IMPACT ASSESSMENT OF SEWERAGE AND INDUSTRIAL EFFLUENTS ON WATER RESOURCES, SOIL, CROPS AND HUMAN HEALTH IN FAISALABAD

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ACRONYMS

As	Arsenic
BCM	Billion Cubic Meters
BOD	Biochemical Oxygen Demand
Ca	Calcium
Cd	Cadmium
Cn	Cyanide
CO_3	Carbonate
COD	Chemical Oxygen Demand
Cl	Chloride
Cr	Chromium
Cu	Copper
CFU	Coli Form Unit
DO	Dissolved Oxygen
EC	Electrical Conductivity
ETPs	Effluent Treatment Plants
F	Fluoride
FDA	Faisalabad Development Authority
Fe	Iron
GoP	Government of Pakistan
GPS	Global Positioning System
HCO_3	Bicarbonate
Hg	Mercury
IWMI	International Water Management Institute
K	Potassium
Mg	Magnesium
Mn	Manganese
N	Nitrogen
Na	Sodium
NEQS	National Environmental Quality Standards
Ni	Nickle
NIBGE	National Institute of Biotechnology and Genetic Engineering
NIH	National Institute of Health
NEAP	National Environmental Action Plan
P	Phosphorous
Pb	Lead
PIMS	Pakistan Institute of Medical Sciences
PNCS	Pakistan National Conservation strategy
PRA	Participatory Rural Appraisal
RSC	Residual Sodium Carbonate
SAR	Sodium Adsorption Ratio
SO_4	Sulphate
TDS	Total Dissolved Solids
TMAs	Tehsil Municipal Administrations
TSS	Total Suspended Solids
UNEP	United Nations Environment Programme
UNICEF	United Nations International Children's Emergency Fund
USAID	United States Agency for International Development
WASA	Water and Sanitation Agency
WHO	World Health Organization
Zn	Zinc

SUMMARY

Growing population and rapid industrialization has increased the volume of wastewater manifolds eventually deteriorating the freshwater resources and surrounding environment due to inappropriate management. Present study was conducted to document the impacts of wastewater on surface and groundwater, agricultural soils, crops grown with wastewater, and human health in Faisalabad.

Wastewater of the city is being disposed off into the rivers Ravi and Chenab through drainage system that comprises Madhuana and Paharang drains and city municipal channels. Water and Sanitation Agency (WASA) treats a part of the municipal channels through oxidation ponds. The discharges of these drains were measured with a pigmy type digital current meter at an interval of two hours. Seepage rate from the drains was also measured in each drain with inflow-outflow method. Samples of wastewater, soils, crops and vegetables grown with wastewater were collected for microbiological, physico-chemical and heavy metal analysis. Samples of drinking water supplied by the WASA, groundwater in the city, groundwater near Rakh Branch canal and groundwater near drainage channels were collected to analyze the extent of contamination. Fish samples grown with low quality groundwater were collected for analysis. Human blood samples were collected for analysis of different water-borne and water-related diseases. A participatory appraisal survey was also conducted to supplement the information regarding the impacts of waster water on ecosystem.

The average volume of wastewater disposed off from city was about 5.28 m^3/sec. After the addition of disposals from other towns and villages during its way, about 7.29 m^3/sec wastewater is finally being discharged into the rivers. The seepage from Pharang and Madhuana drains were 140 lps/100 m and 47 lps/100 m, respectively. Wastewater analysis showed that mean maximum values of BOD and COD were 425 mg/l and 980 mg/l, respectively before discharging into the rivers. Samples exceeding the permissible limit for BOD were 83, 89 and 95 percent in industrial, sewerage and mixed (industrial + sewerage) water samples, respectively. Similarly, samples exceeding the permissible limit for COD were 94, 100 and 97 percent for industrial, sewerage, and mixed types of wastewater, respectively. Highest mean values of TDS (5821 mg/l) were found for Madhuana drain whereas highest mean value of pH (13) was found for city municipal drains. No sample exceeded the permissible limit of TDS and heavy metals for WASA treated water.

For drinking water average percentages of microbiologically unfit samples were 39, 57, 60 and 58 percent for public water supply, groundwater in the city, groundwater near drains and groundwater near canal, respectively. The average values of coliforms were 2625, 1227, 15862 and 4849 CFU/ml for WASA supplies, groundwater in the city, groundwater near drains and groundwater near canal, respectively. Chemical quality of drinking water supplied by the WASA was found satisfactory except a few points. The chemical quality of the groundwater in the city was found very poor. Nearly, 80 percent samples exceeded the permissible limits for TDS, Na, K, Cl, SO_4 and hardness. The quality of groundwater near drains for drinking was found the worst as on average 90 percent samples were found unfit with respect to TDS, Na, K, Cl, SO_4, Ca, and pH. The quality of groundwater near canal was found comparatively better. Mercury concentrations were observed in 9 percent samples of WASA and 8 percent samples of groundwater in the city. Similarly, excessive arsenic was also found in 10 and 6 percent samples of groundwater in the city and groundwater near drains, respectively. The manganese exceeded the permissible limits in 3 percent samples of groundwater near drains.

The chemical quality of irrigation water with respect to TDS, Na, HCO_3, Cl was found entirely unfit. The sulphate contents were found higher in Madhuana and Municipal drains. The WASA treated water was found fit for irrigation but it is being disposed off into the Paharang drain with out any productive use. The concentrations of heavy metals in irrigation wastewater were found within permissible levels.

Contrary to the general perceptions of the farmers, the organic matter contents have been found deficient in all soil samples. The deficiency of organic matter contents increased with depth. The soils irrigated with the wastewater of Paharang and Municipal drains were also found deficient in phosphorus and potassium. An excessive Ni contents were found in soils particularly those irrigated with Madhuana drains and Cd in the soils irrigated with wastewater of Municipal drain.

The vegetables grown with untreated wastewater were found contaminated with Cr, Pb, Cd and Fe. The vegetables irrigated with industrial wastewater showed higher contents of these heavy metals. Wheat, sorghum, berseem, lettuce, mint and turnips were found to have more contaminant uptake capability whereas, sugarcane and barley showed the least contamination.

The fish reared with groundwater showed excessive concentration of all heavy metals upto toxic levels except Cd and Mn. The concentration of lead was particularly very high. Similarly, all samples of fish farm water exceeded the permissible limit of TDS and HCO_3.

Human blood analysis indicated the presence of few cases of Hepatitis E for all types of drinking water sources. Moreover, only one typhoid case was seen. Human blood sample size (100 Nos) was too small to reach to a general conclusion. According to doctors, 30 to 40 percent of the patients were suffering from water-borne diseases. Nearly 75 percent of the industries reported to have proper effluent management systems whereas it was found in less than 25 percent industries.

Irrigation with untreated wastewater should be stopped immediately. Low cost water treatment facilities are needed for industrial units and the strict implementation of environmental policy must be ensured. With the wastewater treatment facilities, nearly 7.27 m^3/sec (1,85,868 AF/year) of the wastewater, which is being disposed off, could be used for irrigation shortening the gap between water demand and supply. Groundwater quality in the city was very poor. Extension, regulation and rehabilitation of the water supplies is highly needed for all residential areas with necessary treatment facilities.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The population of Pakistan has increased up to 153 million in 2006, which was only 32.5 million at the time of independence in 1947. Addition of 120.5 million people during the last 57 years and the projected population of 263 million by the year 2025 has posed a serious threat to the limited natural resources of the country. Besides the high population growth rate, demographic features of the population has been changed due to migration of peoples towards urban centers for better education, health care, employment and other basic amenities of life.

Pakistan, once having surplus water, is now a water deficit country. Per capita water availability which was 5300 m^3 in 1951 has now reduced to 1105 m^3, just touching the water scarcity level of 1000 m^3. The main reasons for declining water availability are rapid population growth, depleting water storage facilities, and pollution/contamination of existing water resources due to discharge of untreated industrial and sewerage effluents into streams/rivers.

1.2 PROBLEM STATEMENT/ISSUES

The disposal of domestic and industrial wastewaters is a serious problem as it is affecting the freshwater resources, human health and agricultural productivity. The problem is more critical in the urban and industrial areas where rapid water quality deterioration has caused widespread water-borne diseases and other irrecoverable damages to the environment. Rapid development and growth in industrialization has adversely affected the environment and surrounding ecosystem. Besides release of toxic gases, noise pollution, inadequate or non availability of sewerage system and expensive wastewater treatment methods, huge quantities of untreated wastewater is disposed off in the drainage system creating a number of environmental issues. Industrial and commercial activities are expanding to meet the growing demands of increasing population ultimately leading to a number of issues like safe drinking water, safe disposal of wastewater and several other related issues.

Wastewater contains pathogenic microorganisms such as bacteria, virus and parasites, which cause diseases. Some toxic elements in the wastewater used for irrigation may enter in the food chain and may result in high salinity levels of soils that affect the yield of salt sensitive crops. Prolonged use of wastewater is hazardous for soil as it may deteriorate the soil structure. The crop growth and yield may be affected by the use of untreated wastewater, due to high concentration of nitrogen, phosphorous and potassium (NPK). For example, urea plant effluent is a rich source of liquid fertilizer but due to high concentration, it has adverse effects on rice and corn yields. The impacts of wastewater on soil are due to the presence of high TDS and heavy metals, which deposit in the soil with the passage of time, causing soil and groundwater pollution.

Besides the above factors, lack of mass awareness, lack of community participation, institutional weakness, lack of capacity and infrastructure, lack of coordination between different stakeholders and lack of resources for operation and maintenance are big problems. However, these issues can be handled with proper planning.

1.3 WASTEWATER AND ITS DISPOSAL

Generally, wastewater consists of domestic and industrial effluents. In many cases rainwater is also disposed of through sewerage network. Domestic wastewater is discharged from residential areas, office buildings, hospitals and commercial markets etc. The rate of domestic wastewater flow varies with time of a day. Usually, peak flow occurs during late morning, business hours, ceremonial and festivals periods. Industrial wastewater is discharged by the industrial units and its quantity and quality depends upon the type of industries, number of units, working hours and quantity of water consumed by the industry. It constitutes a major part of the wastewater in cities engaged in intensive industrial activities. The fluctuations in industrial wastewater flow may take place during the processing of seasonal products. The composition of industrial wastewater depends upon the source that may vary from place to place.

Similarly, rainwater moves across the land surface during and after occurrence of a rain and it carries dissolved or suspended materials. In several cases, the pollutants carried to drains and rivers by surface runoff, consists of sediments, chemicals, heavy metals, nutrients, pesticides, and microbes. The quantity of transported pollutants depends upon the topography and rainfall intensity.

The annual generation of wastewater in Pakistan is about 4.43 billion cubic meters (BCM) out of which 3.06 BCM is municipal and 1.37 BCM is from industries (IUCN, 2006). The annual effluent potential of fifteen main cities of Pakistan is over 2.47 BCM (Table 1.1).

In major cities of Pakistan, Water and Sanitation Agencies (WASA) deal with drainage of wastewater alongwith drinking water supplies while Tehsil Municipal Administrations (TMAs) provide these facilities in small cities. Due to improper estimations of wastewater generation and poor engineering designs of the disposal drains, excessive quantity of wastewater is discharged into these drains exceeding their capacities causing the problems of chocking and overflowing (Figures 1.1 and 1.2).

Figure 1.1: Unmanaged industrial effluents

Figure 1.2: Choking and overflowing of drain

Table 1.1: Sewerage and industrial effluents generated from major cities of Pakistan

City	*Effluent (m^3/sec)*		
	Industrial	*Domestic*	*Total*
Karachi	11.52	24.10	35.62
Hyderabad	NA	1.10	1.10
Quetta	NA	0.22	0.22
Multan	2.54	2.63	5.17
Faisalabad	3.51	2.94	6.45
Kasur	0.61	NA	0.61
Lahore	4.03	17.53	21.56
Rawalpindi/Islamabad	0.70	3.07	3.77
Attock	1.27	0.22	1.49
Mianwali	0.04	0.13	0.17
Bhakkar	0.04	0.09	0.13
Leiah	0.04	0.13	0.17
D.G.Khan	0.18	0.26	0.44
Peshawar	0.35	1.31	1.66
Total	*24.83*	*53.73*	*78.56*
Total (BCM/year)	*0.78*	*1.69*	*2.47*

Source: Khurshid and Waris (1999). NA: Not Applicable

As a result of mismanagement of wastewater, the issues of surface and groundwater contaminations are emerging. Moreover, due to shortage of canal water, wastewater is being used for growing crops and vegetables. Such crops and vegetables take up toxic elements and inject these into the food chain resulting in adverse effects on human health.

1.4 ENVIRONMENTAL POLICY

The first effort to introduce specific legislation for environmental protection in Pakistan was made in 1977. Since then, many institutional, policy and regulatory developments have taken place at the federal and provincial levels. These include promulgation of the Pakistan Environmental Protection Act 1977 and the Pakistan Environmental Protection Ordinance 1983, followed by the National Environmental Quality Standards (NEQS) in 1993 for municipal and industrial effluents, gaseous emissions, motor vehicle exhaust and noise. The environmental protection laws were framed but could not be enforced strictly. In addition, enforcement does not imply effectiveness and even if regulations had been strictly enforced, many industries would have been unable to comply.

