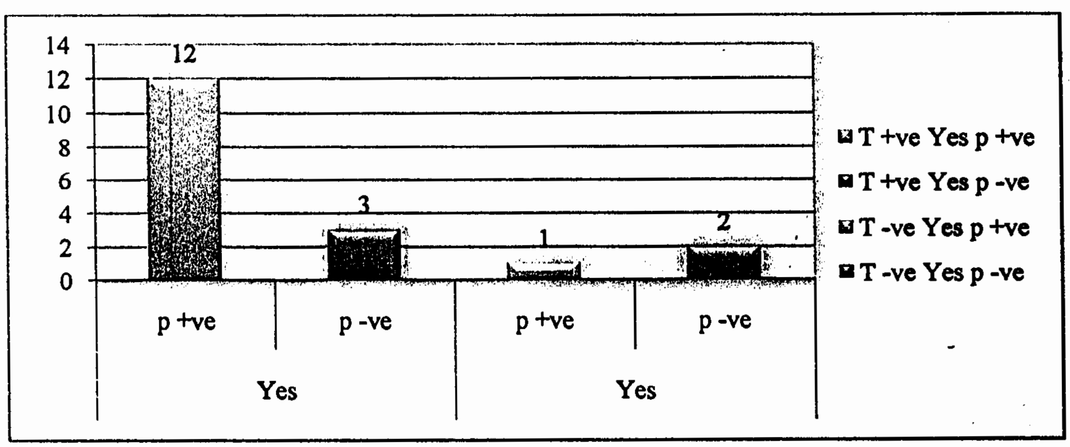
It was found that purification plants comprised of 6 to 12 taps. So at average 9 taps were present to supply water from water purification plants.

Issues

In some water purification plants taps were not working properly. Water was constantly leaking from these taps. Some taps were broken in water purification plants. And some water purification plants did not have sufficient taps. Water coming through taps had low water pressure. So users had to wait for a long time to fill their containers.

Hypo-chlorinators

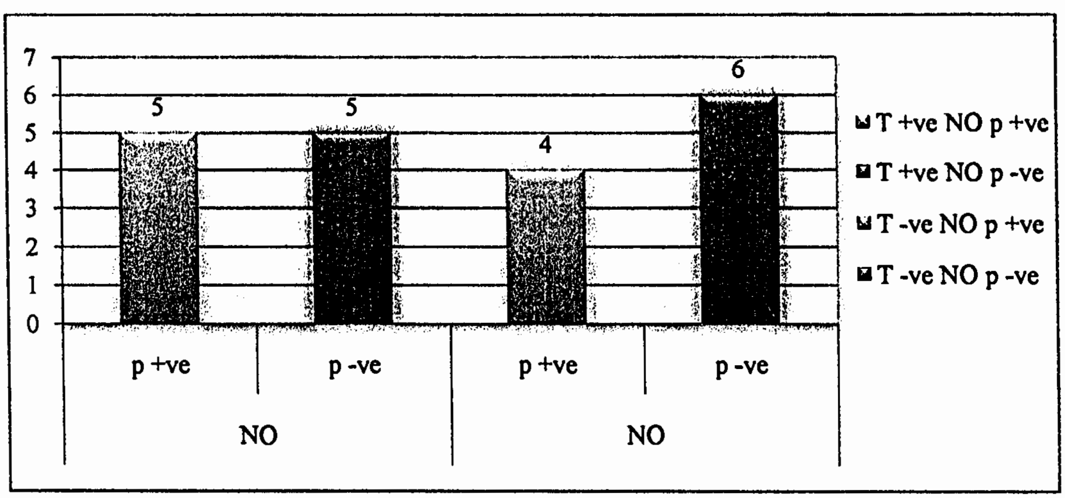
Forty two percent water purification plants were receiving water from source tube wells working with hypo-chlorinators and 58% water purification plants did not have hypo-chlorinators in their source tube wells. Hypo-chlorination method is used to provide baseline chlorination for water distribution network and same water is used for supply from water purification plants. It is worth mentioning that after sand filtration granular activated carbon filter is placed to utilize or de-chlorinate water and the contact time of chlorine required is about 30 minutes according to different studies. But the total contact time of chlorine observed was 18 to 30 seconds which was considered to be insufficient to de-chlorinate water. Therefore, whether hypo-chlorinator was installed or not, had no significant effect on the disinfection of water. Same facts are clear from the figures 4.4.2 and 4.4.3.



T +ve= Tube well unfit; P +ve= Purification plant unfit; T –ve= Tube well fit
P -ve= Purification plant fit; Yes= With hypo-chlorinator

Figure 4.4.2 Fit/unfit tube wells and water purification plants working with hypo-chlorinators

In Figure 4.4.2 'Yes' shows the presence of hypo-chlorinators attached with the source tube wells of the water purification plants, 'T +ve' is used for tube well unfit, 'T -ve ' is used for tube well fit, 'P +ve' is used for water purification plant unfit and 'P -ve' is used for water purification plant fit . A total of 15 tube wells that were working with hypo-chlorinators had faecal contamination (T +ve). Out of these 15 contaminated (T +ve) tube wells; 12 water purification plants were providing unfit (p +ve) water to the users, whereas 3 water purification plants were supplying fit (p -ve) water. This figure also describes that a total of 3 tube wells that were working with hypo-chlorinators were fit (T -ve). These 3 fit (T -ve) tube wells had 1 water purification plant providing unfit (p +ve) water and 2 water purification plants providing fit (p -ve) water. This shows the ineffective working of the water purification plants. Even in the presence of hypo-chlorinators in the tube wells, faecal contamination was observed.



T +ve= Tube well unfit; P +ve= Purification plant unfit; T-ve= Tube well fit
P –ve = Purification plant fit; NO= Without hypo-chlorinator

Figure 4.4.3 Fit/unfit tube wells and water purification plants working without hypo-chlorinators

In figure 4.4.3 'NO' represents the absence of hypo-chlorinators in the source tube wells of the water purification plants, 'T +ve' is used for tube well which were unfit, 'T -ve' is used for tube well which were fit, 'P +ve' is used for water purification plant which were unfit and 'P -ve' is used for water purification plant which were fit. A total of 10 tube wells were providing unfit (T +ve) water to water purification plants in the absence of chlorine disinfection by hypo-chlorinators. These 10 unfit tube wells were associated with 5 water purification plants that were providing unfit (p +ve) water and 5 fit (p -ve) water purification plants. A total of 10 tube wells were providing fit (T -ve) water that were the source tube wells of 4 unfit (p +ve) and 6 fit (p -ve) water purification plants. So, it is clear that hypo-chlorinators installed or not installed had no significant effects on water quality.

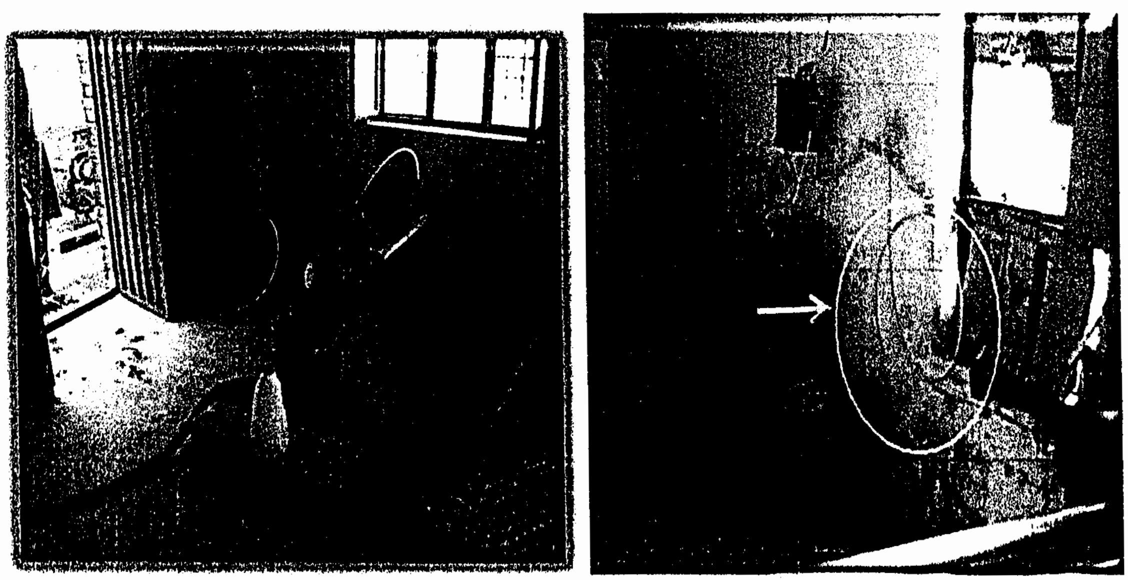


Figure 4.4.4 Hypo-chlorinators working and not working in tube wells

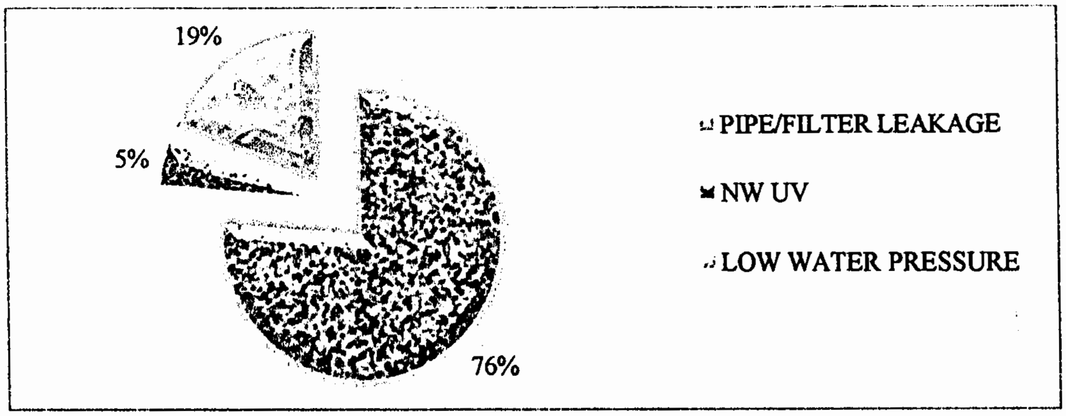


Figure 4.4.5 Percentage of limitations in partially working water purification plants

Figure 4.4.5 illustrates the percentage of limitations or issues in partially working water purification plants. Nineteen percent water purification plants had the problem of low water pressure. While in 5% purification plants ultra violet set was out of order. In 76% water purification plants leaked pipes and filters were found. This is the major problem that was observed during the study period. Purification plants were working even with the broken pipes and leaked micron filters. Leakages in filters and pipes cause microbiological contamination. If UV lamp is not working then it cannot kill micro-organisms when water is exposed to it. Low water pressure causes users to suffer while standing in queues.