National assembly established another act on September 3, 1997 but there was no procedural detail and regularity mechanism in this act. According to this act "no person shall discharge any effluent or waste in excess of National Environmental Quality Standards (NEQS)". The Pakistan Environmental Protection Act 1997 provides the protection, conservation, rehabilitation and improvement of the environment to control the pollution and promote the sustainable development. While comparing NEQS announced on 24th August 1993 with those announced on 10th August 2000, only six parameters for inland water discharge namely: pH, temperature, TSS, fluoride (F), cyanide (CN) and iron (Fe) were revised. This revision of NEQS by Pakistan Environmental Protection Agency does not serve the purpose for Pakistan where environment concept is totally new and has to be digested in true sense by public and the industrial sectors. Essential parameters such as BOD and COD were not even touched. The limits of NEQS should be revised so that all those industries aspiring to establish and operate effluent treatment plants (ETPs) facilities could adopt these easily.

The National Environmental Action Plan (NEAP) was approved by the Pakistan Environment Protection Agency and implemented in February 2001. The objective of NEAP was to initiate actions and programs that could safeguard public health, promote sustainable livelihoods and enhance quality of life of the people of Pakistan. It would focus on taking immediate measures to achieve a visible improvement in rapidly deteriorating quality of air, water and land, through effective co-operation between the government agencies and civil societies.

There is no act to control the use of untreated or semi-treated wastewater for agricultural uses. According to the standards for municipal and liquid industrial effluents, COD and BOD of wastewater should not exceed 150 mg/l and 80 mg/l, respectively (GoP, 1993). However, WASA and municipal administrations do not have enough resources to test and treat the wastewater before disposing off. WASA is vending the wastewater to the farmers due to lack of legal support for the development of infrastructure for untreated wastewater distribution for use in the agriculture. In fact, it is violation of the existing environmental regulations.

1.5 PROPOSED PROJECT

Faisalabad is the third most populous and largest industrial city of Pakistan. It is surrounded by the Rakh Branch and Jhang Branch canals while wastewater is drained through the Madhuana and Paharang drains into the rivers Ravi and Chenab, respectively. Irrigation with wastewater is common due to scarcity of canal water, particularly in the areas located near to the industrial units. Due to improper planning in industrial growth and haphazard urbanization, the city is facing several environmental issues. To document the issues of wastewater management and its impacts in Faisalabad, a study was conducted with the following objectives.

1.6 OBJECTIVES

1. To undertake survey, sample testing and industry-wise analysis of effluents.
2. To carry out an impact assessment of wastewater on water resources, soil, crops and human health, and dissemination of these to the beneficiaries/users.
3. To devise a viable mitigation plan for treatment and management of wastewater for a safe environment.

CHAPTER 2

WASTEWATER AND ITS IMPACTS

Wastewater and its impacts on surface and groundwater resources, soil, crops, human health and environment are as follows.

2.1 CONTAMINATION OF SURFACE AND GROUNDWATER RESOURCES

Disposal of untreated wastewater into drains and ultimately into the rivers, deteriorates the water quality and harms the aquatic life. Khurshid *et al.,* (1999) reported that due to discharge of untreated effluents from industries, the Dissolved Oxygen (DO) level is decreasing whereas Biological Oxygen Demand (BOD) and Total Dissolved Solids (TDS) are increasing in the river Ravi. In China, with the rapid expansion of the energy, chemicals and metallurgical industries alongwith growth of cities, there is widespread surface water pollution. All major rivers have been seriously contaminated from large cities that discharge great quantities of untreated industrial and urban wastes (Smil, 1980). Anand (1980) reported that in India, heavy industries such as steel processing and petrochemical complexes have caused a serious deterioration of water supplies in Bombay, Calcutta and Madras. Untreated waste from agro-industrial processes alongwith effluents from new factories in Asia, Africa and Latin America have destroyed fisheries and reduced available water supplies. Particularly in Asia, localized pollution from agro-industrial operations, such as sugar and palm oil processing mills, adversely affected the water supplies, fisheries and agriculture (USAID, 1979).

Untreated wastewater is also being used for growing vegetables and crops due to shortage of canal water, reliability in its supply and high nutritional value. Due to seepage from drains and settling basins, groundwater quality is being contaminated. Hoek *et al.,* (2002) conducted a case study on wastewater in Haroonabad, Pakistan. They concluded that groundwater in the entire Haroonabad area was brackish and was not usable for drinking or other domestic purposes. High levels of salinity, fecal contamination and nitrates were observed in the groundwater immediately below wastewater-irrigated fields. It was also revealed that wastewater irrigation had further deteriorated the groundwater quality compared to canal-irrigated fields. Leaching of salts, nitrates, heavy metal contents and micro organisms contaminate groundwater and limit its beneficial use (Hussain *et al.,* 2002).

Impacts of wastewater on groundwater depend upon many factors such as depth of water table, type of soil and quality of wastewater. In irrigated areas with shallow fresh water tables, impact of wastewater irrigation on groundwater quality is substantial (Hussain *et al.,* 2001). A study conducted on assessment of groundwater quality for Faisalabad by different methods (Graphical plotting, Logarithmic nomograph, Trilinear plotting) concluded that groundwater of the Faisalabad city was not suitable to be used directly for domestic, irrigation and industrial purposes. Main causes of groundwater pollution were the increasing industrial and domestic wastes (Hassan *et al.,* 1997).

Hussain and Hanjra (1996) evaluated the impacts of industrial wastewater on groundwater quality in Fasialabad. The analysis of groundwater samples collected from hand pumps and wells located within a radius of one kilometer of industrial effluent disposal area, showed very high concentration of dissolved salts, trace elements and heavy metals. Concentrations of chloride (Cl), sulphate (SO_4), TDS and DO in groundwater were much higher than average concentrations in sewage effluents. Generally, fifty to seventy percent of irrigation water percolates into the groundwater during disposal of wastewater (Rashed *et al.,* 1995).

Kahlown *et al.,* (2006) concluded that quality of water is getting worse with passage of time. The result of 5-year monitoring revealed that 46 percent water samples were found contaminated with coliforms and Fe, 23 percent samples were found contaminated due to excessive Ca, Na, Cl and SO_4 whereas 8 percent samples were found with higher values of hardness, turbidity, NO_3, F and Pb than permissible limits.

A number of studies have attempted to assess the impact of unmanaged and untreated wastewater disposal on groundwater resources in various regions. However, the general conclusion is that improper disposal of wastewater has the potential to adversely affect groundwater resources of the area.

2.2 SOIL DEGRADATION

Pakistan is facing a serious threat of soil degradation due to the use of hazardous wastewater for irrigation. This is because of the fact that less than one percent of major industries in the province of Punjab are equipped with properly operating treatment plants (Bhatti, 1996). The practice of using untreated wastewater for irrigation is a common practice and is likely to continue in the foreseeable future. According to an estimate, about 20 million hectares (Mha) in 50 countries are being irrigated with raw or partially treated wastewater. Wastewater use is causing negative impacts on health of residents and ecosystems. Continuous use of wastewater results in soil salinity and overall reduction in productivity of soil leading to lower crop yields. Chandio *et al.,* (2001) concluded that the quality of soil was changed and the use of untreated wastewater for irrigation was unsafe for food production. Generally, the wastewater contains higher amount of TDS which contaminates the soil matrix and affects crop production. Leaching of the salts below root zone was found to be the main cause of groundwater contamination (Bond, 1999). Juwarkar *et al.,* (1999) observed that increase in application of sewage sludge from 0 to 90 ton/ha has increased organic matter, decreased bulk density and infiltration rate of soil. Udayasoorian *et al.,* (1999) in Tamil Nadu showed that continuous irrigation with treated paper mills wastewater increased the soil pH, EC, organic carbon, N, P, K, exchangeable sodium percentage, Na, Ca and K. Similarly, irrigation with tannery effluent increased the pH, EC and ESP of soil. Babar and Tariq (1998) analyzed physical and chemical parameters of drainage Channel-1 of Faisalabad city. Due to discharge of effluents of textile processing units into the channel, high values of EC, pH, Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC) and Total Suspended Solids (TSS) were found. This water was found unfit for irrigation unless it is mixed with canal water. Moreover, highly odorous substances escaping from the channel were badly polluting the environment in the surrounding localities.

Application of sewage sludge at 20 tons/ha reduced the bulk density of soil, pore space and available macro and micronutrients, besides reducing fertilizer dose by 50 percent of recommended level for rice in Tamil Nadu (Ramulu, 1994). Prasad (1996) recorded high available N contents of soils irrigated with sewage water than that of tubewell water. Juwarkar (1987) observed an increase in soil pH, electrical conductivity and exchangeable sodium percentage with irrigation of wastewater from pulp and paper industry. Baddesha *et al.,* (1986) also observed increase in organic carbon, N, P, K, Ca and Mg while decrease in soluble sodium content in the soil (0 -30 cm layer) was seen with application of sewerage water. Ajmal and Khan (1985) found that textile effluents were rich in BOD, COD, Cl, SO_4 and trace metals such as K, Ca and Mg. The application of such contaminated wastewater for irrigation lead to higher concentration of these elements in the soil. Several other studies such as Ensink (2003); Future Harvest (2001); Mitra and Gupta (1999); Westcot (1997) and Pescod (1992) have also shown that the use of untreated wastewater deteriorates soil properties and reduce crop yields.

2.3 CONTAMINATION OF CROPS

Wastewater irrigation may provide higher crop yields, additional water for irrigation and saving in cost of fertilizer. Impacts of wastewater on crops may differ depending upon the quality of wastewater, type of wastewater, nature of crops grown and overall farm water management practices. Keraita *et al.,* (2003) showed that the use of polluted irrigation water deteriorates the quality of crops and vegetables. Malathi (2001) found that the germination percent alongwith root and shoot growth of vegetables like ladyfinger, brinjal, chili, tomato and bitter gourd was better with treated wastewater as compared to untreated wastewater. Plant growth characteristics of these vegetables were better with wastewater irrigation than well water irrigation and further increase in growth was observed with higher proportion of well water. Sundaramoorthy and Lakshmi (2000) reported that seedling stage is the most sensitive stage in the life cycle of plant and is more vulnerable to physical and chemical adversities. The seedling growth of groundnut varieties gradually increased with 10 percent concentration of tannery effluent but on the other hand market surveys by International Water Management Institute (IWMI) in Kumasi, Accra and Tamale showed that it was difficult to find any vegetables like lettuce, spring onions and cabbage that were not contaminated with faecal coliforms. Helminth eggs were also commonly found on such vegetables. There are guideline values, set by the World Health Organization (WHO) and United Nations Environment Programme (UNEP) which place restrictions on crop production with wastewater and suggest primary treatment before its use (Blumenthal *et al.,* 2000; Mera and Cairncross 1989).

Lai (2000) reported that despite the general abundance of freshwater resources, wastewater, both domestic and industrial, is used extensively in peri-urban areas of Hanoi particularly in the Thanh Tri, and Tu Liem districts. Wastewater significantly contributes to food production and food security in these cities. About 80 percent of Hanoi's vegetable demand is satisfied from wastewater irrigation and the system seems to be generally accepted by consumers. Delgado *et al.,* (1999) reported that wastewater irrigation of vegetables and fodder may serve as the transmission route for heavy metals in the human food chain, particularly in South Asia, where per capita milk consumption is the highest among the developing world and is growing rapidly.

Gadallah (1996) reported that the wastewaters from fertilizer and oil industries alongwith sewerage origin showed significant phototoxic effects on radical growth and retarded the growth of sunflower plants. Aziz *et al.,* (1996) found that treated oil refinery wastewater met irrigation standards, hence suitable for crop production. Wastewater irrigated soil maintained the soil properties and high plant growth alongwith desired contents of protein, carbohydrate, and grain yield. Better crop performance was achieved due to the availability of additional nutrients in treated wastewater. Raneeshkumar *et al.,* (1990) observed increase in root and shoot length, dry matter accumulation and crop productivity of cluster bean with 15 percent concentration of chemical factory effluents. Rice varieties germination was decreased by 52 to 57 percent under 100 percent industrial effluent applications. The shoot and root length alongwith dry weight increased with up to 50 percent effluents application and decreased with higher concentration. Swaminathan *et al.,* (1989) reported that 100 percent concentration of glucose factory effluents retarded germination, seed vigor and hypocotyls development in groundnut but diluted effluents up to 50 percent favored these factors. Singh and Mishra (1987) found that chemical properties of soil were adversely affected by effluent generated by the nitrogenous manufacturing factory. Seed germination, dry matter, pigment contents, yield of both rice and corn were also badly affected by effluent application with concentration greater than 10 percent. Day *et al.,* (1975) concluded that irrigation with treated wastewater leads to higher wheat grain yields and higher protein with no change in fiber content. It was also found that treated wastewater is a potential source of irrigation water plus a rich source of fertilizer and gives higher potential yields.

A number of studies such as Joroen *et al*., (2002); Shahalum *et al.,* (1998); Howe and Wagner (1996); Ali (1987); Marten *et al.,* (1980); Bole and Bell (1978) and Sidle *et al.,* (1976) were conducted to evaluate the effects of wastewater irrigation on crops. It was found that use of treated wastewater increased grain yields and protein content in grains, therefore suitable for crop production. Untreated wastewater generally contains useful nutrients but also other constituents that may be toxic for plant growth.

2.4 DISEASES AND HUMAN HEALTH

Consumption of contaminated drinking water, crops, vegetables and fish etc. ultimately affect human health. Farmers who were irrigating their lands with untreated wastewater around Haroonabad had a significantly higher occurrence of diarrhea disease than those who irrigated their land with canal or tubewell water (Hoek *et al.,* 2002). Blumenthal *et al.,* (2001) and Shuval *et al.,* (1989) reported serious public health problems due to the use of wastewater. Wastewater carries a wide range of pathogenic organisms posing a risk to agricultural workers, crop handlers and consumers. High levels of nitrogen in wastewater may result in nitrate pollution of groundwater, which could lead to adverse effects on human health. Feenstra *et al.,* (2000) reported that the use of untreated wastewater for irrigation posed a high risk to human health in all age groups. However, the degree of risk varies among the various age groups. Untreated wastewater irrigation encourages higher prevalence of hookworm.