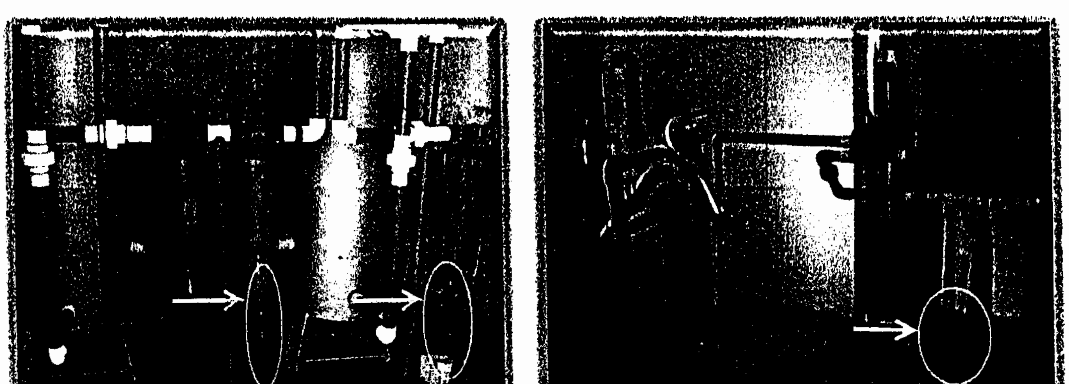
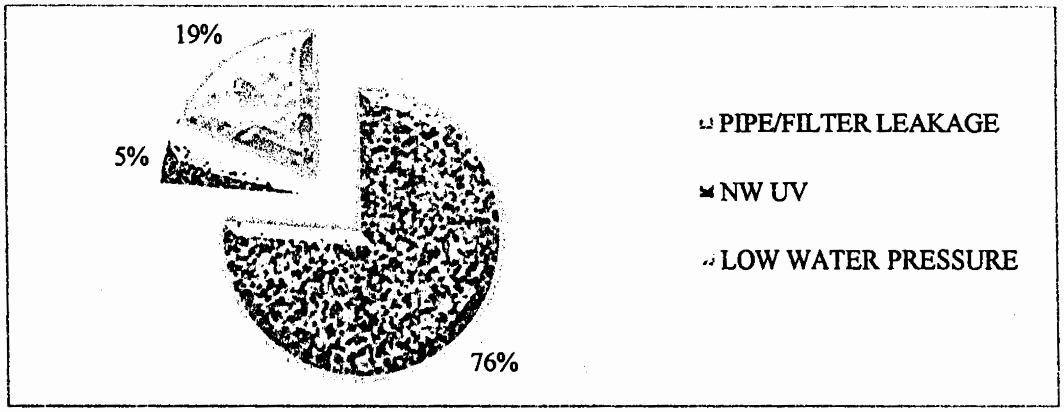


Figure 4.4.6 Leaked micron filters



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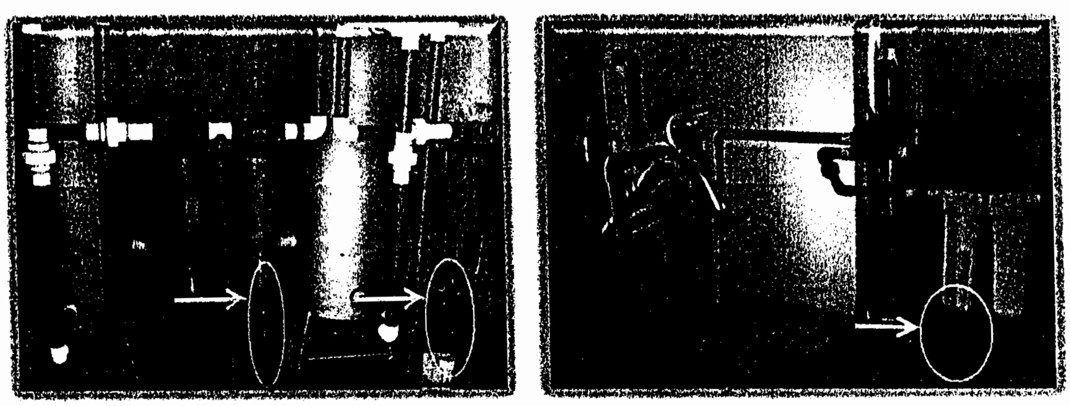

Figure 4.4.6 Leaked micron filters

Other Issues

Operators who were operating water purification plants did not know about the equipments present in purification plant. They were not trained. They were actually operators of tube wells. They did not have the idea of when to change micron filters, therefore micron filters became chocked and bio-films appeared. If some problem arose with the operation of ultra violet lamp, they even could not solve that problem. One operator had the responsibility of more than two water purification plants. As a result they either did not open water purification plants at their specific time or opened water purification plants for very short time. They did not know about the backwash procedure of filters. In some water purification plants there was problem of electricity supply and even then they were operating and providing contaminated water to people. Operators had irresponsible behaviour towards the maintenance of purification plants. They did not clean even the surroundings of purification plants. Operators were not provided with manuals or standards given from manufacturers for operating equipments installed in water purification plants.

Users had complaints about the unhygienic condition of water purification plants, low water pressure, and long distance to fetch water from purification plants, bad smell and off taste from the water due to low filter change frequency and separate time and place for females to fetch water. People had to cover long distances to fetch water; therefore they used to take water in 5 to 6 different containers and stored water at home for 3 to 4 days which is also a reason for contamination. Sometimes containers were not properly washed and fungus appeared inside containers.

All these issues related to water purification plants have resulted in faecal contamination in water provided from water purification plants and ultimately caused waterborne diseases among urban population of Rawal Town.

4.5 Waterborne Diseases among Urban Population

Table 4.5.1 Monthly record of Diarrhoeal Patients Each Month at Holy Family Hospital (PEADS OPD) from (1990 - 2009)

YEARS	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
1990											44	199	243
1991	228	250	217	166	711	447	301	320	272	247	144	130	3433
1992	142	103	164	195	201	144	142	205	157	100	110	108	1771
1993	94	62	62	126	172	211	206	298	139	60	88	51	1569
1994	53	52	52	227	240	324	332	244	135	90	59	37	1845
1995	40	54	58	33		232	425	550	350	226	148	71	2187
1996	74	66	245	325	210	411	305	228	254	261	168	150	2697
1997	109	106	202	285	311	410	403	495	433	292	207	247	3500
1998	172	247	606	557	740	1023	864	797	547	642	334	442	6971
1999	228	297	335	589	830	782	735	592	394	329	279	399	5789
2000	221	321	296	402	592	481	508	570	369	102	234	57	4153
2001	179	288	277	404	127	146	57	153	160	144	84	150	2169
2002	155	85	128		64	164	312	234	430	489	165	380	2606
2003	46	53	155	418	646	323	387	59	45	7	32	33	2204
2004	25	16	67	117	58	160	32	99	20	30	6	20	650
2005	43	35	50	60	23	54	46	37	51	11	94	71	575
2006	48	30	24		52	110	89				15		368
2007	260	200	220	229	225	260	170	180	100	45	62	63	2014
2008	98	100	120	130	175	160	150	200	175	160	130	100	1698
2009	75	85	280	200	210	250	260						1360
TOTAL													47802

Table 4.5.1 shows all records of patients suffering from diarrhoea (waterborne disease) every month during 20 years. It also gives total diarrhoeal patients every year.

Forty seven thousand eight hundred and two diarrhoeal patients were recorded during 20 years in Holy Family Hospital PEADS OPD.

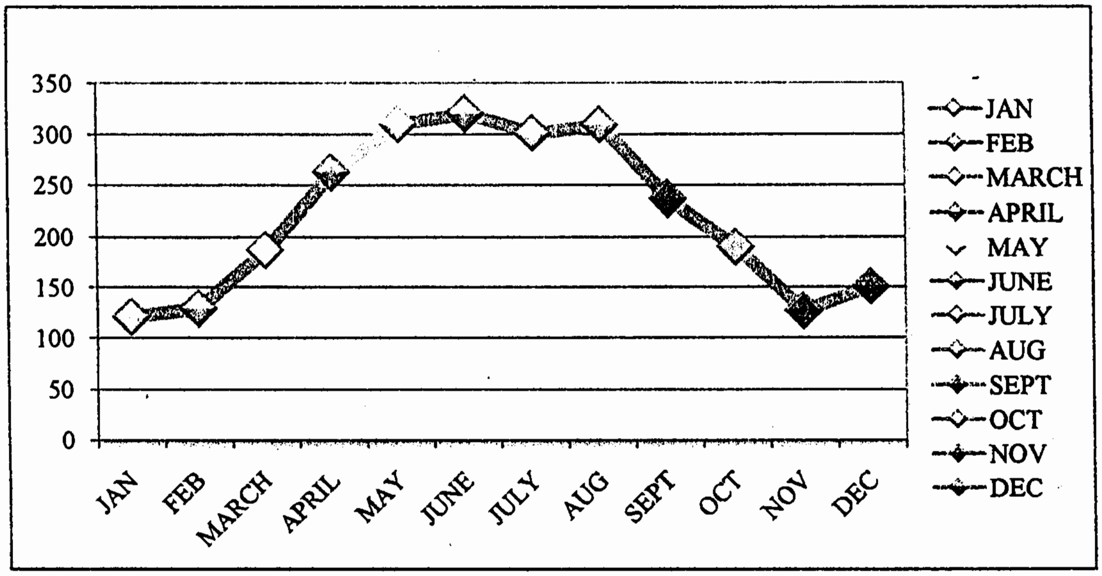

Figure 4.5.2 Average monthly trend of total diarrhoea patients in Holy Family Hospital (PEADS OPD)

Figure 4.5.2 illustrates the trend of average total patients suffering from diarrhoea from January to December every year in PEADS OPD of Holy Family Hospital. The line chart shows increasing trend from January (average 121 diarrhoeal patients) to June (average 310 diarrhoeal patients). From July to August there was slight decrease in average total diarrhoeal patients to about 301 patients. From October to November total average diarrhoeal patients decreased to about 126 patients. So it is clear from the chart that number of diarrhoeal patients was higher in the months from May to August. During these months more water is used for drinking purpose.

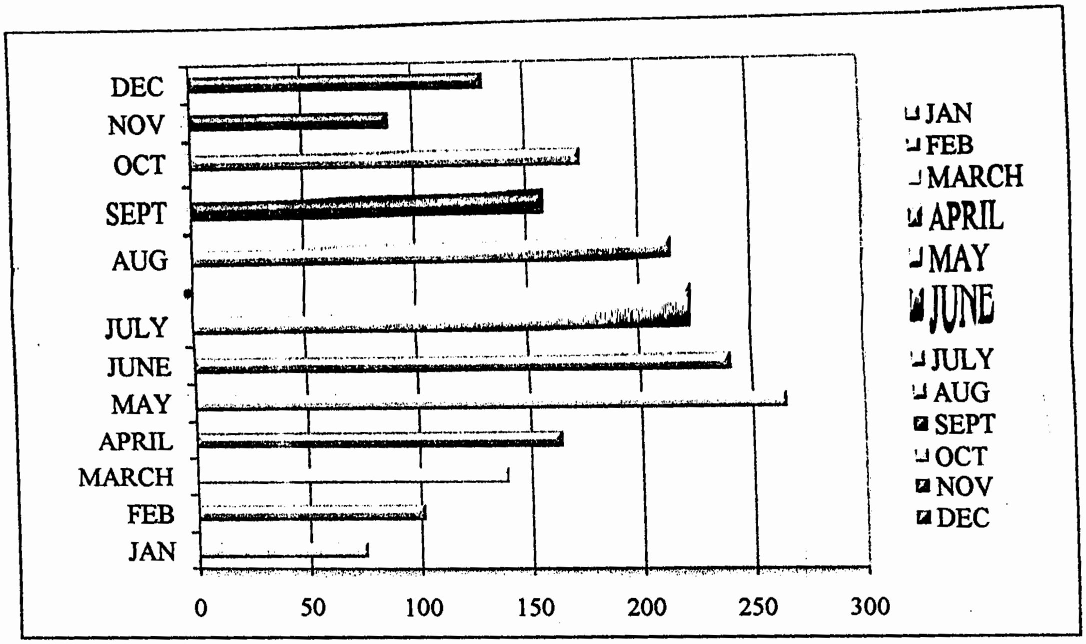

Figure 4.5.3 Standard deviation of waterborne disease/diarrhoeal patients per month in holy family hospital (PEADS OPD)

Figure 4.5.3 is about the standard deviation among waterborne disease/diarrhoeal patients each month in PEADS OPD of Holy Family hospital from 1990 to 2009. From January to April there was slight increase in the standard deviation of about 164 diarrhoeal patients. Standard deviation is more in the month of May to about 265 patients. Standard deviation of diarrhoeal patients then decreased from June to December to about 136 patients. Least standard deviation was observed in the months of January (76 patients) and November (90 patients). So more standard deviation was in summer season that is from May to August in which people drink more water.

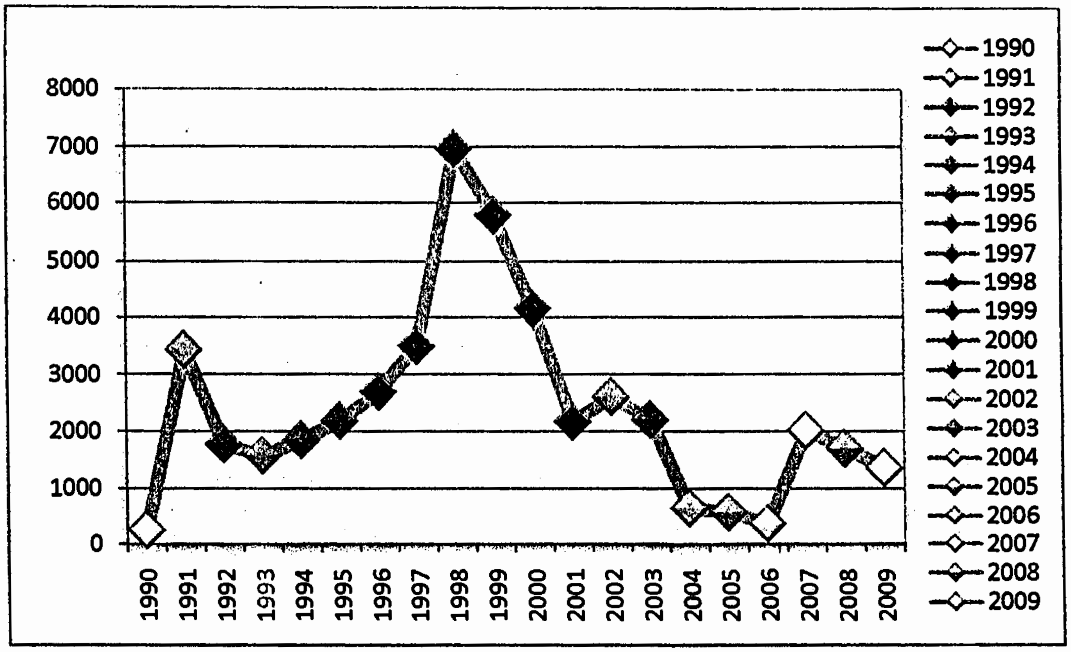

Figure 4.5.4 Yearly trend of total diarrhoeal patients in Holy Family hospital (PEADS OPD)

Figure 4.5.4 shows the yearly trend of total diarrhoeal patients in holy family hospital during 20 years. From the year 1990 to 1991 there was an increase in the total number of diarrhoeal patients from about 243 to 3433 patients. Next year in 1992 number of diarrhoeal patients decreased to 1771 patients. From 1993 to 1997 there was slight increase in total number of diarrhoeal patients to about 3500 patients. Eventually there was an increase in the total number of diarrhoeal patients to about 6971 patients in 1998. The line chart shows decreasing trend in the total number of diarrhoeal patients in holy family hospital from 1998 to 2006 (368 diarrhoeal patients). From 2007 the trend of total diarrhoeal patients started to increase. So more diarrhoeal patients were observed in the year 1998 and least diarrhoeal patients were observed in the year 2006.

Table 4.5.5 List of Patients (Gastroenteritis) From June to 8th July 2009 in Holy Family Hospital

DEPARTMENT	NO. OF VISITED PATIENTS
Main ER	787
PEADS ER	905
PEADS OPD	504
Grand Total	2196

Table 4.5.5 shows the list of patients suffering from gastroenteritis only in one month. Total 2196 gastrointestinal patients were recorded in Holy Family hospital. Out of which 787 patients were recorded in main ER, 905 patients were in PEADS ER and 504 patients were found in PEADS OPD.

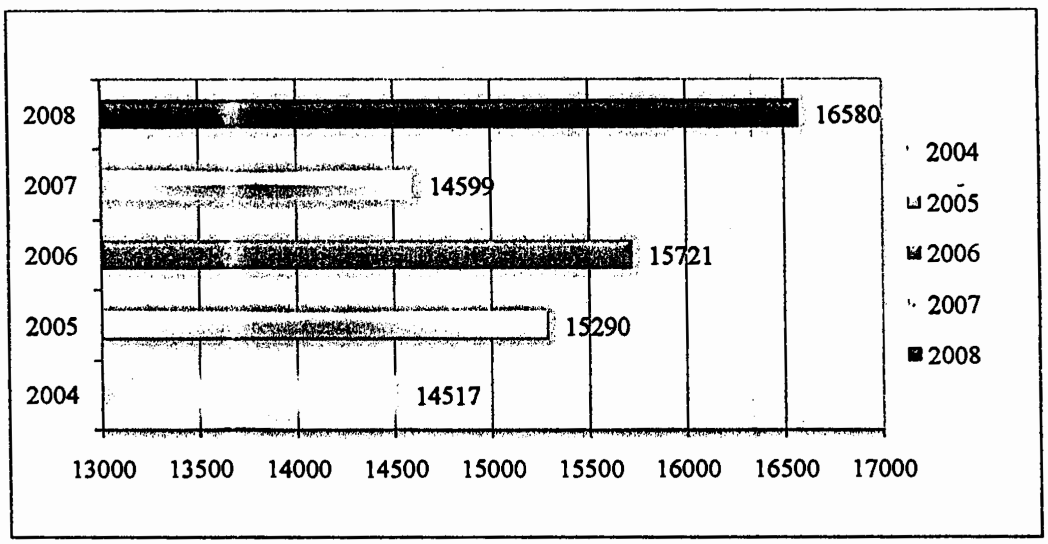

Figure 4.5.6 Total waterborne disease patients in Benazir Bhutto hospital from 2004 to 2008

Figure 4.5.6 gives the total number of waterborne disease patients in Benazir Bhutto hospital for five years from 2004 to 2008. In 2004 there were 14517 waterborne diseased patients. Higher number of waterborne diseased patients was observed in 2008. Water purification plants started to be installed in 2006. Therefore in 2007 some decrease was observed in the total number of waterborne disease patients. But waterborne disease patients were at peak in 2008 to about 16580 patients just because physical maintenance of water purification plants was not done by operators. Filter change frequency was low which resulted in the bacteriological contamination of water provided by these water purification plants. Hence, result was the increase in the number of patients suffering from waterborne diseases.