Fasiha (1999) reported that untreated disposal of domestic waste is multiplying water-born diseases in Pakistan. It was estimated that all reported cases of illness and 40 percent of all deaths in Pakistan were attributed to water-born diseases. Eighty one thousand nine hundred and ninety six cases of water-born diseases were registered in public health units of Rawalpindi in 1998. Fecal contamination of drinking water supplies is the cause of diarrhea, typhoid, cholera and viral hepatitis in Pakistan. Diarrhea continues to be the biggest cause of infant mortality. Poor water management gives rise to stagnant water pools resulting in high incidence of water-related diseases such as Malaria (UNICEF, 1997).

Rab (1997) reported that in 1993-94 explosive water-borne epidemic of hepatitis occurred in two sectors of Islamabad. National Institute of Health (NIH) Islamabad carried out investigations, which revealed that it was due to an operational breakdown of the water treatment plant. Drinking water containing more than 0 CFU/ml is considered polluted and not fit for drinking purpose, regardless of the source and the type of treatment. Production of drinking water from contaminated sources carries a great risk of viral contamination (WHO, 1995). Cooper (1991) stated that nitrates and trace organic chemicals leaching to the groundwater were considered a potential health risks to the human beings. However, there is limited documented evidence that these chemicals were the cause of human diseases.

Several studies showed that the use of untreated wastewater in agriculture increased the risk of transmitting bacterial infections to consumers and farm workers. Children and infants had the highest infection of diarrhea and gastrointestinal disease (Cifuentes *et al.,* 2000; Habbari *et al.,* 2000; Downs *et al.,* 1999; Olivieri *et al.,* 1996 and Shuval *et al.,* 1986).

2.5 IMPACTS ON ENVIRONMENT

There may be several causes of environmental degradation but the main problem amongst is the untreated disposal of wastewater. The industrial activities have already caused substantial air and water pollution leading to adverse effect on the vegetation as well as human beings and aquatic life. Mubin *et al.,* (2002) found that out of 10 main industries in Karachi, the leather industries were the main cause of pollution and environmental damages. It is the major factor creating toxicity. Twenty five percent issues associated with industrial wastewater could be solved if only leather industry dispose of its effluents after treatment. Therefore, it was recommended to restrict leather industry to treat its industrial waste before disposal. In many developing countries, wastewater used for irrigation, is often inadequately treated. In Asia wastewater treated by effective treatment plant is 35 percent; in Latin America and Caribbean is 14 percent, in North America 90 percent and 66 percent in Europe (WHO/UNICEF, 2000). Ayade (1998) reported that excessive use of chemical fertilizers in agriculture has caused considerable damage to various soils in India. This has reduced the productivity of the agriculture. The industrial activity has caused considerable damage to surface and groundwater due to release of effluents. The human activity in the urban areas generates waste material, which gets mixed up in the municipal water supply. The large-scale livestock and poultry operations can pollute freshwater due to phosphorus and nitrogen, which is generated in the poultry farms. Ziai (1993) observed that environmental impacts due to the sewerage irrigation practices were against the environmental quality standards. It was recommended that before considering the beneficial effects of sewerage irrigation, it is essential to evaluate strictly every possible environmental hazard. Pollution in river Ravi has baldy affected fish and other aquatic life. It has been estimated that due to effluent discharge to the river Ravi, annual production of fish has decreased by nearly 5000 tons (PNCS, 1992). Rath (1990) studied the environmental hazards of the Talcher Industrial Complex and their socio-economic impacts in the Brahmani flood-plains. The author concluded that in spite of higher flow of water in the river, the pollution level of water had gone up due to more effluent from the Talcher Industrial Complex. High contamination of water and due to algae growth, the fish and other wild lives in the river were depleting.

CHAPTER 3

STUDY DESIGN

A reconnaissance survey of the study area was carried out in order to plan the project activities in consultation with local government and the University of Agriculture, Faisalabad. The preliminary information about salient features of the area like location, type, size of industries and nature of wastewater generated by different kinds of industries, drinking water sources, drainage system, sources of irrigation water, extent of wastewater utilization, fish farming practices and information regarding water-born diseases were also collected.

3.1 STUDY AREA

3.1.1 General

Faisalabad is located in the Rechna doab i.e. the area between the rivers Ravi and Chenab. The total geographical area of the Faisalabad district is 5,856 km^2 with a total population of 3.54 million (Wikipedia, 2006). Faisalabad was a famous market town for agricultural products during the colonial period. The expanding urban sprawl led to the establishment of a number of agro-based textile industries in the city. There were only five industrial units at the time of independence. The textile industry extensively flourished afterwards as a result of various incentives given by the State from time to time. The city has now attained the status of Pakistani Manchester, as there are dozens of textile mills with other subsidiary units. There are 512 large industrial units, out of which 328 are textile while 92 units are engaged in engineering works and other 92 with food processing activities. Other industries include; hosiery, carpet, rugs, lace, printing, publishing and pharmaceutical products etc. In addition, there are 12000 household industries including nearly 6000 power looms (Wikipedia, 2006). Most of the major industries are located along various intercity roads like Faisalabad-Jaranwala, Faisalabad-Sargodha, Faisalabad-Samundari, Faisalabad-Shahkot and Faisalabad-Jhang roads. The study was however confined to the Faisalabad city and its surroundings over an area of 122 km^2 at spherical coordinates of $31^o25'$ N and $73^o09'$ E located at an altitude of 300 m above mean sea level (Figure 3.1).

3.1.2 Sewage Disposal System

According to an estimate, 6.45 m^3/sec effluents were being generated in Faisalabad (Khurshid *et al.*, 1999) and were mainly being disposed off through two surface drains; Paharang and Madhuana. WASA Faisalabad has established a network of small municipal drainage channels for the collection of sewerage and industrial effluents. The sewage disposal system has 26 pumping stations with a cumulative pumping capacity of 3.0 cumecs and 23 disposal stations with a total disposal capacity of 11.29 cumecs. According to the WASA, improved local sewerage facility has been extended up to 91 percent of the households (WASA, 2004). The operational efficiency of the existing disposal system however, is very poor due to non-maintenance, choking and overloading beyond its capacity. Consequently, the manholes overflow (Figure 3.2).

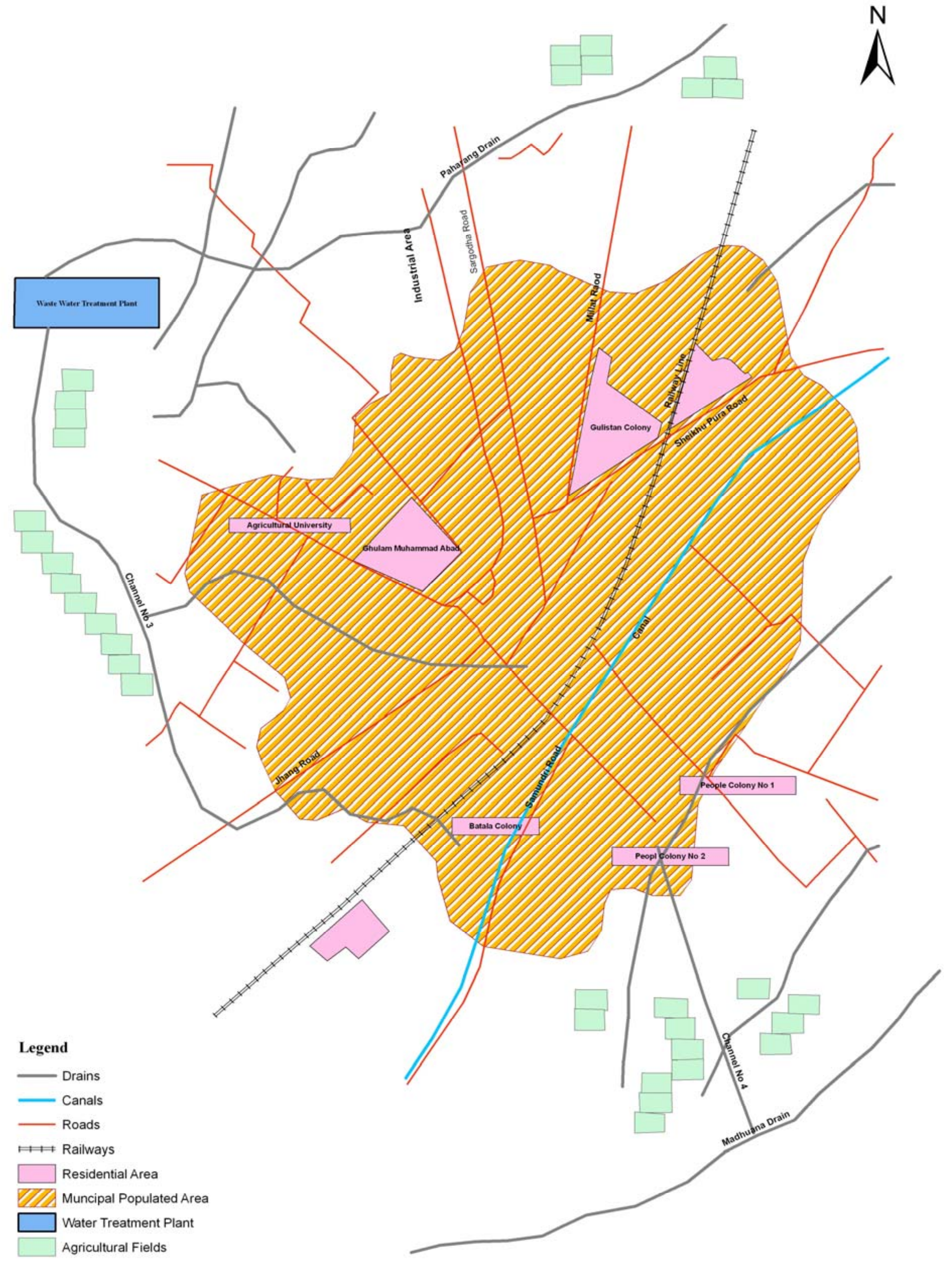


Figure 3.1: Map of Faisalabad city

Figure 3.2: A view of overflowing sewerage system of Rasheedabad

Most of these city sewage disposal channels e.g. Channels Nos. 1, 2 and 3 dispose of into the Paharang drain and Channel No. 4 into Madhuana drain. Madhuana drain originates from Khurarianwala, passes near to the city, collects wastewater from the eastern side of the city and discharges it into the River Ravi. The effluents generated in the western parts of the city are drained through the Paharang drain into the River Chenab (Figure 3.3).

WASA Wastewater Treatment Ponds

A biological wastewater treatment plant has been established by the WASA to treat effluents of Channel No. 3 at Chokera village. It spreads over 16.2 ha land. It has been designed for an average discharge of 90,000 m^3/day. There are 16 ponds in this system, out of which four are dry sludge-ponds.

Six ponds are anaerobic while the remaining six are facultative or maturation ponds. Both the anaerobic and facultative ponds are in the form of two parallel rows. Each row of the system has 3 anaerobic ponds and 3 facultative ponds. The anaerobic ponds are smaller in area whereas the facultative ponds occupy larger area. The primary treatment takes place in the anaerobic pond, whereas secondary treatment takes place in facultative ponds. The wastewater of Channel No. 3 is diverted to pass through a mesh prior to its temporary storage in a sump to segregate solid waste. The water from sump is pumped into the treatment ponds by six tube wells. It is constructed at a higher altitude than the surrounding fields. Wastewater is directed to the anaerobic ponds where it stays for 1-2 days and passes through the series of three facultative ponds. The treated water is ultimately discharged into the main Paharang drain without any productive use (Figure 3.4).

3.1.3 Drinking Water Sources

The main sources of drinking water are the public water supply and groundwater pumped through hand pumps and centrifugal pumps.