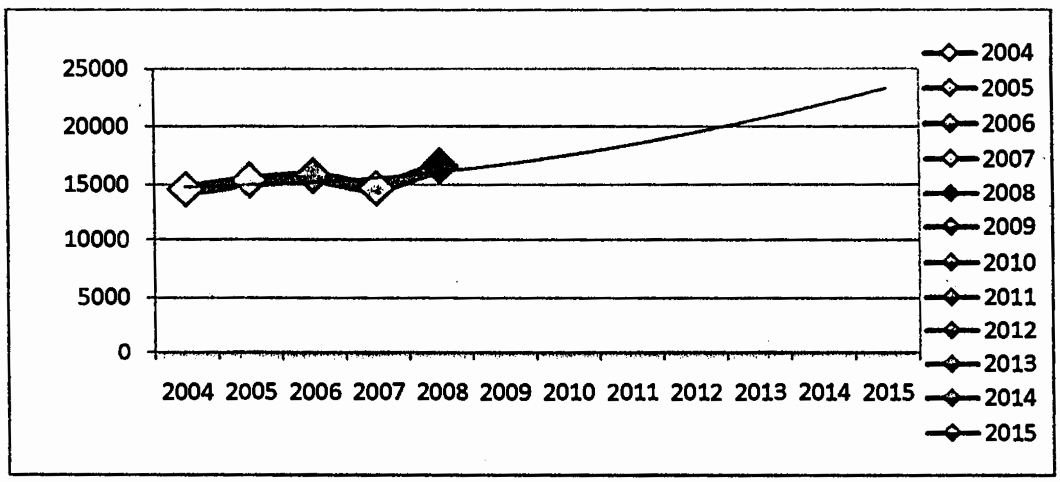

Figure 4.5.7 Increasing Trend of total number of waterborne diseased patients every year in Benazir Bhutto hospital

Figure 4.5.7 shows the variation between total number of waterborne diseased patients from 2004 to 2008 and it also gives the idea about future trend of waterborne diseased patients. From 2004, line charts shows the gradual increasing trend in the number of waterborne diseased patients up to 2006. In order to control the epidemic condition of urban population, TMA took initiative to install water purification plants in 2006. It worked and number of waterborne diseased patients decreased in 2007. But by 2007 there was again an increase in the number of waterborne diseased patients because water purification plants were not maintained by operators and they became source of waterborne pathogens. It can be clearly seen that the trend of total waterborne diseased patients will remain increasing for the future years if maintenance of water purification plants is not taken into account.

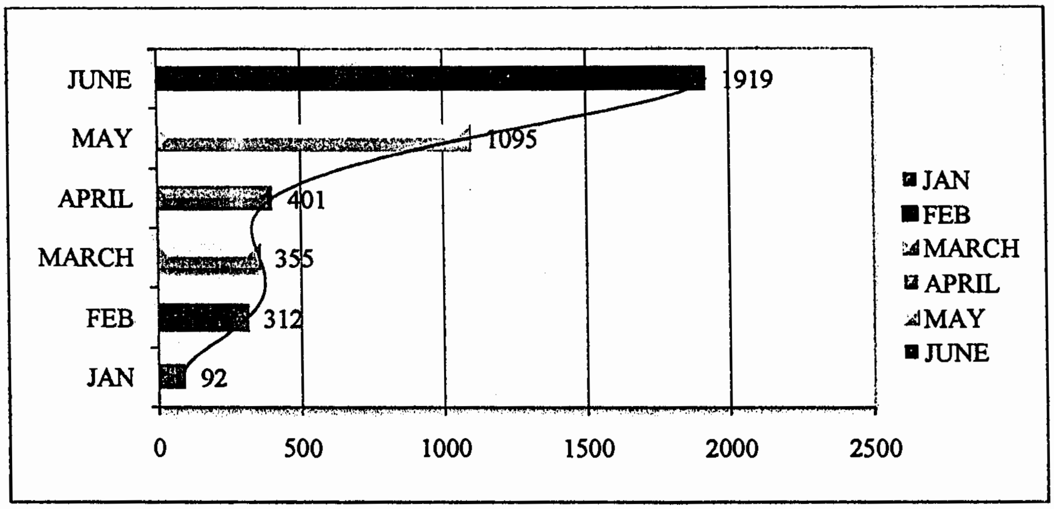

Figure 4.5.8 Total number of waterborne diseased patients each month

Figure 4.5.8 shows total number of waterborne diseased patients from the month of January to the month of June in PHC hospital. In the month of January total number of waterborne diseased patients was 92 patients which gradually increased up to April (401 patients). At the start of summer season (May) diarrhoeal patients eventually increased and there number remained so till June to about 1919 patients. Trend line shows remarkable increase in the number or waterborne diseased patients from April to June. This shows that waterborne diseases spread widely among urban population in summer season because there is a higher consumption of drinking water provided by water purification plants.

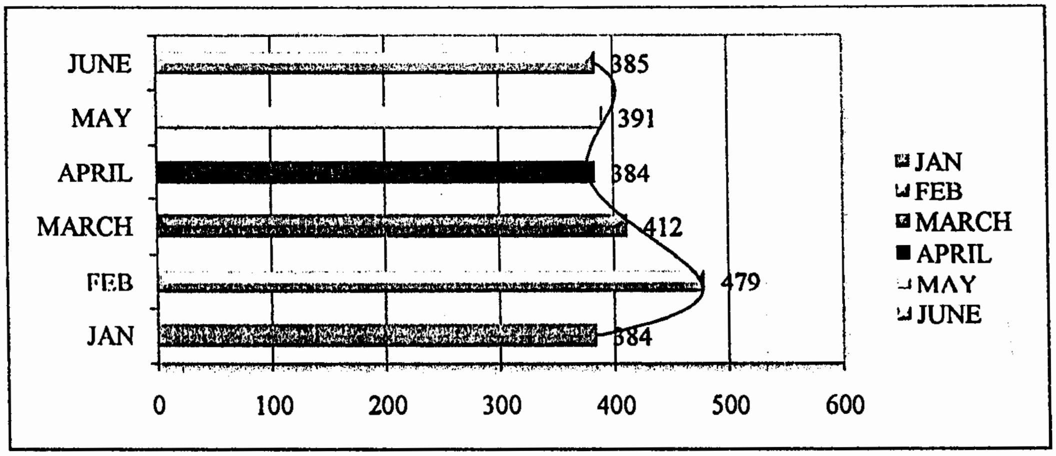

Figure 4.5.9 Total other water-related diseased patients from January to June in PHC hospital

Figure 4.5.9 illustrates the total water-related diseased patients other than waterborne diseased patients in PHC hospital from January to June. Other Water-related diseased patients increased from January to February to about 479 patients. Then total number of water-related diseased patients gradually decreased till June to about 385 patients.

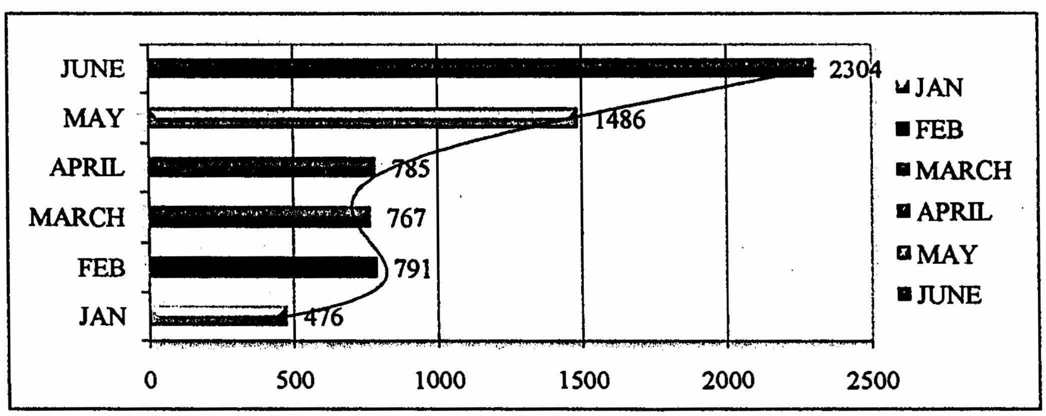

Figure 4.5.10 Total waterborne and other water-related diseased patients in PHC hospital

Figure 4.5.10 is about the total number of waterborne diseased patients and water-related diseased patients in PHC hospital from January to June. In January there were 476 waterborne diseased patients. Number of both water related and waterborne diseased patients remained almost constant till April (785 patients). From May, total number of waterborne and water-related diseased patients eventually increased from 1486 to 2304 patients. Trend line shows increasing trend of both water-related and waterborne diseased patients from winter to summer season.

4.6 Conclusions

The current study reveals poor quality of drinking water provided from water purification plants and source tube wells in Rawal town of Rawalpindi city. The study covers wide range of issues related to water purification plants that cause bacteriological contamination of drinking water and hence resulting in the wide spread of waterborne and water-related diseases among urban population of Rawal town.

The estimated population of Rawal town in 2009 was 1128316 inhabitants. In Rawal town, 60 sampled water purification plants were operating for an average of 3 hours and supplied 405000 litres water at the rate of 500 gallons/hr, which was not fulfilling the water demand of about 2820790 litres at 2.5 L/person/day. So only 14% population of Rawal town was served with drinking water provided by water purification plants and service short fall was found to be 86% in 2009.

The more the AOH (average operating hours) of the water purification plants, the more would be the WS (water supplied) by these water purification plants in each UC, as a result the less would be the SSF (service short fall) of drinking water provided by these water purification plants in each UC.

Regarding water quality tests, Out of 60 samples of water purification plants; 49 samples were analyzed by 'water check' kits and some were analyzed at PCRWR. It was found that 26 (43%) water purification plants were providing unfit water and 23 (38%)

water purification plants were providing safe water to urban population of Rawal Town. Out of 60 samples of source tube wells 42 tube well samples were analyzed by 'water check' kits and some at PCRWR. After analysis of water quality of tube well samples, 25 (42%) tube wells were providing bacteriologically contaminated water directly to urban population as wells as to water purification plants. Seventeen (28%) tube wells were found to be free of bacteriological contamination. Fifty eight percent water purification plants were working with hypo-chlorinators and 42% water purification plants were working without hypo-chlorinators.

The existing design of water purification plants installed in Rawal town has certain issues that cause microbiological contamination. For disinfection purpose chlorine contact time was not sufficient for the removal of microbiological pathogens. Chlorine reaches in granular activated carbon filter in just 18 to 30 seconds, which disables granular activated carbon filter to de-chlorinate or utilize chlorine after sand filtration. Therefore presence or absence of hypo-chlorinators was ineffective. Another issue was with 1 micron filter which allows spores of bacteria and viruses to be passed out and causes appearance of bio-films on the membranes of 1 micron filters. Sanitization mechanism and backflow system was not present in the existing design. Leakages in micron filters, containers of sand and GAC filters, pipes and in taps were observed. Filter change frequency was very low and random. In some purification plants, ultra violet system was found out of order. Some purification plants were found operating even in the absence of electricity. All these issues directly relate to the microbiological contamination in drinking water provided from these water purification plants to the urban population and cause waterborne and water-related diseases among urban population of Rawal town.

Trend of waterborne and other water-related diseases from both Holy Family and PHC hospitals was found to be increasing in summer season due to increase in the consumption of drinking water. In Benazir Bhutto hospital waterborne diseased patients started increasing from 2007 when water purification plants installed in year 2006 were not maintained by operators and became the source for the growth of microbiological pathogens.

So, due to the irresponsible behaviour of higher authority towards water purification plants, lack of operator training and awareness about the equipments installed in water purification plants, low filter change frequency and faults in the existing design have resulted in the growth of microbiological pathogens in drinking water provided from water purification plants and caused wide spread of waterborne diseases among urban population of Rawal town in Rawalpindi.

4.7 Recommendations

1. As water purification plants were observed to be operating for an average of 3 hours per day and served only 14% of urban population of Rawal town and caused 86% service short fall. So it is recommended that operating hours for water purification plants should be 3+3 = 6 hours.

Table 4.7.1 Status of Drinking Water Provision after Increasing Operating Hours

Year	Total Ucs	1998 Pop	2009 Estimated Pop	Available WPP	Observed WPP Operating Hrs	Water Supplied by WPP (@500g/hr)	Water Demand (2.5L)	Service Short Fall	%age Short Fall	Un Served Pop	Served Pop	% Served Pop
2009	46	781927	1128316	60	6	810000	2820790	2010790	71%	557394	570922	29%

Table 4.7.1 clearly shows that after increasing operating hours to 6 hours; water purification plants will supply 810000 litres water at the rate of 500 gallons/hr which will decrease water demand of estimated 1128316 inhabitants at 2.5 L/person/day to about 2820790 litres in Rawal town. Percentage of served population will increase up to 29% and percentage of service short fall will decrease from 86% to 71%.

2. Table 4.1.2 clearly shows that water purification plants were unevenly distributed in each union council without considering respective population densities of these union councils. So it is recommended that water purification plants should be evenly installed in each UC according to their population densities. So that water demand of 2.5 L/person/day for each UC may be fulfilled.

3. In order to check out even distribution of water purification plants in each union council, it is recommended to have spatial distribution of water purification plants to check out the equal coverage area of every purification plant in each UC. In this way it will be easy for WASA to install additional water purification plants in areas that require purification plants to be installed considering there population.

4. As existing design of water purification plant has different issues that result in microbiological contamination in water provided by water purification plants, so, 3 alternative designs of water purification plants are recommended.

Alternative 1

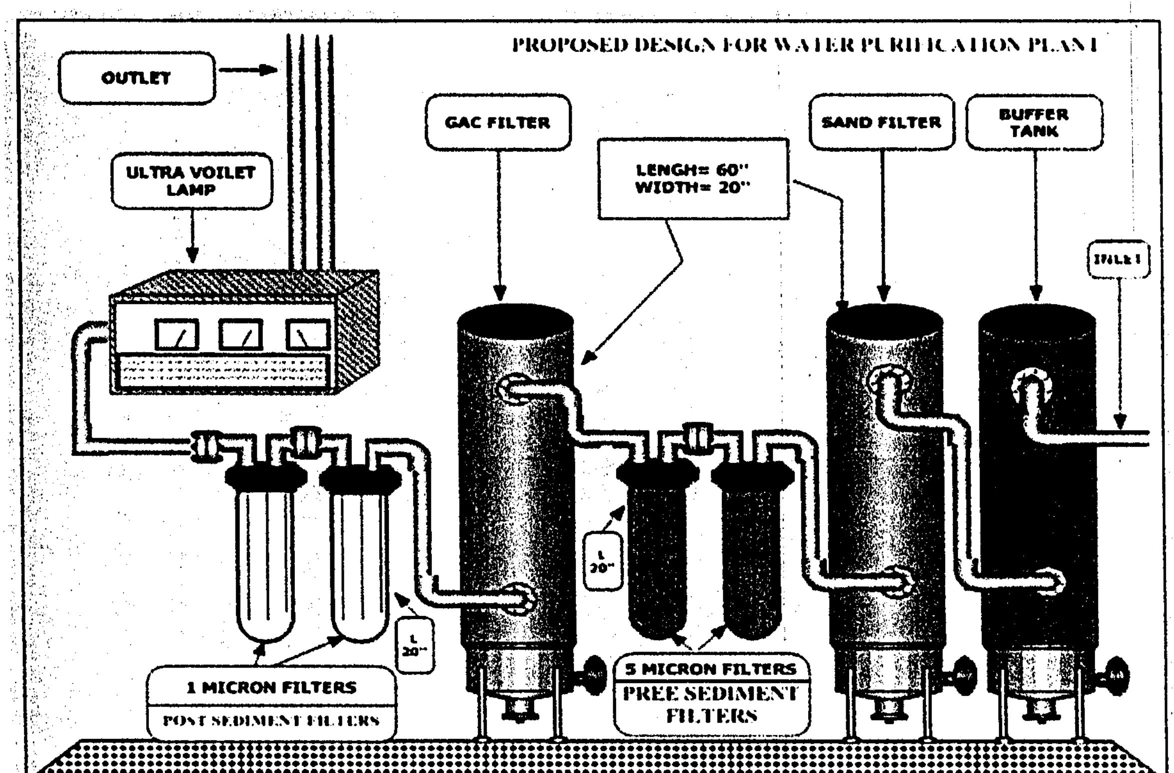

Figure 4.7.2 Proposed design of water purification plant (alternative 1)

Figure 4.7.2 exhibits the proposed design of water purification plant as alternative number 1. As chlorine contact time was not achieved in the existing design and after sand filtration it reached in granular activated carbon in just 18 – 30 seconds; the required chlorine contact time according to different studies should be 30 minutes. So, it is recommended to install a buffer tank for pre chlorination before sand filter. Chlorine will stay in the buffer tank to achieve required chlorine contact time and to kill micro-organisms more effectively.