Public Water Supply

Water and Sanitation Agency is a subsidiary of Faisalabad Development Authority (FDA). It was established in 1978 under the development of cities act 1976. WASA provides facilities

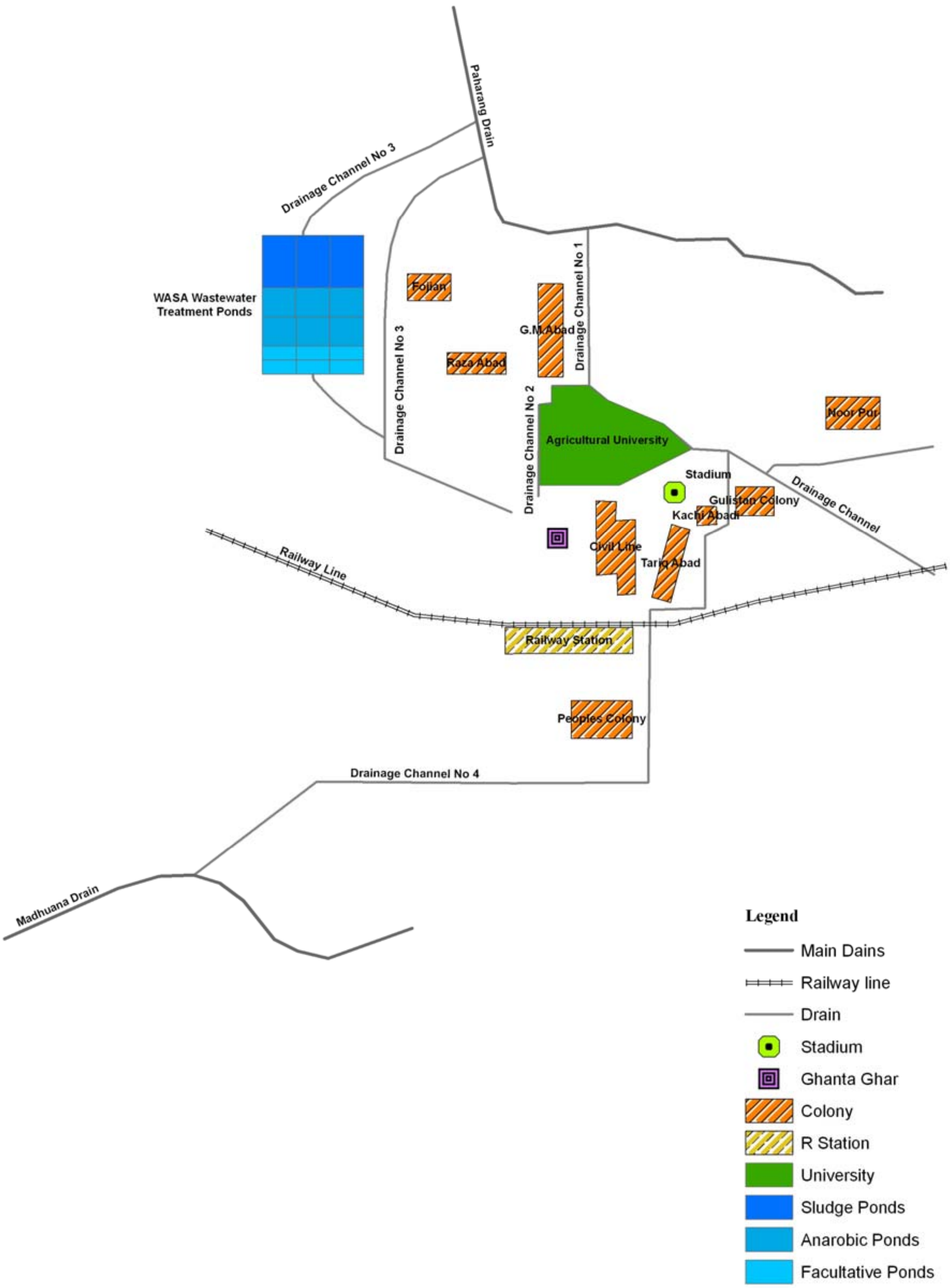


Figure 3.3: Drainage system of Faisalabad city

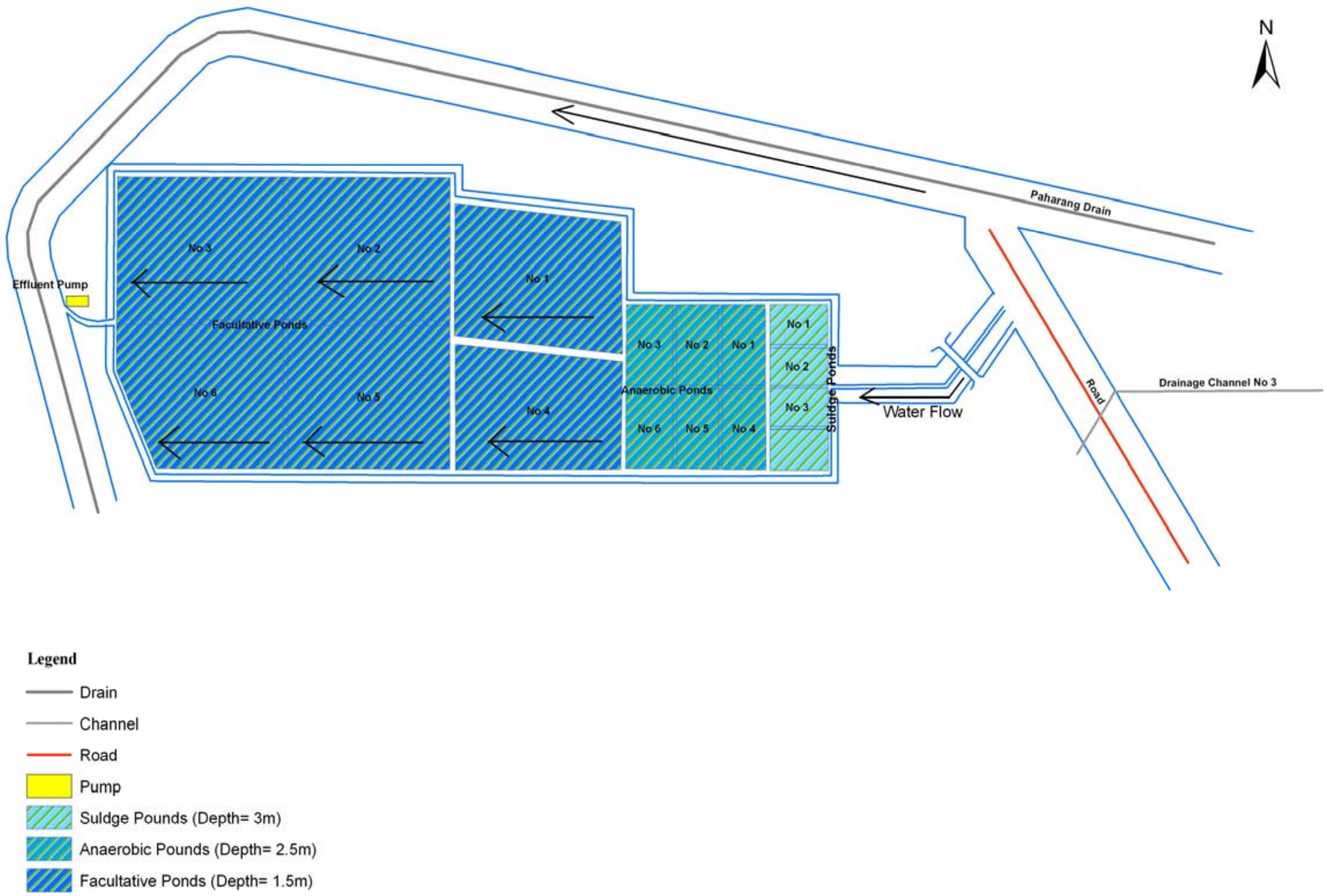


Figure 3.4: Schematic diagram of Chokera wastewater treatment ponds

of water supply, sewerage and drainage to 50, 65 and 80 percent of the residents of Faisalabad city, respectively. The present drinking water requirement of city is 620740 m^3/day, which is estimated to increase to 738075 m^3/day by 2010 (WASA, 2004). As the installation of tubewells within and close to the city was not feasible due to poor quality of groundwater, WASA has, therefore, installed 34 tubewells along the bank of Chenab River near the city of Chiniot and 30 along the banks of Rakh branch canal in order to supply good quality drinking water (WASA, 2004). The water is transported to the city through a network of pipelines. Due to long water supply network, the water gets contaminated due to deterioration of supply lines and intermittent water supply.

Groundwater

A major portion of the population has installed their own centrifugal pumps for their domestic and drinking water needs. The spatial variation of the pumped groundwater quality is very high as it depends on depth and location of well. The community having awareness regarding low quality of public water supplies and hazardous groundwater fetch their drinking water in cans from pumps installed at different locations along the banks of Rakh Branch canal passing through the city.

3.2 MEASUREMENT OF DRAINS DISCHARGE

To determine the discharge of Paharang and Madhuana drains, straight sections of the drains were selected outside the city to include all the inflows. The discharge of the Madhuana drain was measured near Chak 81 Jhang Branch and at Qaim Shah near river Ravi. Similarly the discharge of Paharang drain was measured at downstream of Chokera village and Warah Pind near river Chenab.

The locations of discharge measurements were identified at bridges with two compartments. The breadth of each compartment of the bridge was measured. Similarly, the flow depth of each compartment of the bridge was measured at three locations. Simple averaging method was used to determine the flow depth. The area of each of the compartment was measured by multiplying the average depth with its respective breadth. The pigmy type digital current meter was used to determine the velocity of flow in each compartment. The velocity of flow was measured at two depths i.e. at 0.2d and 0.8d and was averaged to get mean value. The area of each compartment was multiplied with its respective velocity to get the flow rate of each compartment. The total discharge passing through the bridge was determined by adding up discharges of the two compartments.

Similarly, seepage of wastewater was also computed by measuring discharge at two different points of drains. The difference in measured discharge of two points gave quantity of seepage after the deduction of evaporation. Crop Wat 4 Window Version 4.2 was used to calculate evaporation by using metrological data collected by IWMI (Kaleemullah *et al.,* 2001).

3.3 SAMPLE COLLECTION AND ANALYSIS

Based upon the reconnaissance survey, two types of data were collected: (a) Physical Samples and (b) Participatory Rural Appraisal (PRA). Physical samples included: (i) industrial and sewerage wastewater (at the outlet and after mixing with the drain) (ii) drinking water (iii) wastewater irrigation (iv) wastewater irrigated soils, vegetables and crops (v) farm fish and fish pond water and (vi) human blood. The PRA focused on documenting information provided by:

(i) General public about drinking water source, its quality and waterborne diseases

(ii) Farmers about qualitative and quantitative impacts of wastewater irrigation on crops

(iii) Industrialists about generation, treatment, management and disposal of wastewater

(iv) Medical practitioners about the existence and causes of water-borne diseases.

3.3.1 Wastewater

The wastewater samples were collected from the inflow sources and from the confluence of the source with the drainage channel. Each sampling point was marked with Global Positioning System (GPS). The name, locality and characteristics of the industry or source type were recorded. A total of 255 effluent samples covering almost all industrial zones and all types of the city sewerages were collected. Three samples were collected at each sampling point, for chemical, biological and heavy metal analysis.

Wastewater, irrigation water, fish farm water and drinking water samples for Physico-chemical analysis were collected in polystyrene bottles of 1 liter capacity. Before collecting the samples, the bottles were washed properly and rinsed thoroughly several times first with water and then with distilled water. Two ml/liter of HNO_3 were used as a preservative in the sampling bottles for heavy metals. BOD and COD samples were kept in an icebox during transporting to the laboratory.

Parameters Analyzed for Wastewater

The wastewater samples were analyzed for various biological, chemical and heavy metal parameters from the Nuclear Institute of Biotechnology and Genetic Engineering (NIBGE) Faisalabad and the PCRWR laboratories at Islamabad.

BOD and COD Analysis

(i) Biological Oxygen Demand (BOD)

Biological oxygen demand refers to the amount of oxygen that would be consumed if all the organics in one liter of water were oxidized by bacteria and protozoa (Wikipedia, 2006). Biological oxygen demand is used to determine how much oxygen would be used by aerobic microorganisms in water to decompose organic matter. If these aerobic bacteria are using too much of the dissolved oxygen in the water, then there will not be enough left over for the fish, insects, and other organisms that rely on oxygen. The first step in measuring BOD is to obtain equal volumes of water from the source to be tested and dilute each specimen with a known volume of distilled water, which has been thoroughly shaken to insure oxygen saturation. After this, an oxygen meter is used to determine the concentration of oxygen within one of the bottles. The remaining bottle is then sealed and placed in darkness and tested after five days.

The range of possible readings can vary considerably. Water from an exceptionally clear lake might show a BOD of less than 2 mg/l of water. Raw sewage may give readings in the hundreds and food-processing wastes may be in the thousands (Wikipedia, 2006).

(ii) Chemical Oxygen Demand (COD)

The chemical oxygen demand is a measure of water quality and is defined as the quantity of oxygen used in oxidizing all the organic and inorganic materials in water. COD is used to estimate the amount of a pollutant in an effluent and is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water (e.g. lakes and rivers), making COD a useful measure of water quality. It is expressed in milligrams per liter (mg/l), which indicates the mass of oxygen consumed per liter of solution (Wikipedia, 2006). BOD and COD are the efficency indicators of wastewater treatment plant. Analysis of BOD and COD were conducted according to 'Standard methods for the examination of water and wastewater (Anonymous, 1998).

Physico-Chemical Analysis

The analysis was divided into two categories: (a) Physical and (b) Chemical:

Physical analysis includes: pH, Electrical Conductivity (EC), , Turbidity, Colour where as chemical analysis includes Carbonate (CO_3), Bicarbonate (HCO_3), Sodium (Na), Potassium (K), Magnesium (Mg), Calcium (Ca), Sulphate (SO_4), Chloride (Cl), Hardness, Total Dissolved Solids (TDS), Alkalinity. The methods used for analysis of physico-chemical and heavy metals are given in Table 3.1. The brief description of each parameter is given below:

Physical Parameters

(i) pH

pH is the measure of acidity or basicity of an aqeous solution or liquid. The concentration of the hydrogen ions will be more in acidic solutions. pH is defined as the negative logarithm of the hydrogen ion concentrations of any aqueous solution. i.e. $pH = -\log [H^+]$.

A pH value of 7 indicates the solution is neutral, values greater than 7 makes it basic while less than 7 values of pH indicates acidity. The pH of human blood is 8.2; acidity of blood causes abnormal heart beating and increases the pulse rate (Wikipedia, 2006). Methods used for physico-chemical and heavy metals analysis in wastewater, drinking water, irrigation water and fish farm water are given in Table 3.1.

(ii) Electrical Conductivity (EC)

Electrical Conductivity (EC) estimates the amount of total dissolved salts (TDS), or the total amount of dissolved ions in the water. The water with more salt contents conducts more current when a potential is applied through it. Distilled or deionized water has very few dissolved ions and so there is almost no current flow across the gap (low EC). It is measured in μS/cm (Wikipedia, 2006).