Alternative 2

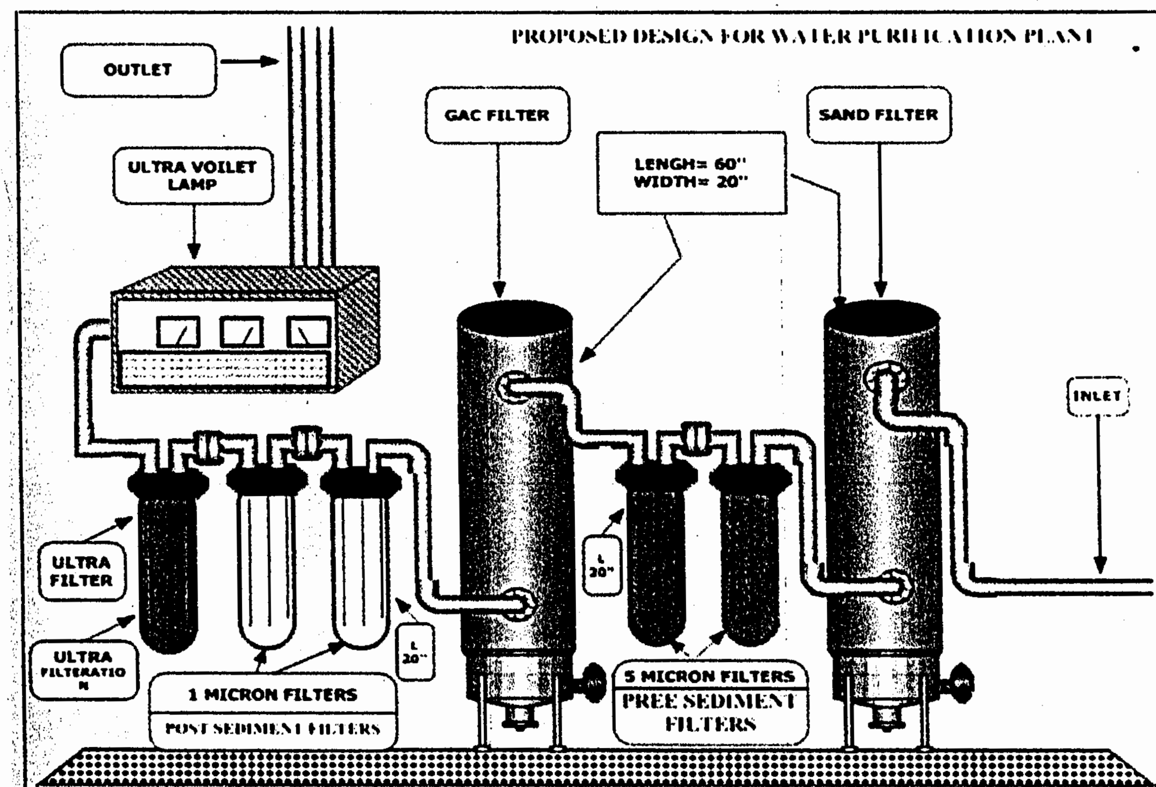

Figure 4.7.3 Proposed design of water purification plant (alternative 2)

Figure 4.7.3 exhibits second recommended design of water purification plant. As 1 micron filter allows the spores of bacteria and viruses to pass out from the membranes and resulted in the appearance of bio-films on the membranes of micron filters and became the source for the growth of microbiological pathogens. Therefore, it is recommended to install ultra filter just after 1 micron filter for ultra filtration and to kill all microbiological pathogens.

Alternative 3

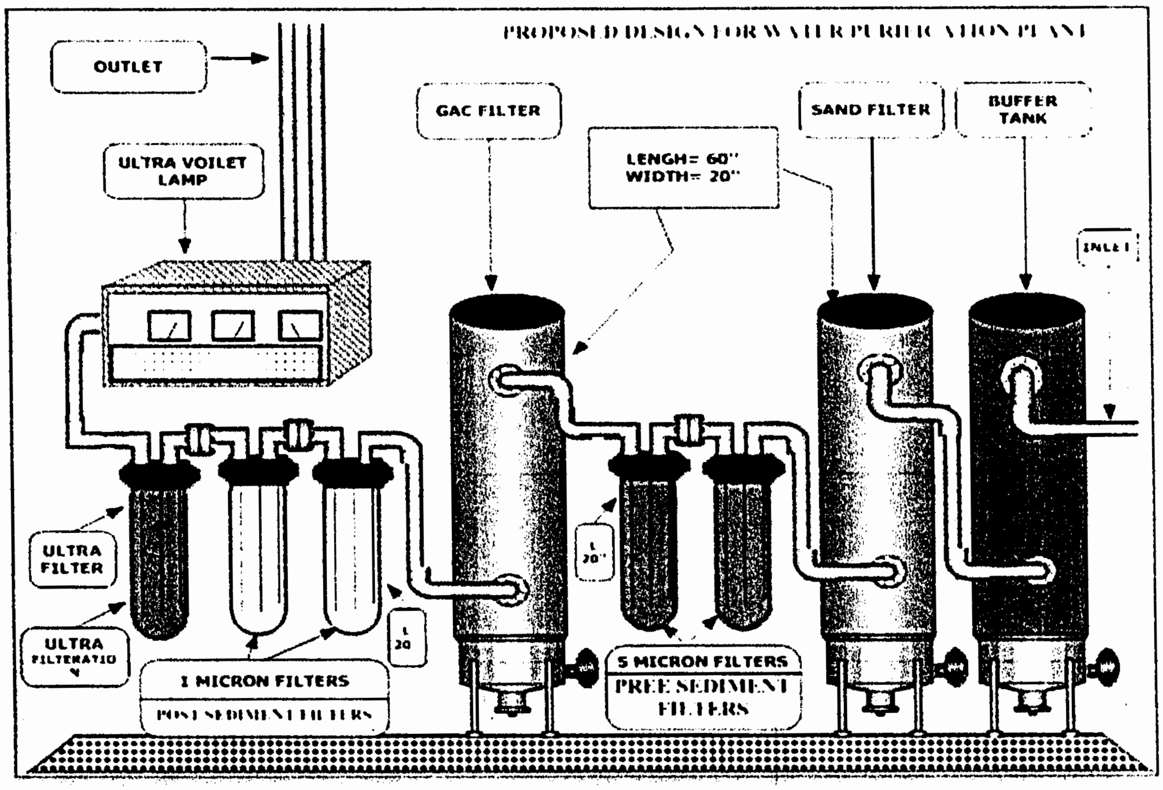

Figure 4.7.4 Proposed design of water purification plants (alternative 3)

Figure 4.7.4 exhibits the third alternative design of water purification plant. For better and efficient treatment of drinking water, third alternative is recommended that is to install both pre chlorination buffer tank before sand filter and ultra filter after 1 micron filter. This proposed design will surely kill all microbiological pathogens that resulted in waterborne diseases among urban population of Rawal town.

5. It is recommended to install piping for sanitization, backwash system, proper ultra violet system and non corrosive material such as stainless steel and fiber glass for filter containers.

6. As it is observed that operators of water purification plants had even no idea about the equipment installed in purification plants and single operator had the duty to operate more than two purification plants as well as tube wells. So, it is recommended that there should be proper training of operators by organizing proper workshops for them and there should be awareness among them about the equipment installed and training for resolving emergency problems regarding equipment installed in water purification plants. It is recommended that there should be separate operators for operating purification plants and every single operator should not have to operate more than two water purification plants. It is recommended that operators should follow standard operating procedures (SOP) given by manufacturers of the equipment installed. Micron filters and filter media should be timely changed by operators. Operators should have proper training to operate ultra violet system.

7. It is recommended not to install water purification plants with those tube wells already providing safe and clean water. Water purification plants should be installed with tube wells supplying unfit water to communities.

8. It is recommended to install and run subsidized water shops/ subsidized bottled water as done by Philippine and other Far East countries because this approach is easy to implement, handled, maintained and economically beneficial.

9. It is recommended to develop regular monitoring schedule by higher authorities to monitor quality of drinking water provided by water purification plants.

10. It is recommended that Water and Sanitation Agency should keep records of waterborne diseased patients with their locations from all hospitals in Rawalpindi to identify areas which are provided with microbiologically contaminated water.

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APPENDIX

Water purification plant's operational status with hypo-chlorinators

Tw No	Water Purification Plant Address	Working	Hypo-chlorinator
74A	Union Council# 1, Ratta Amral Chungi Millad Nagar	W	No
74B	Jamiya Masjid Mai Sharfan, Ratta Amral	W	Yes
76A	Imam Bargah Road Milad Nagar, Ratta Amral	PW	Yes
75	Bhoosa Bazar, Dhoke Ratta	NW	
78	Water Purification Plant, Tohidi Road	W	Yes
86	Mohallah Gulshan Data, Dhoke Hassu	W	No
160	Union Council# 10, Khayaban-e -Sir Syed, Sector 2	PW	Yes
168	Union Council # 10, Khayaban-e-Sir Syed	W	Yes
166	Muhammadi chowke Khayaban-e-Sir Syed	W	Yes
162A	Union Council # 11, Khayaban-e-Sir Syed	W	No
105	Union Council # 13, Khayaban-e-Sir Syed, Dhoke Najju	W	No
169	Union Council # 13, Noor Pariyan, New Katariyan	PW	No
2	Union Council # 13, F Block, New Katariyan	PW	No
4	Quaid-i-Azam Park, Satellite Town F Block	W	Yes
1	New katariya market	W	Yes
10	Mutton Market, Pindora	NW	
8	Nawaz Shrif Park, Dhoke Babu Irfan	NW	
117	D Block New Town, Commercial Market	W	Yes
129A	B Block, Commercial Market	W	No
125	High School, Mohallah Muslim	W	Yes
15	Water Purification Plant, Dhoke Kala Khan	W	Yes
7	Water Purification Plant, Data Ganj Baksh Road	PW	Yes
175A	Union Council # 23, Dhoke Kashmiriyan	PW	Yes
17B	Union Council # 24, Mohallah Aliabad	W	No
21	Water Purification Plant, 6 Road, A Block	PW	No
36	Water Purification Plant, Satellite Town, C Block	W	Yes
28	Water Purification Plant, Raheem Town	W	No
28A	Water Purification Plant, UC Nazim Town Muslimabad	W	Yes
31	Union Council # 28, Muslim Town	W	No
30	Water Purification Plant, Service Road, Muslim Town	W	Yes
32	Water Purification Plant, Behari Colony	W	No
48	Union Council # 30, Graveyard Road Qasimabad	PW	No

45A	Water Purification Plant, Haq Nawaz Road, Qasimabad	NW	
45	Union Council # 31, Water Purification Plant	W	No
37	Water Purification Plant, Behria Town, Sultanpura	PW	No
133	Water Purification Plant, Bunni Chock	W	No
132	Union Council # 33, Kohati Bazar	PW	Yes
131	Union Council # 33, Kartarpura	PW	Yes
131A	Water Purification Plant, Mohallah Feroze Pura	W	No
148	Union Council #34, Bunni Thana	PW	No
148A	Union Council # 34, Private Filter	W	Yes
149	Water Purification Plant, Bunni Mohallah	W	No
154	Union Council # 35, Water Purification Plant	PW	No
74	Water Purification Plant, Lai Pull, Dhoke Ratta	W	Yes
72A	Union Council # 36, College, Mohanpura	PW	No
71	Union Council # 36, Dispensory Road, Mohanpura	PW	No
144	Water Purification Plant, Peerwadahi Pul	W	No
140A	Water Purificaion Plant, Tire Bazar, Ganj mandi	W	No
136A	Water Purificaion Plant, Chittian Hattian	W	No
150	Water Purificaion Plant, Pull Shah Nazar, Jamiya Masjid Road	W	No
52	Union Council # 42, Near committee Chowk, Dhoke Elahi	NW	
46	Opposite Committee Chock, Millat Colony	W	No
48A	Mohallah Qasimabad, Talab Taliyan	W	No
47	Union Council # 43, Water Purification Plant	NW	
51	Water Purification Plant, Dhoke khabba	NW	
58B	Union Council # 45, Water Purification Plant	PW	Yes
64	Near TMA Office, Liaqat Road	W	No
60B	Water Purification Plant, Chaman Zar Colony	W	Yes
64A	Water Purification Plant, DAV College Road	W	No
70	Water Purification Plant, Fawara chock	PW	No

W = Working; NW = Not Working; PW = Partially Working; TW = Tube Wells

Geographic coordinates of water purification plants

UCS	TW	WPP	UTM East Coordinates	UTM North Coordinates
1	74A	Union Council# 1, Ratta Amral Chungi Millad Nagar	43 318641E	37 20234N
1	74B	Jamiya Masjid Mai Sharfan, Ratta Amral	43 318588E	37 20665N
1	76A	Imam Bargah Road Milad Nagar, Ratta Amral	43 318479E	37 20832N
1	75	Bhoosa Bazar, Dhoke Ratta	43 318184E	3720776N
2	78	Water Purification Plant, Tohidi Road	43 318389E	37 21049N
6	86	Mohallah Gulshan Data, Dhoke Hassu	43317312E	3722622N

10	160	Union Council# 10, Khayaban-e -Sir Syed, Sector 2	43 318613E	37 23748N
10	168	Union Council # 10, Khayaban-e-Sir Syed	43 318366E	37 23566N
11	166	Muhammadi chowke Khayaban-e-Sir Syed	43 319130E	37 22806N
11	162A	Union Council # 11, Khayaban-e-Sir Syed	43 319308E	37 22867N
13	105	Union Council # 13, Khayaban-e-Sir Syed, Dhoke Najju	43 319111E	37 23765N
13	169	Union Council # 13, Noor Pariyan, New Katariyan	43 319915E	37 24376N
13	2	Union Council # 13, F Block, New Katariyan	43 319704E	37 24755N
13	4	Quaid-i-Azam Park, Satellite Town F Block	43 320113E	37 24633N
13	1	New katariya market	43319913E	3724372N
17	10	Mutton Market, Pindora	43 320847E	37 24899N
17	8	Nawaz Shrif Park, Dhoke Babu Irfan	43 321458E	37 25061N
19	117	D Block New Town, Commercial Market	43 320802E	37 23986N
20	129A	B Block, Commercial Market	43 321199E	37 23653N
20	125	High School, Mohallah Muslim	43320573E	3722840N
21	15	Water Purification Plant, Dhoke Kala Khan	43322486E	3725098N
23	7	Water Purification Plant, Data Ganj Baksh Road	43 322031E	37 24325N
23	175A	Union Council # 23, Dhoke Kashmiriyan	43 322698E	37 24540N
24	17B	Union Council # 24, Mohallah Aliabad	43 322695E	37 23874N
25	21	Water Purification Plant, 6 Road, A Block	43 321838E	37 24049N
26	36	Water Purification Plant, Satellite Town, C Block	43 321760E	37 22992N
27	28	Water Purification Plant, Raheem Town	43 323372E	37 23096N
27	28A	Water Purification Plant, UC Nazim Town Muslimabad	43322941E	3722789N
28	31	Union Council # 28, Muslim Town	43 322402E	37 22531N
28	30	Water Purification Plant, Service Road, Muslim Town	43322648E	3722415N
29	32	Water Purification Plant, Behari Colony	43 323181E	37 22663N
30	48	Union Council # 30, Graveyard Road Qasimabad	43 321017E	37 21311N
31	45A	Water Purification Plant, Haq Nawaz Road, Qasimabad	43 321295E	37 21416N
31	45	Union Council # 31, Water Purification Plant	43 321854E	37 21478N
31	37	Water Purification Plant, Behria Town, Sultanpura	43 321390E	37 22384N
33	133	Water Purification Plant, Bunni Chock	43 320258E	37 21871N
33	132	Union Council # 33, Kohati Bazar	43 320499E	37 22074N
33	131	Union Council # 33, Kartarpura	43 320535E	37 22153N
33	131A	Water Purification Plant, Mohallah Feroze Pura	43320696E	3722219N
34	148	Union Council #34, Bunni Thana	43 320229E	37 22146N
34	148A	Union Council # 34, Private Filter	43 320317E	37 22535N
34	149	Water Purification Plant, Bunni Mohallah	43220154E	3721915N
35	154	Union Council # 35, Water Purification Plant	43 319621E	37 22288N
36	74	Water Purification Plant, Lai Pull, Dhoke Ratta	43 318805E	37 20587N
36	72A	Union Council # 36, College, Mohanpura	43 319265E	37 20579N
36	71	Union Council # 36, Dispensory Road, Mohanpura	43 319326E	37 20382N

37	144	Water Purification Plant, Peerwadahi Pul	43 319166E	37 22161N
38	140A	Water Purificaion Plant, Tire Bazar, Ganj mandi	43 319183E	37 21 344N
39	136A	Water Purificaion Plant, Chittian Hattian	43320218E	3721161N
41	150	Water Purificaion Plant, Pull Shah Nazar, Jamiya Masjid Road	43 319857E	37 21685N
42	52	Union Council # 42, Near committee Chowk, Dhoke Elahi	43 320588E	37 20776N
42	46	Opposite Committee Chock, Millat Colony	43 320874E	37 21113N
42	48A	Mohallah Qasimabad, Talab Taliyan	43321023E	3721313N
43	47	Union Council # 43, Water Purification Plant	43 321088E	37 20967N
43	51	Water Purification Plant, Dhoke khabba	43 321526E	37 20672N
45	58B	Union Council # 45, Water Purification Plant	43 320685E	37 19945N
46	64	Near TMA Office, Liaqat Road	43 320166E	37 20347N
46	60B	Water Purification Plant, Chaman Zar Colony	43 320674E	37 19638N
46	64A	Water Purification Plant, DAV College Road	43 320213E	37 20760N
46	70	Water Purification Plant, Fawara chock	43 319649E	37 20672N

Limitations in partially working water purification plants

TW NO	PURIFICATION PLANT ADDRESS	PIPE LEAKAGE	FILTER LEAKAGE	NOT WORKING UV	LOW WATER PRESSURE
76A	Imam Bargah Road Milad Nagar, Ratta Amral		Yes	Yes	Yes
160	Union Council# 10, Khayaban-e -Sir Syed, Sector 2		Yes		
169	Union Council # 13, Noor Pariyan, New Katariyan		Yes		
2	Union Council # 13, F Block, New Katariyan		Yes		
7	Water Purification Plant, Data Ganj Baksh Road	Yes			
175A	Union Council # 23, Dhoke Kashmiriyan		Yes		
21	Water Purification Plant, 6 Road, A Block		Yes		
48	Union Council # 30, Graveyard Road Qasimabad	Yes	Yes		Yes
37	Water Purification Plant, Behria Town, Sultanpura		Yes		
132	Union Council # 33, Kohati Bazar		Yes		
131	Union Council # 33, Kartarpura		Yes		Yes
148	Union Council #34, Bunni Thana		Yes		
154	Union Council # 35, Water Purification Plant	Yes			
72A	Union Council # 36, College, Mohanpura		Yes		
71	Union Council # 36, Dispensory Road, Mohanpura		Yes		
58B	Union Council # 45, Water Purification Plant		Yes		
70	Water Purification Plant, Fawara chock				Yes

Tube wells unfit/water purification plants unfit

Tw No	Tw Unfit	Purification Plant Address	PP Unfit
160	+ve	Union Council# 10, Khayaban-e -Sir Syed, Sector 2	+ve
168	+ve	Union Council # 10, Khayaban-e-Sir Syed	+ve
4	+ve	Quaid-i-Azam Park, Satellite Town F Block	+ve
1	+ve	New katariya market	+ve
117	+ve	D Block New Town, Commercial Market	+ve
7	+ve	Water Purification Plant, Data Ganj Baksh Road	+ve
17B	+ve	Union Council # 24, Mohallah Aliabad	+ve
36	+ve	Water Purification Plant, Satellite Town, C Block	+ve
28A	+ve	Water Purification Plant, UC Nazim Town Muslimabad	+ve
30	+ve	Water Purification Plant, Service Road, Muslim Town	+ve
32	+ve	Water Purification Plant, Behari Colony	+ve
37	+ve	Water Purification Plant, Behria Town, Sultanpura	+ve
132	+ve	Union Council # 33, Kohati Bazar	+ve
136A	+ve	Water Purificaion Plant, Chittian Hattian	+ve
58B	+ve	Union Council # 45, Water Purification Plant	+ve
64A	+ve	Water Purification Plant, DAV College Road	+ve