(iii) Turbidity

Turbidity is the measure of suspended solids of a liquid. More suspended solids make it more turbid and vice versa. WHO (2004) documented that turbidity level beyond 5 NTU is generally objectionable.

Chemical Parameters

(i) Carbonate (CO_3) and Bicarbonate (HCO_3)

Simple carbonate salts tend to be insoluble in water, with solubility constants of less than 1×10^{-8}. For an aqueous solution, carbonate exists in three forms. In strongly basic conditions, the carbonate ion predominates. In weakly basic conditions, bicarbonate ion is prevalent. In acid conditions, aqueous carbon dioxide is the main form (Wikipedia, 2006).

(ii) Sodium (Na)

Sodium is a soft, waxy, silvery reactive metal belonging to the alkali metals that is abundant in natural compounds. It reacts violently with water and oxidizes in air necessitating storage in an inert environment. Sodium ions are necessary for regulation of blood and body fluids, transmission of nerve impulses, heart activity and certain metabolic functions. Mostly people consume it in the form of sodium chloride or table salt. ACU-Cell (2003) indicated that deficiency of sodium in the body may appear as mental apathy, low blood pressure, fatigue, depression, seizures, dehydration etc. Similarly, the excess presence can cause edema, hypertension, stroke, headaches, kidney damages, stomach problems and nausea.

Table 3.1: Methods for physico-chemical and heavy metals analysis in wastewater, drinking water, irrigation water and fish farm water

Sr. No	*Parameters*	*Analysis Method Used/Equipment*
1	pH	pH Meter, Hanna Instrument, Model 8519, Italy
2.	Electrical Conductivity	Conductivity method, Coductivity meter (HACH, USA)
3	Turbidity	Turbidity Meter, Lamotte, Model 2008, USA
4	Colour	Sensory Test
5	Carbonate	2320, Standard method (1992)
6	Bicarbonate	2320, Standard method (1992)
7	Sodium	Flame Photometer PFP7, UK
8	Potassium	Flame Photometer PFP7, UK
9	Magnesium	2340-C, Standard method (1992)
10	Calcium	3500-Ca-D, Standard method (1992)
11	Sulphate	SulfaVer4 (Hach-8051) by Spectrophotometer
12	Chloride	Titration (Silver Nitrate), Standard Method (1992)
13	Hardness	EDTA Titration, Standard method (1992)
14	TDS	2540C, Standard method (1992)
15	Alkalinity	2320, Standard method (1992)
15	Cadmium	Graphite furnace method of AAS Vario 6 (Analytic Jena, Germany)
16	Copper	Graphite furnace method of AAS Vario 6 (Analytic Jena, Germany)
17	Lead	Graphite furnace method of AAS Vario 6 (Analytic Jena, Germany)
18	Manganese	Graphite furnace method of AAS Vario 6 (Analytic Jena, Germany)
19	Mercury	Hydride generation method of AAS Vario 6 (Analytic Jena, Germany)
20	Zinc	Graphite furnace method of AAS Vario 6 (Analytic Jena, Germany)
21	Chromium	Graphite furnace method of AAS Vario 6 (Analytic Jena, Germany)
22	Nickle	Graphite furnace method of AAS Vario 6 (Analytic Jena, Germany)
23	Arsenic	Hydride generation method of AAS Vario 6, Analytik Jena AG
24	Iron	TPTZ method (HACH Cat. 26087-99)

Source: Kahlown *et al.*, 2006.

(iii) Potassium (K)

Potassium is a soft silvery-white metallic alkali metal that occurs naturally bound to other elements in seawater and many minerals. It oxidizes rapidly in air, is very reactive in water and resembles sodium chemically. The potassium is very significant body mineral important to both cellular and electrical function. The total potassium in the body and blood serum varies from 4-5 mg/100 ml. Potassium deficiency causes irregular and rapid heart beat, hypertension, muscle weakness, bladder weakness, kidney disease and asthma whereas overdose may appear as irregular/ rapid heart beat, cystitis, bladder infection, ovarian, cysts and weakened immune system (ACU-Cell, 2003). An increased level of potassium in the blood is known as hyperkalemia appears as reduced renal function, an abnormal breakdown of protein and severe infection (Aparna, 2001).

(iv) Magnesium (Mg)

Magnesium is a very essential component of human diet but most of the diets are likely to be deficient. Even a mild deficiency causes sensitiveness to noise, nervousness, irritability, mental depression, confusion, twitching, trembling, apprehension, insomnia, muscle weakness and cramps in the toes, feet, legs, or fingers (Wikipedia, 2006). About 19 grams of magnesium per 70 kg human body weight is involved in the synthesis of protein as well as acts as co-factor in 300 enzymatic reactions (ACU-Cell, 2003).

(v) Calcium (Ca)

Calcium reacts with water displacing hydrogen and forming calcium hydroxide. Calcium is essential in muscle contraction, building strong bones, teeth, blood clotting, nerve impulse transmission, regulating heartbeat, and fluid balance within cells. Its deficiency causes ostereoprosis and weakening of the bones (Wikipedia, 2006).

(vi) Sulphate (SO_4)

Almost all ionic compounds with sulfate anions are soluble in water at standard temperature and pressure. Sulfates, also known as sulfur oxides, are important in both the chemical industry and biological systems (Wikipedia, 2006).

(vii) Chloride (Cl)

The most common form of chloride is table salt, which is sodium chloride. In water, it dissolves into Na and Cl ions. Chloride ions have important physiological roles. In the central nervous system, the inhibitory action of glycine and some of the other actions relies on the entry of Cl into specific neurons . A normal 70 kg human body weight contains about 81 grams of chloride through 45 litres of drinking water. One gram table salt (NaCl) per person per day is essential for human health. A daily dietary intake of 45 mg chloride per kg of body weight is sufficent upto 18 years of age (Kahlown *et al.,* 2006).

(viii) Hardness

Negative association between water hardness and cardivascular disease have been observed. Very hard water can cause household pipes choking, scaling, incrustations on kitchen utensils and increasing soap consumption. Hard water can create both nuisance and economic burden to community (Kahlown *et al.,* 2006)

(ix) Total Dissolved Solids (TDS)

Total dissolved solids (TDS) in water are inorganic salts and small amounts of organic matter. TDS in water may be originated from natural sources, sewage effluent discharges, urban runoff and industrial discharges. TDS is linked to taste, hardness, corosion properties and tendency to incrustation. TDS in drinking water may even have beneficial health effects (Kahlown *et al.,* 2006).

(x) Alkalinity

Alkalinity is a measure of the buffering capacity of water, or the capacity of bases to neutralize acids. Alkalinity does not refer to pH, but instead refers to the ability of water to resist change in pH. The presence of buffering materials helps neutralize acids as they are added to the water. These buffering materials are primarily the bases bicarbonate, carbonate and occasionally hydroxide, borates, silicates, phosphates, ammonium, sulfides, and organic ligands. Waters with low alkalinity are very susceptible to changes in pH. Waters with high alkalinity are able to resist major shifts in pH (Wikipedia, 2006).

Heavy Metal Analysis

The heavy metals namely Cd, As, Pb, Cu, Hg, Cr, Zn, Fe, Ni and Mn have been tested in different type of samples. The sources of these heavy metals, their impact on the agricultural soils, its produce and movement through different environmental units have been covered in the subsequent sections.

(i) Cadmium (Cd)

Cadmium is an extremely toxic metal commonly found in industrial area, particularly where any ore is being processed or smelted. Sources of soil contamination by Cd are the mining and smelting of Cd and Zn, atmospheric pollution from metallurgical industries (incineration of plastic containers and batteries), sewage sludge application to the land, the burning of fossils, fuels, electroplating, industrial paints, batteries etc. Continuous use of phosphatic fertilizers has also been found to increase the cadmium level of the soils. It may remain in the soil from 15 to 1100 years. Aerosols particles from urban or industrial air pollutions and wastewater irrigation have also been found to increase the cadmium level. Cadmium uptake by the plants from contaminated soils is very high although it varies from soil to soil depending upon its textural and chemical properties (Alloway, 1990).

(ii) Copper (Cu)

It is an important micronutrient of human body as well as for the soils and irrigation water. Low levels of copper are essential for maintaining good health, however, high levels can cause harmful effects such as irritation of the nose, mouth and eyes, vomiting, diarrhea, stomach cramps, nausea, and even death. The copper uptake of plants has been found maximum in the soils with pH of 5.5. The higher concentrations of copper in the soil are addition from smelters, fertilizers, sewage sludges and pesticides. Under such conditions, a relatively higher level of pH is desired in order to overcome excessive levels in plants. The soils do not have excessive copper unless it is deposited by some industrial activities, livestock manure, and atmospheric deposition. The leaching capability of copper out of the root-zone is very low and soils have shown copper concentration of 110 to 1500 mg/kg (Alloway, 1990).

(iii) Lead (Pb)

Lead is a highly toxic substance producing a wide range of adverse health effects. Both adults and children can suffer from the effects of lead poisoning. Lead poisoning causes mental impairment by depositing in the brain. The most common sources of lead poisoning are petrol vehicle exhausts, paints, urban dust, that are transferred to the human body by food, water, and air. Lead and its compounds tend to accumulate in soils and remain accessible to the food chain. The maximum recommended soil accumulation is 550-1000 mg/kg, but if it exceeds the limit of 100 mg/kg, the application of sewage sludge should be stopped (Alloway, 1990).

(iv) Manganese (Mn)

Manganese prevalence beyond the permissible limits can cause damage to the brain, liver, kidneys, and the developing fetus. Most of the crops are sensitive to its deficiency in soils and show retarded growth. Smilarly the Mn toxicity symptoms have been found in a wide range of crops including soyabean, cotton, tobacco and rice grown in soils with high available Mn. The higher concentrations of manganese in the soils are due to increased industrial activities (Alloway, 1990).

(v) Mercury (Hg)

Mercury is one of the most toxic elements of nature. Its exposure poses severe health risks by damages the nervous system and sometimes produces irreversible defects. In this respect methyl mercury is the most dangerous. The increased environmental concentrations of mercury are mainly attributed to mining or smelting of ores particularly those of Cu and Zn, burning of fossil fuels, industrial productions process of mercury cells and waste incinerations. The main channel of mercury transfer to the human body is fish. In general the availability of soil mercury to plants is low because the roots serve as a barrier to its uptake (Alloway, 1990).

(vi) Zinc (Zn)

Zinc is an essential trace element for humans, animals and higher plants. The deficiency of Zn in humans and animals causes reduced appetite, growth depression, skin lesions and impotency. Its deficiency in most of the plants lead to stunted growth, especially maize, sorghum, flax, hops, cotton, legumes, grapes, citrus and fruit trees. Just like its deficiency, excessive concentration of Zn in agricultural soils is equally toxic as the crops up take it causing adverse effects on their hygienic quality as well as on livestock and human diet. The availability of zinc to the plants from the soils is however affected by a number of factors like pH, organic matter, adsorption sites, microbial activity and moisture regime. Wastewater irrigation with high Zn contents will therefore lead to its accumulation to toxic levels posing severe health risks for the human by entering into the food chain (Alloway, 1990).

(vii) Chromium (Cr)

Chromium is essential component of human diet in very small amounts i.e. 200 μg/day. Less chromium intake causes cardiovascular diseases, intolerance to glucose and decreased glycogen reserve. The most prominent source of chromium are phosphatic fertilizers that have been reported to contain 30-3000 mg/kg. Another important source of chromium is the atmospheric deposition from the metallurgical industries. The chromium is also released during metal plating, anodizing, ink manufacture, dyes, pigments, glass, ceramics, glues, tanning, wood preserving, textiles and corrosion inhibitors (Alloway, 1990).

(viii) Nickel (Ni)

Nickel is an important micronutrient of the plants and its deficiency indicates reduced germination and seedling vigor followed by disruption of grain filling. It is also found essential for the growth of microorganisms. Nickel plays an essential role in human metabolism. Agricultural land receiving irrigation of domestic origin may be prone to nickel toxicity. Nickel is more toxic to the plant growth than other elements (Alloway, 1990)**.**

(ix) Arsenic (As)

Arsenic levels may be elevated due to mineralization, contamination from industrial activity and the use of arsenic based pesticides. The Indus basin aquifers have been found contaminated with arsenic mainly because of its widespread usage in pesticides. The tubewell irrigation is also causing its deposition in the soils. The contamination of food crops through uptake from the soils is very rare but its uptake by the humans through drinking water is a hot issue of the subcontinent. High arsenic intake damages the kidneys by depositing in the human body (Alloway, 1990).

Arsenic contaminated water may lead to serious health hazards when used for drinking, washing and food preparation. Arsenic is difficult to detect while ingesting, as it is tasteless, ordorless and colorless. The effects are not commonly visible and people can absorb significant quantities of arsenic without any immediate health complications. Generally, a healthy person will withstand the arsenic poison for a longer period than an undernourished or weak person who will perish quickly. Similarly, children are more vulnerable sensitive. Arsenic can damage the nervous system and is also carcinogenic as it can cause various type of cancer. It can enter the metabolic system of newborn children (Kahlown *et al.,* 2003 and Kahlown *et al.,* 2004).

The data collected through National Water Quality Monitoring Program (NWQMP) during (2001-2004) also revealed the presence of arsenic in some locations/cities of Punjab and Sindh. The situation in southern Punjab and central Sindh is alarming and needs urgent attention towards its solution (Kahlown *et al.,* 2006).