+ve = Unfit; TW = Tube Well; PP = Purification Plant

Tube wells fit/water purification plants fit

Tw No	TW Fit	Purification Plant Address	PP Fit
74A	-ve	Union Council# 1, Ratta Amral Chungi Millad Nagar	-ve
78	-ve	Water Purification Plant, Tohidi Road	-ve
86	-ve	Mohallah Gulshan Data, Dhoke Hassu	-ve
166	-ve	Muhammadi chowke Khayaban-e-Sir Syed	-ve
169	-ve	Union Council # 13, Noor Pariyan, New Katariyan	-ve
2	-ve	Union Council # 13, F Block, New Katariyan	-ve
133	-ve	Water Purification Plant, Bunni Chock	-ve
48A	-ve	Mohallah Qasimabad, Talab Taliyan	-ve

-ve = Fit

Tube wells unfit/water purification plants fit

Tw No	TW Unfit	Purification Plant Address	PP Fit
125	+ve	High School, Mohallah Muslim	-ve
175A	+ve	Union Council # 23, Dhoke Kashmiriyan	-ve
31	+ve	Union Council # 28, Muslim Town	-ve
131	+ve	Union Council # 33, Kartarpura	-ve
131A	+ve	Water Purification Plant, Mohallah Feroze Pura	-ve
148A	+ve	Union Council # 34, Private Filter	-ve
140A	+ve	Water Purificaion Plant, Tire Bazar, Ganj mandi	-ve
46	+ve	Opposite Committee Chock, Millat Colony	-ve
70	+ve	Water Purification Plant, Fawara chock	-ve

+ve = unfit; -ve = fit

Tube wells fit/purification plants unfit

TW No	TW Fit	Purification Plant Address	PP Unfit
15	-ve	Water Purification Plant, Dhoke Kala Khan	+ve
21	-ve	Water Purification Plant, 6 Road, A Block	+ve
148	-ve	Union Council #34, Bunni Thana	+ve
72A	-ve	Union Council # 36, College, Mohanpura	+ve
64	-ve	Near TMA Office, Liaqat Road	+ve

-ve = fit; +ve = unfit

Tube wells fit/purification plants not working

TW No	TW Fit	Purification Plant Address	PP nw
10	-ve	Mutton Market, Pindora	nw
8	-ve	Nawaz Shrif Park, Dhoke Babu Irfan	nw
52	-ve	Union Council # 42, Near committee Chowk, Dhoke Elahi	nw
47	-ve	Union Council # 43, Water Purification Plant	nw

-ve = fit; nw = not working

Tube wells not known/purification plants not working

TW No	TW nk	Purification Plant Address	PP nw
75	nk	Bhoosa Bazar, Dhoke Ratta	nw

45A	nk	Water Purification Plant, Haq Nawaz Road, Qasimabad	nw
51	nk	Water Purification Plant, Dhoke khabba	nw

nk= not known

Tube wells not known/purification plants not known

TW No	TW nk	Purification Plant Address	PP nw
162A	nk	Union Council # 11, Khayaban-e-Sir Syed	nk
129A	nk	B Block, Commercial Market	nk
45	nk	Union Council # 31; Water Purification Plant	nk
74	nk	Water Purification Plant, Lai Pull, Dhoke Ratta	nk

nk = not known

Tube wells not known/purification plants fit

TW No	TW nk	Purification Plant Address	PP Fit
28	nk	Water Purification Plant, Raheem Town	-ve
48	nk	Union Council # 30, Graveyard Road Qasimabad	-ve
154	nk	Union Council # 35, Water Purification Plant	-ve
71	nk	Union Council # 36, Dispensory Road, Mohanpura	-ve
150	nk	Water Purificaion Plant, Pull Shah Nazar, Jamiya Masjid Road	-ve
60B	nk	Water Purification Plant, Chaman Zar Colony	-ve

nk = not known; -ve = fit

Tube wells not known/purification plants unfit

TW No	TW nk	Purification Plant Address	PP Unfit
74B	nk	Jamiya Masjid Mai Sharfan, Ratta Amral	+ve
76A	nk	Imam Bargah Road Milad Nagar, Ratta Amral	+ve
105	nk	Union Council # 13, Khayaban-e-Sir Syed, Dhoke Najju	+ve
149	nk	Water Purification Plant, Bunni Mohallah	+ve
144	nk	Water Purification Plant, Peerwadahi Pul	+ve

nk = not known; +ve = unfit

Tube wells unfit/purification plants unfit with hypo-chlorinators

TW No	WPP Address	Hypo-chlorinator	TW Unfit	PP Unfit
160	Union Council# 10, Khayaban-e -Sir Syed, Sector 2	Yes	+ve	+ve
168	Union Council # 10, Khayaban-e-Sir Syed	Yes	+ve	+ve
4	Quaid-i-Azam Park, Satellite Town F Block	Yes	+ve	+ve
1	New katariya market	Yes	+ve	+ve
117	D Block New Town, Commercial Market	Yes	+ve	+ve
7	Water Purification Plant, Data Ganj Baksh Road	Yes	+ve	+ve
36	Water Purification Plant, Satellite Town, C Block	Yes	+ve	+ve
28A	Water Purification Plant, UC Nazim Town Muslimabad	Yes	+ve	+ve
30	Water Purification Plant, Service Road, Muslim Town	Yes	+ve	+ve
132	Union Council # 33, Kohati Bazar	Yes	+ve	+ve
58B	Union Council # 45, Water Purification Plant	Yes	+ve	+ve

+ve = unfit

Tube wells fit/purification plants unfit with hypo-chlorinators

TW No	WPP Address	Hypo-chlorinator	TW Fit	PP Unfit
15	Water Purification Plant, Dhoke Kala Khan	Yes	-ve	+ve

-ve = fit; +ve = unfit

Tube wells fit /purification plants fit with hypo-chlorinators

TW No	WPP Address	Hypo-chlorinator	TW FIT	PP FIT
78	Water Purification Plant, Tohidi Road	Yes	-ve	-ve
166	Muhammadi chowke Khayaban-e-Sir Syed	Yes	-ve	-ve

-ve = fit;

Tube wells unfit/purification plants fit with hypo-chlorinator

TW No	WPP Address	Hypo-chlorinator	TW Unfit	PP Fit
125	High School, Mohallah Muslim	Yes	+ve	-ve
175A	Union Council # 23, Dhoke Kashmiriyan	Yes	+ve	-ve
131	Union Council # 33, Kartarpura	Yes	+ve	-ve
148A	Union Council # 34, Private Filter	Yes	+ve	-ve

+ve = unfit; -ve = fit

Tube wells unfit/purification plants unfit without hypo-chlorinator

TW No	WPP Address	Hypo-chlorinator	TW Unfit	PP Unfit
17B	Union Council # 24, Mohallah Aliabad	No	+ve	+ve
32	Water Purification Plant, Behari Colony	No	+ve	+ve
37	Water Purification Plant, Behria Town, Sultanpura	No	+ve	+ve
136A	Water Purificaion Plant, Chittian Hattian	No	+ve	+ve
64A	Water Purification Plant, DAV College Road	No	+ve	+ve

+ve = unfit

Tube wells fit/purification plants unfit without hypo-chlorinator

TW No	WPP Address	Hypo-chlorinator	TW Fit	PP Unfit
21	Water Purification Plant, 6 Road, A Block	No	-ve	+ve
148	Union Council #34, Bunni Thana	No	-ve	+ve
72A	Union Council # 36, College, Mohanpura	No	-ve	+ve
64	Near TMA Office, Liaqat Road	No	-ve	+ve

-ve = fit; +ve = unfit

Tube wells fit/purification plants fit without hypo-chlorinators

TW No	WPP Address	Hypo-chlorinator	TW Unfit	PP Fit
74A	Union Council# 1, Ratta Amral Chungi Millad Nagar	Yes	-ve	-ve
86	Mohallah Gulshan Data, Dhoke Hassu	Yes	-ve	-ve
169	Union Council # 13, Noor Pariyan, New Katariyan	Yes	-ve	-ve
2	Union Council # 13, F Block, New Katariyan	Yes	-ve	-ve
133	Water Purification Plant, Bunni Chock	Yes	-ve	-ve
48A	Mohallah Qasimabad, Talab Taliyan	Yes	-ve	-ve

-ve = fit

Tube wells unfit/purification plants fit without hypo-chlorinator

TW No	WPP Address	Hypo-chlorinator	TW Unfit	PP Fit
48	Union Council # 30, Graveyard Road Qasimabad	Yes	+ve	-ve
149	Water Purification Plant, Bunni Mohallah	Yes	+ve	-ve
154	Union Council # 35, Water Purification Plant	Yes	+ve	-ve
72A	Union Council # 36, College, Mohanpura	Yes	+ve	-ve

48A	Mohallah Qasimabad, Talab Taliyan	Yes	+ve	-ve
64A	Water Purification Plant, DAV College Road	Yes	+ve	-ve

+ve = unfit; -ve = fit

Waterborne and water related diseased patients (PHC Hospital)

Month	Daily OPD Attendance	Diarrhea / Dysentery in < 5 YRS	Diarrhea / Dysentery in > 5 YRS	Enteric Fever / Typhoid Fever	Worm Infestation	Dermatitis& Eczema	Scabies
JANUARY	6001	51	23	18		20	384
FEBRAURY	6245	228	39	45		49	479
MARCH	5846	155	165	5	30	49	412
APRIL	5652	169	184	9	39	39	384
MAY	5529	554	432	5	104	41	391
JUNE	5598	882	715	9	313	98	385