(x) Iron (Fe)

Iron is one of the most important micronutrient of humans, plants and is required in greater quantities in comparison to other micronutrients like Zn, Mn etc. Low iron intake in the human body results in destruction of hemoglobin and thus the oxygen absorbing capacity of the body. High intake on the other hand causes diarrhea and some other malicious complications. Iron uptake capacity of the plants is very high particularly in the leafy crops. Most of the crops have been found sensitive to iron deficiency especially barley, rice, soyabean and sugar beat etc. These crops show stunted growth under iron deficient conditions of soils and irrigation water. The Indus basin aquifers have been evidenced to be iron contaminated (Alloway, 1990).

Environmental Quality Standards for Wastewater

The permissible limits for industrial effluents are quite high in comparison to those for drinking water. The international environmental quality standards of municipal and liquid industrial effluents have been followed to analyze the fitness of collected samples. The wastewaters with these levels of contamination are supposed to be safe and not a source of pollution to the surface drains and natural streams. The standards are given in Table 3.2.

3.3.2 Drinking Water

To estimate the extent of drinking water contamination, four different types of categories were developed. These are public water supplies, groundwater in the city, groundwater near drains and can water (groundwater pumped near canal banks).

Public Water Supply

Two hundred and seventy (270) samples of drinking water supplied by the WASA were collected from different localities of the city. The locations of the sampling points were marked with GPS. Based upon supply arrangements, these samples have been classified into five zones. The detailed classification of these zones is given in Table 3.3.

Table 3.2: Environmental quality standards for industrial and sewerage effluent

Parameters	*Units*	*Permissible Limits*	*Parameters*	*Units*	*Permissible Limits*	*Parameters*	*Units*	*Permissible Limits*
BOD	mg/l	80	As	µg/l	1000	pH	Unitless	6-10
COD	mg/l	150	Pb	µg/l	500	TDS	mg/l	3500
Fe	µg/l	2000	Cd	µg/l	100	Cl	mg/l	1000
Mn	µg/l	1500	Cu	µg/l	1000	SO_4	mg/l	600
Ni	µg/l	1000	Hg	µg/l	10	TSS	mg/l	150
Zn	µg/l	5000	Cr	µg/l	1000	Temp.	^{0}C	40

Source: NEQS (2005).

Groundwater in the City

In most parts of the city, groundwater is not drinkable due to high salinity, bad taste and smell. Due to unawareness and financial constraints, residents are using low quality groundwater for drinking. Zoning of city groundwater has been kept the same as that for public water supply in order to compare its degree of fitness with that supplied by the WASA. A total of 483 samples were collected from different zones (Table 3.4).

Groundwater Pumped near Drains

The quality of groundwater pumped near surface drains i.e. the Paharang and Madhuana was considerably important from study point of view as it may contain hazardous substances that may be fatal for the consumers. Similarly, the quality of groundwater becomes questionable if the pumps are located close to the drainage channels (Figure 3.5). In order to analyze the quality of these drinking water sources, the area was divided into three zones. The classification and number of samples collected from each class are given in Table 3.5.

Figure 3.5: A hand pump installed close to drain

Table 3.3: Classification of drinking water samples supplied by WASA

Zone	*Localities*	*No of Samples*		
		Microbiological	*Chemical*	*Heavy Metal*
W-I	Peoples Colony No 1, Peoples Colony No. 2, Madina Town, Samanabad, Al-Masoom Colony, Maqsoodabad, Batala Colony, Nisar Colony, Ali Town, Hasan Pura, Maqbool Road, Karamat Colony, Sattelite Town, Shehzad Colony, Younis Town, Nawab Town, D-type Colony, Garden Colony, Rachna Town, Elahiabad etc.	34	34	34
W-II	Nishatabad, Hajiabad, Gulistan Colony, Amin Town, Shareef Pura, Noor pur, Akbar Town, Sardar Town and Ghaziabad etc.	4	4	4
W-III	Jamil Town, View Town Colony, Ghulam Muahammadabad, Saidabad, Mustafa Abad, Agri University, Punjab Medical College and Rajawali etc.	23	23	23
W-IV	Muzaff Colony, Sitara Colony, Sanora Town, Shadab Colony, NIAB Colony, Gulfishan Colony, Rashidabad etc.	12	12	12
W-V	Jinah Colony, Clock Tower, Gulberg, Afghanabad, Guru Nanak Pura, Tariq Abad, Chabban and Islam nagar etc.	17	17	17
Total		*90*	*90*	*90*

Table 3.4: Classification of groundwater in the city used for drinking

Zone	*Localities*	*No of Samples*		
		Microbiological	*Chemical*	*Heavy Metal*
CG-I	Peoples Colony No 1, Peoples Colony No. 2, Madina Town, Samanabad, Al-Masoom Colony, Maqsoodabad, Batala Colony, Nisar Colony, Ali Town, Hasan Pura, Maqbool Road, Karamat Colony, Sattelite Town, Shehzad Colony, Younis Town, Nawab Town, D-type Colony, Garden Colony, Rachna Town, Elahiabad etc.	61	61	61
CG-II	Nishatabad, Hajiabad, Gulistan Colony, Amin Town, Shareef Pura, Noor pur, Akbar Town, Sardar Town and Ghaziabad etc.	12	12	12
CG-III	Jamil Town, View Town Colony, Ghulam Muahammadabad, Saidabad, Mustafa Abad, Agri University, Punjab Medical College and Rajawali etc.	18	18	18
CG-IV	Muzaff Colony, Sitara Colony, Sanora Town, Shadab Colony, NIAB Colony, Gulfishan Colony, Rashidabad etc.	38	38	38
CG-V	Jinah Colony, Clock Tower, Gulberg, Afghanabad, Guru Nanak Pura, Tariq Abad, Chabban and Islam nagar etc.	32	32	32
Total		*161*	*161*	*161*

Table 3.5: Classification of the groundwater near drains used for drinking

Zone	*Localities*	*No of Samples*		
		Microbiological	*Chemical*	*Heavy Metal*
D-I	Along Paharang Drain i.e. Chak No. 7, Bawa Chak, Dhanola, Millat Road, Kamalpur, Muradabad, Sonapur and Chokera, etc.	21	21	21
D-II	Along Madhuana Drain i.e. Madhuana pind, Chak No.77 Luke, Khanuana, Khojianwala, Muhammadwala and Khurrarianwala etc	10	10	10
D-III	Along city drainage channels i.e. Ghulam Muhammadabad, Gulistan Colony No. 2, Nishatabad, Hajiabad, Saeedabad, Rajawali, Hussainabad and Aiwanwala Pind etc.	34	34	34
Total		*65*	*65*	*65*

Groundwater near Canal (Can Water)

A small segment of community is using groundwater pumped at the banks of the Rakh Branch canal (Figure 3.6). In order to analyze the quality of can water, 123 drinking water samples were collected. The logical zone of can water have been further classified into three physical zones i.e. pumpage from the canal banks before entering in the city, the city reach and after crossing the city. The number of samples collected from each zone has been given in Table 3.6.

Figure 3.6: Can water is transported for drinking

Table 3.6: Classification of groundwater near canals (can water) samples

Zone	*Localities*	*No of Samples*		
		Microbiological	*Chemical*	*Heavy Metal*
CW-I	Farooqabad, Manawala, Amin Town, Gatwala, Madina Town, Paradise Valley, Raza Town and Wapda City etc.	23	23	23
CW-II	Al-Masoom Colony, Samundari Road, Abdullahpur, D-Type Colony, Samanabad, Dar-ul-Ehsan and Ameen Park etc.	15	15	15
CW-III	Chak No 233, Al-Janat and Trust Hospital etc.	3	3	3
Total		*41*	*41*	*41*

Parameters Analyzed for Drinking Water

In addition to the physico-chemical and heavy metal analysis, the drinking water was also analyzed for microbiological analysis.

Microbiological Analysis

Coliforms

Coliform bacteria originate as organisms in soil or vegetation and in the intestinal tract of warm-blooded animals. This group of bacteria has long been an indicator of the contamination of water with possible presence of intestinal parasites and pathogens. The coliform bacteria are relatively simple to identify and are present in much larger numbers than the more dangerous pathogens. Coliform bacteria react to the natural environment and treatment processes in a similar fashion as other pathogens do. Thus by observing coliform bacteria, the increase or decrease of many pathogenic bacteria can be estimated. Effects of bacterial ingestion include abdominal crams and diarrhea (Wikipedia, 2006). Analysis of coliforms were done according to standard methods for the examination of water and wastewater (Anonymous, 1998). The water samples for microbiological analysis were collected in clean, sterilized plastic bottles (200 ml). The taps were properly cleaned and allowed to flow for a few minutes before collecting the samples. Samples were kept cool and in the dark while transporting to the laboratory.

Guidelines for Drinking Water

The World Health Organization (WHO), Pakistan Standard Quality Control Authority (PSQCA), Kingdom of Saudi Arabia (KA) and European Commission (EC) guidelines have been followed to determine the fitness of drinking water (Table 3.7).

Table 3.7: Drinking water quality standards

Parameters	*Units*	*Permissible Limits*	*Parameters*	*Units*	*Permissible Limits*
pH	Unitless	6.5-8.5	K^+	mg/l	12
EC	µS/cm	NGVS*	Na^+	mg/l	200
Turbidity	NTU	5	Ca^{2+}	mg/l	75
Colour	TCU	15	Cu	µg/l	2000
TDS	mg/l	1000	Cd	µg/l	3
Alkalinity	m.mol	NGVS	Cr	µg/l	50
Coliforms	cfu/ml	0	As	µg/l	10
Hardness	mg/l	500	Pb	µg/l	10
SO_4	mg/l	250.0	Fe	µg/l	300
CO_3	mg/l	NGVS	Mn	µg/l	100
HCO	mg/l	NGVS	Ni	µg/l	20
Cl	mg/l	250	Zn	µg/l	3000
Mg	mg/l	150	Hg	µg/l	1

Source: PSQCA, Kingdom of Saudi Arabia (KA), European Commission (EC), WHO drinking water quality standards (2004).

*No Guideline Value Set.

3.3.3 Wastewater Irrigation

The irrigation with wastewater is a common practice in the peri-urban area of the city. Wastewater irrigation samples were collected from scattered places to determine their degree of toxicity. Seventy-five (75) wastewater irrigation samples were collected from about 25 places and analyzed for BOD/COD, physico-chemical parameters and heavy metals through different methods as mentioned earlier. The detailed classification of the collected samples is given in Table 3.8.

WHO and FAO's Guidelines for Irrigation Water Quality

The international irrigation water quality standards have been followed to analyze the fitness of the collected wastewater irrigation samples. The permissible limits are given in Table 3.9.

Irrigation with these levels of contaminations is supposed not to pollute the soils and agricultural produce.

Table 3.8: Classification of wastewater irrigation samples

Zone	*Source*	*No of Samples*		
		BOD/COD	*Chemical*	*Heavy Metal*
IW-I	Paharang Drain	5	5	5
IW-II	Madhuana Drain	2	2	2
IW-III	Municipal Drains	18	18	18
Total		*25*	*25*	*25*

Table 3.9: International irrigation water quality standards

Parameters	*Units*	*Permissible Limits*	*Parameters*	*Units*	*Permissible Limits*
TDS	mg/l	1500	As	µg/l	100
Na	mg/l	230	Pb	µg/l	5000
Ca	mg/l	230	Fe	µg/l	5000
Mg	mg/l	100	Mn	µg/l	200
SO_4	mg/l	500	Ni	µg/l	200
HCO_3	mg/l	400	Zn	µg/l	5000
Cl	mg/l	400	Hg	µg/l	2
Cd	µg/l	10	Cu	µg/l	200
Cr	µg/l	100			

Source: WHO (1989)

3.3.4 Soils Irrigated with Wastewater

A number of farmers are using wastewater to irrigate their crops due to shortage of canal water and this practice is common in the peri-urban areas. Therefore, to study the impacts of wastewater irrigation on soil health, 178 soil samples up to 45 cm depth with an interval of 15 cm were collected for chemical and heavy metal analysis (Table 3.10).

Parameters Analyzed for Agricultural Soils

The soil samples have been analyzed for heavy metals and chemical analysis, which include ECe, pH, SAR, organic matter and N, P, K.

(i) Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio (SAR) is very important test for the irrigation water and agricultural soils, which is also known as sodicity index. Sodium has outstanding capability to de-structure the soils and hence reduces the infiltrating capacity of soils. SAR is calculated as

$$SAR = [Na^{+}] / [(Ca^{2+} + Mg^{2+})/2]^{1/2}$$

Where,

SAR = Sodium Adsorption Ratio

$[Na^{+}]$ = Sodium concentration

$[Ca^{2+}]$ = Calcium concentration

$[Mg^{2+}]$ = Magnesium concentration

(ii) Organic Matter (OM)

It consists of a variety of components. These include plant residuals, microorganisms, organic traction and stable organic matter (humus). Organic matter improves soil structure, maintain tilth and minimize the soil erosion. The soils having five percent organic matter are considered highly productive.

(iii) Nitrogen (N)

Nitrogen is applied to crops in the form of nitrogen fertilizer. It is the most limiting element in crop production, since large amounts are removed annually during cultivation etc. Excessive nitrogen burns the crops and deficiency in nitrogen retards plant growth.

(iv) Phosphorous (P)

It is an important micronutrient of agricultural soils and its deficiency in soils reduces their productivity. The plants up take most part of it from the soils. Therefore, its levels should be maintained in soils to keep fully productive. The collected samples of agricultural soils have been compared with the international agricultural soils standards in order to determine their level of fertility and contamination. The permissible levels of tested parameters for agricultural soils are given in Table 3.11.

Table 3.10: Classification of the agricultural soil samples

Zone	*Irrigation Source*	*Depth (cm)*	*No of Samples*	
			Chemical	*Heavy Metal*
S-1	Paharang drain	0-15	5	5
		15-30	5	5
		30-45	5	5
S-2	Madhuana drain	0-15	3	3
		15-30	3	3
		30-45	1	1
S-3	Municipal drains	0-15	22	22
		15-30	22	22
		30-45	23	23
		Total	*89*	*89*

Table 3.11: International agricultural soil standards

Parameters	*Units*	*Permissible Limits*	*Parameters*	*Units*	*Permissible Limits*
P	mg/kg	> 7	Cd	mg/kg	1.0
K	mg/kg	> 80	Cr	mg/kg	100
Organic Matter	%w/w	> 0.86	As	mg/kg	30
SAR	Unitless	NGVS*	Pb	mg/kg	500
pH	Unitless	4-8.5	Fe	mg/kg	NGVS
EC	µS/cm	4000	Mn	mg/kg	500
Cu	mg/kg	100	Ni	mg/kg	20
Hg	mg/kg	1.0	Zn	mg/kg	250

Source: Alloway (1990)   *No Guideline Value Set.

The methods used for analysis of chemical parameters (N, P, K, SAR, O.M, pH and EC) for soil were done according to Rump and Krist (1992). Method used for analysis of heavy metals of soil, vegetables and fish were done after digestion by acid digestion method followed by flame atomic absorption spectrometry by direct aspiration into an air/nitrous oxide acetylene flame.

3.3.5 Vegetables and Crops Grown with Wastewater

The wastewater, soils and vegetable samples have been collected from the same place to determine their interrelationship and to evaluate the contaminant uptake capability of different species. Fifty-one (51) vegetable samples of different species grown from wastewater like tomato, wheat, brinjal, sugarcane, turnips, radish, carrots, chilies etc were collected from different locations to determine heavy metals and N, P, K contents. The source, type of wastewater and locations were recorded with GPS. The detailed classification of the collected samples is given in Table 3.13. Analysis of N, P, K in vegetables/crops were done according to HLS Tandon (2004).

The FAO/WHO's Guidelines for Vegetables

The guideline values set by the FAO and WHO have been followed to evaluate the degree of toxicity of vegetables and crops irrigated with wastewater. The maximum permissible concentrations of trace elements and other parameters for fruits and vegetables are given in Table 3.12.

Table 3.12: Maximum permissible levels for vegetables/crops for trace elements and macronutrients

Parameters	*Max. Level (mg/kg)*	*Parameters*	*Max. Level (mg/kg)*
As	0.43	Mn	500
Pb	0.30	Zn	99.40
Cd	0.20	Ni	67.90
Cu	73.30	N	10-50
Cr	2.30	P	10-40
Fe	425.50	K	10-40

Source: Weigert (1991), FAO/WHO (2001), Pendias & Pendias (1992).

3.3.6 Fish Farm Water

There is significant evidence that fish absorb different contaminants if reared in polluted waters particularly the heavy metals like mercury, lead and chromium. In most of the fish farms located in and around Faisalabad, low quality groundwater was being used for fish rearing. To assess the level of toxicity of fish farms, water samples of six fish farms located in the different localities were collected for chemical and heavy metal analysis. The water samples were acidified at the time of collection in order to reduce possible loss of metals by adsorption on the walls of sampling containers. The analysis of the farm water for different heavy metals and chemicals were carried out at the NIBGE and PCRWR laboratories Islamabad. The higher concentration of heavy metals like, Cd, Cr, As, Pb and Hg in water may adversely affect not only the aquatic organisms but also ingesting organisms.

Table 3.13: Classification of the vegetable samples

Zone	*Irrigation Source*	*Specie*	*No of Samples*	
			Chemical	*Heavy Metal*
V-I	Paharang drain	Wheat	3	3
		Turnip	2	2
		Sugarcane	1	1
		Cauliflower	4	4
		Mustard	1	1
		Radish	2	2
V-II	Madhuana drain	Wheat	3	3
		Mustard	1	1
		Carrot	1	1
V-III	Municipal drains	Berseem	2	2
		Maize	2	2
		Sugarcane	1	1
		Radish	2	2
		Chilli	2	2
		Wheat	4	4
		Barle	1	1
		Tomato	2	2
		Brinjal	2	2
		Mustard	2	2
		Spinach	2	2
		Beans	1	1
		Sorgham	2	2
		Bitter gourd	1	1
		Lettuce	1	1
		Sugarbeat	1	1
		Mint	1	1
		Garlic	1	1
		Potato	1	1
		Carrot	1	1
		Turnip	1	1
Total			*51*	*51*

Farm Fish

All fish species do uptake contaminants particularly the heavy metals like Cr and Pb but the uptake capability of different varieties is different. Grass Corp has more contaminant uptake capability. Similarly, the older fish develop more concentrations of contaminants as compared to its young fellows. The concentration of essential trace metals is generally higher in the aquatic organisms, which they receive from the water. Therefore, the excessive amount of pollutants in the water is the sole cause of higher concentration levels of these trace elements in the reared fish (Wikipedia, 2006). The profile of fish farm water samples is given in Table 3.15. Three water samples from each farm were collected for chemical, heavy metal and biological analysis.

Thirteen fish samples of five different species including Mori, Rahoo, Grass Corp, Gulfarm and Hybrid belonging to different age groups were collected from the fish farms. The fish samples, after collection, were washed with deionized water to remove adhering particles, mucous and other materials that can absorb metal. These samples were then placed in polythene bags and brought to the laboratory. The fish samples have been analyzed for heavy metals such as Cd, Cu, Pb, Cr, Ni, Fe, Mn, Zn.

Fish Farm Water Quality Standards

The fish farm water have been analyzed for the parameters as detailed in Table 3.14

Table 3.14: International fish farm water quality standards

Parameters	*Units*	*Permissible Limits*	*Parameters*	*Units*	*Permissible Limits*
pH	Unitles	7-8.5	K	mg/l	N.A
EC x 10^{-6}	µs/cm	1.65	Na	mg/l	N.A
Temperature	C^o	20-30	Ca	mg/l	10-160
Colour	Unitless	Blue/light green	Cu	mg/l	N.A
TDS	mg/l	50-1000	Cd	mg/l	N.A
Alkalinity	mg/l	50-400	Cr	mg/l	N.A
Dissolved Oxygen	mg/l	5-12	As	mg/l	N.A
Hardness	mg/l	50-400	Pb	mg/l	N.A
SO_4	mg/l	N.A*	Fe	mg/l	N.A
CO_3	mg/l	0-100	Mn	mg/l	N.A
HCO_3	mg/l	50-400	Ni	mg/l	N.A
Cl	mg/l	40-1000	Zn	mg/l	N.A
Mg	mg/l	N.A	Hg	mg/l	N.A

Source: Govt. of Punjab Fisheries Department (2002) * Not Available

Table 3.15: Profile of the fish farms

Sr. No	*Farm*	*Source of Water*	*Specie*	*Age (Year)*	*Weight (kg)*
1	Satiana Hetchery Farm Chack # 38 GB	Groundwater	Grass Corp Rahoo Mori	1 1 1	1.5 1 1
2	Chack # 107 RB, Faisalabad	Groundwater	Hybrid	0.5	0.5
3	Chack # 73 RB Jaranwala Faisalabad	Groundwater	Grass Corp Mori	1 1	1.5 1
4	Chak # 73. RB Khurainwala Faisalabad	Groundwater	Grass Corp Grass Corp	1 1	1.25 1.25
5	Khuriian Wala	Groundwater	Mori Raoo	1 1	0.5 0.5
6	Govt. Fish Farm, Himat Pura	Groundwater	Mori Mori Gulfam	0.5 1 1	1 1 1

3.3.7 Human Blood Samples

The effect of low quality water on human health and the status of water-borne diseases in the area were assessed by conducting human blood sampling for various water-borne/related diseases as recommended by the experts of National Institute of Health (NIH) and Pakistan Institute of Medical Sciences (PIMS) Islamabad. One hundred human blood samples were collected for this purpose. The collections of samples were distributed amongst various classes based upon different parameters like age, gender, drinking water sources and locality. The collection procedure has been adopted in order to get the status of water-borne and water-related diseases from different aspects (Table 3.16). The human blood samples have been tested for the following water-borne and water-related diseases in the Shifa International Lab, Islamabad.

(i) Hepatitis A (ii) Hepatitis E (iii) Typhoid (iv) Gastroenteritis (v) Malaria. The detail of these diseases is given below.

(i) Hepatitis A

The malfunction of liver caused by the viral infection of Hepatitis A is found normally in children and young adults. The virus is transferred to the human body by the infected water and food. The human body in stool excretes this virus. Therefore, lack of drainage of wastewater is one of the most prominent reasons of its epidemical spread. Boiling and filtering of drinking water may prevent humans from this infection. The defensive mechanism of the body implicitly detects and overpowers the virus in 2 to 6 weeks, that’s why the death ratio of the infected patients is very low. Once the disease is recovered, it never reoccurs (Wikipedia 2006).

(ii) Hepatitis E

The epidemiological spread and prevention measures of this virus are the same as those for Hepatitis A. However, this viral infection is particularly dangerous for pregnant women, therefore, 20 to 30 percent of such patients die while others do recover in 2 to 6 weeks without any medication (Wikipedia 2006).

Table 3.16: Classification of the human blood samples

Zone	*Drinking Water Source*	*Category*	*No. of Samples*
HB-I	Groundwater pumped near surface drains (Paharang, Madhuana)	Male Child	4
		Female Child	4
		Young Male	5
		Young Female	4
		Old Male	4
		Old Female	4
HB-II	Can water (groundwater pumped near the canal)	Male Child	4
		Female Child	5
		Young Male	4
		Young Female	4
		Old Male	4
		Old Female	4
HB-III	Groundwater in the city	Male Child	4
		Female Child	4
		Young Male	4
		Young Female	4
		Old Male	5
		Old Female	4
HB-IV	Public water supply	Male Child	4
		Female Child	4
		Young Male	5
		Young Female	4
		Old Male	4
		Old Female	4
		Total	*100*

Old: Above 40 Years   Young: 16-40 Years   Child: 5-15 Years

(iii) Typhoid

The disease is caused by an organism (salmonella), which is carried to the humans mostly by drinking water. Its presence in the human blood is tested by the widal test. Typhoid may prove fatal in some cases if persists for a longer period of time (Wikipedia, 2006).

(iv) Gastroenteritis

Enteric pathogens E.coli, bacteria and other microorganisms transferred to human body by the feacal contamination of drinking water and food cause gastroenteritis. In ninety percent cases these are not carried to the human blood. However, continuous consumption of such waters and food may lead to its slight concentration in human blood, which causes enteric fever. Enteric fever proves fatal in some cases (Wikipedia 2006).

(v) Malaria

It is water related disease and the bacteria are carried to the human blood by mosquitoes (Female Anopheles), which grow enormously on wastewater ponds. Inadequate wastewater management and easy access of mosquitoes to human body are the main causes of this disease. This bacterium causes severe fever, increases the human body temperature as much as 104 ^{o}F and patient suffer from severe shivering (Wikipedia, 2006).

3.4 PARTICIPATORY RURAL APPRAISAL

Participatory rural appraisal was also conducted through specifically designed questionnaires to get information about general public health, perception of the people about hazardous impacts of bad quality drinking water and any protective measures etc. The survey has further been divided into four sub-categories i.e. information from common masses, farmers, industries, hospitals and private clinics.

3.4.1 Common Masses Survey

Hundred specifically designed questionnaires were filled from the common masses with appreciable degree of social, academic and intellectual scattering in the city, The objective was to assess their degree of awareness about drinking water quality and its impacts on health. The views and perceptions of the people belonging to different educational and financial backgrounds were documented. The responses of governmental or non-governmental organizations for remedial measures were also noted in the survey.

3.4.2 Farmers Survey

Specific questionnaire was developed to document information provided by the farmers about the suitability and impact of irrigating fields with municipal wastewater on the health of the farming community, soil fertility, crop quality, yield and its long-term impacts. Twenty farmers were interviewed from different places of Faisalabad.

3.4.3 Industrial Survey

The selected industrial units were surveyed. The information regarding size, chemical processes, quantity of wastewater generated, hazardous chemicals discharged treatment before disposal and the ultimate disposal was obtained through specific questionnaires alongwith relevant record from industries. Thirty industries were surveyed as detailed in Table 3.17.

Table 3.17: List of industries surveyed

S. No	*Industries*	*S. No*	*Industries*
1	Nishat Group Limited	16	M.N Textiles
2	Lily Fabrics	17	Texto Textile Units
3	Arzoo Textiles	18	Aitamad Textiles
4	Chenab Group	19	Firdaus & Kausar Textiles
5	Magna Dying Factory	20	Aala Processing Units
6	Amtex Textiles	21	Kashmir Banaspati
7	Interloop Textiles	22	Kelash Fabrics
8	Alfaisal Textiles	23	Shamsee Gatta Factory
9	Bashir Dying Industries	24	Kalsum Dying Unit
10	Kay & Emms Textiles	25	Ali Hajvari Chemical Factory
11	Mumtaz Mahal Dying Units	26	Vita Bread
12	Kamal Dying & Printing Mills	27	Afzal Textile Unit
13	Ashraf Zia Textiles	28	Kamal and Zubari Dying
14	Abdur Rehman Textile	29	Akbar Dying
15	M.K Processing Units	30	Crescent Textiles

3.4.4 Hospitals and Private Clinics Survey

A survey of hospitals and private clinics was also carried out to determine major diseases prevailing in each locality, the perceptive causes, the views, and percentage of patients with water-borne diseases alongwith recommendations from qualified doctors about remedial measures. Twenty-five questionnaires from scattered places were filled which provided the status of water-borne and water-related diseases in each locality.

A documentary was prepared about status of wastewater management and practices in Faisalabad, which is attached as CD with this report.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 DISCHARGE MEASUREMENT OF WASTEWATER

The discharge of the two main effluent carrier drains of Faisalabad i.e. Paharang and Madhuana was measured. The discharge of Paharang drain was first measured at Chokera after the addition of city inflows, and then measured at Warah Pind before discharging into the river Chinab. Similarly, discharge of Madhuana drain was initially measured at Chak No 81 Jhang Branch after receiving all city inflows and then measured at Qaim Shah near river Ravi in the month of September. Pigmy type digital current meter was used to record discharges at the interval of two hours for 10-hours in a day in order to get the maximum, minimum and average discharges. The measured discharges are given in Table 4.1 and 4.2.

Table 4.1: Measured discharge of wastewater in Faisalabad

Paharang drain		*Madhuana drain*	
Time	*Discharge (m^3/sec)*	*Time*	*Discharge (m^3/sec)*
11.00 AM	2.18	12.00 AM	3.01
1.00 AM	2.68	2.00 PM	2.97
3.00 PM	2.39	4.00 PM	2.89
5.00 PM	2.23	6.00 PM	2.77
Average	*2.37*	*Average*	*2.91*

Table 4.2: Measured discharge of Paharang and Madhuana drains being disposing off in rivers

Paharang drain		*Madhuana drain*	
Time	*Discharge (m^3/sec)*	*Time*	*Discharge (m^3/sec)*
8.00 A.M	2.91	8.00 A.M	3.78
10.00 AM	3.33	10.00 AM	3.86
12.00 PM	3.84	12.00 PM	4.03
2.00 PM	3.49	2.00 PM	4.47
4.00 PM	3.09	4.00 PM	4.21
6.00 PM	2.80	6.00 PM	4.00
Average	3.24	Average	4.05

The average discharge of Madhuana Drain is almost 20 percent more than that of Paharang drain. It collects the disposals of Sheikhupura road, Khurrarianwala industrial area, and sewerage effluents from southern part of the city. The maximum discharge of Madhuan drain at Chak No. 81 Jhang Branch was 3 m^3/sec at 12.00 PM with mean discharge of 2.91 m^3/sec whereas the peak flow rate of Madhuana drain at Qaim Shah near river Ravi was 4.47 m^3/sec at 2: 00 PM with the mean discharge of 4.05 m^3/sec. The peak discharge of Pharang drain at Chokera was 2.68 m^3/sec at 1.00 PM with the mean discharge of 2.37 m^3/sec whereas the peak discharge of the Paharang drain at Warah Pind near the river Chinab i.e. 3.84 m^3/sec was recorded at 12: 00 PM with the mean discharge of 3.24 m^3/sec. The approximate total average effluent disposed of into the rivers was 7.29 m^3/sec.

4.1.1 Seepage of Wastewater

Seepage of wastewater was measured by inflow and outflow method. For measuring the seepage losses at Madhuana drain, a straight section of 1500 m at Chak No. 81 Jhang Branch was taken. The discharge was measured by a pigmy type digital current meter. The discharge at inflow was 2.89 m^3/sec and at outflow was 2.18 m^3/sec. CropWat 4 Version 4.2 was used to calculate evaporation by using meteorological data of Kaleemullah *et al.,* (2001) that was 3.02 mm/day. The net seepage of wastewater at Madhuan drain was 0.047 m^3/sec (47 lps)/100 m length. Similarly, seepage of wastewater in the Paharang drain was also measured at a straight section of 300 m at Chokera village. The discharge at inflow was 2.18 m^3/sec and at outflow it 1.76 m^3/sec. The net seepage of wastewater in the Paharanag drain was 0.14 m^3/sec (140 lps)/100 m length. The seepage losses at the Paharang drain was about 33 percent greater than that measured at the Madhuana drain at selected points.

4.2 COMPOSITION OF WASTEWATER

The collected wastewater samples were analyzed for the biological, chemical and heavy metal parameters and compared with the NEQS wastewater quality standards.

4.2.1 BOD and COD Analysis

The wastewater quality in terms of exceeding the permissible limit of different sources is given in Table 4.3 whereas mean values of BOD and COD is given in Table 4.4. Samples exceeding the permissible limit for BOD were 91, 87, 80, 100 and 100 percent for Paharang drain, Madhuana drain, Municipal drains, drains before discharging into rivers and rivers after receiving effluents, respectively. Similarly, the samples exceeding the permissible limit for COD were 94, 95, 100, 100 and 100 percent for Paharnag drain, Madhuana drain, Municipal drains, before discharging into rivers and rivers after receiving effluents, respectively.

Table 4.3: BOD and COD of wastewater samples

Source	*Samples (No)*	*BOD*			*COD*		
		Within limit (No)	*Exceeding limit (No)*	*Exceeding limit (%)*	*Within limit (No)*	*Exceeding limit (No)*	*Exceeding limit (%)*
drain	*35*	3	32	91	2	33	94
Madhuana drain	*38*	5	33	87	2		95
Municipal drains	*5*	1	4	80	0	5	100
Drains, before discharging into rivers	*3*	0	3	100	0	3	100
Rivers after receiving effluents	*4*	0	4	100	0	4	100

The high BOD and COD values indicate the presence of organic and inorganic substances in the effluents. Starch may be one of the biggest contributors for it as it is being used extensively in textile industry. It shows a biologically degraded water quality situation for the ecosystem.

Table 4.4: Mean values of BOD and COD of samples exceeding the permissible limit for different wastewater sources (mg/l)

Parameter	*Permissible Limits*	*drain*	*Madhuana drain*	*Municipal drains*	*Drains before discharging into Rivers*	*Rivers after receiving effluents*
BOD	*80*	255	97	336	425	187
COD	*150*	937	738	911	980	360

Highest mean value of BOD (425 mg/l) and COD (980 mg/l) was recorded for drains prior to its disposal into the river. It indicated that BOD and COD increased during the way to its final disposal point due to subsequent incorporation of biodegradable and chemical substances (Figure 4.1)

Figure 4.1: Madhuana drain discharged into the river Ravi

The results for BOD & COD of wastewater samples of different types are given in Table 4.5. The samples exceeded the permissible limit for BOD were 83, 89, 95 and 100 percent in the industrial, sewerage, mixed (industrial + sewerage) and WASA treated water, respectively. Similarly, the samples exceeded the permissible limit for COD were 94, 100, and 97 percent for industrial, sewerage and mixed water, respectively.

Table 4.5: BOD and COD of different types of effluent samples

Effluent Type	*Samples (No)*	*BOD*			*COD*		
		Within limit (No)	*Exceeding limit (No)*	*Exceeding limit (%)*	*Within limit (No)*	*Exceeding limit (No)*	*Exceeding limit (%)*
Industrial	*35*	6	29	83	2	33	94
Sewerage	*9*	1	8	89	0	9	100
Mixed	*40*	2	38	95	1	39	97
WASA Treated	*1*	0	1	100	1	0	0

All types of effluents have shown absolute violation of permissible concentrations. However, the biological treatment of wastewater by the WASA has reduced the BOD and COD. The mean values of BOD and COD for different types of effluent are given in Table 4.6.

Table 4.6: Mean values of BOD and COD of samples exceeding the permissible limit for different wastewater types (mg/l)

Parameter	*Permissible Limits*	*Wastewater Type*			
		Industrial	*Sewerage*	*Mixed*	*WASA Treated*
BOD	*80*	312	242	293	87
COD	*150*	803	858	755	*

*Samples found within permissible limit.

The industrial samples showed highest value of BOD (312 mg/l) followed by mixed (Industrial + sewerage) samples. Unsaturated substances (organic and inorganic) in the industrial effluents may be responsible for such high values. COD of sewerage water was the highest due to toxic elements in city sewerage water. The WASA treated samples were found within permissible limit for COD whereas BOD was very close to the permissible limit.

BOD and COD Profile of the Paharang Drain

At its start, Paharang drain receives the effluents of Karari drain carrying the sewerage effluents of the Chak Jhumrah area with BOD and COD of 204 and 505 mg/l, respectively. No big drainage channel discharges into it a long way up till village Dhanola. The discharge of drain at this point was very low. The BOD and COD of the drain water have been found within permissible limit till Dhanola village. The discharge of drain increased many folds between village Dhanola and Sargodha road due to incorporation of effluents of a number of industries as detailed in Table 4.7. The Jaguar (Pvt) limited is the only industry having its wastewater treatment plant, which usually remains non-functional due to high operational costs. The sequence of fall of various inflow sources of Paharang drain and resultant change in the biological conditions is shown in Figures 4.2 to 4.5.

Table 4.7: Major influents of the Paharang drain

Sr. No	***Influent Sources***	***Chemicals Used***	***Discharge (m^3/hr)***
1	**Bashir Dying and Printing Factory Chak No. 7.**	**Synthetic dye stuff, Cr, Cu**	**150**
2	**Ali Hajveri Chemical Factory Chak No. 7.**	**Pb, NH_3, Phosphat, Resin, Tolven, Xylene etc.**	**50**
3	**Jaguar, Kay & Emms**	**NaOH,**	**150**

	Textiles etc.	**Hydrosulphites, Thiosulphate.**	
4	**Mumtaz Mahal dying unit Chak No. 7.**	**Cr, Cu, Pb, Sn, Cd**	**100**
5	**Sewage Effluent of WASA**	**Detergents etc**	**500**
6	**Bread Factory Chak No. 7**	**$NaHCO_3$**	**50**
7	**Chiniot Drainage Channel**	**Organic substances, Detergents etc.**	**1000**
8	**Channel No 1 Kurri Road**	**Miscellaneous**	**300**
9	**Channel No. 3 Chokera Village.**	**Domestic garbage etc.**	**800**
10	**City Sewage Chokera**	**Detergents, Organic matter**	**300**

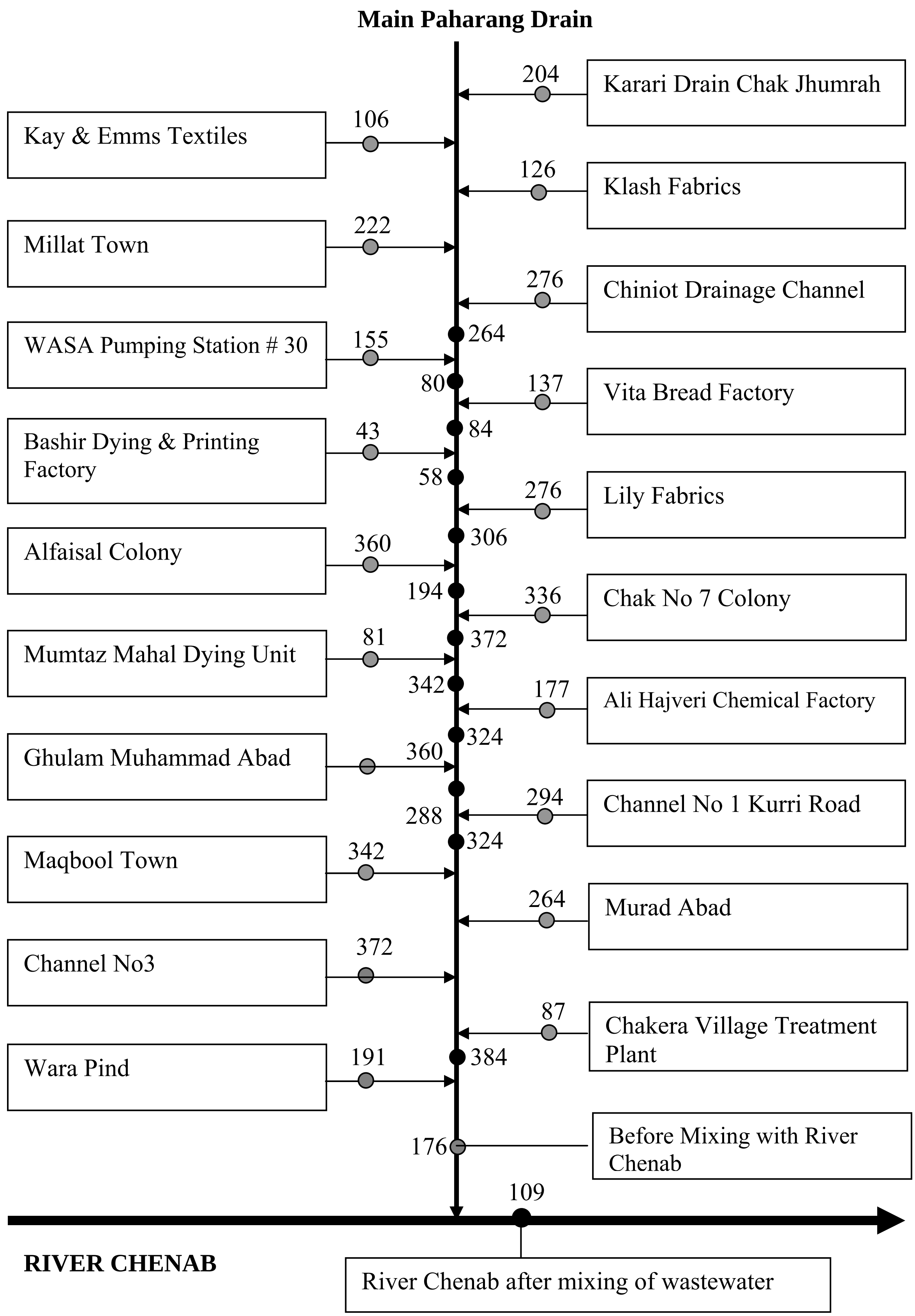


Figure 4.2: BOD (mg/l) profile of Paharang drain

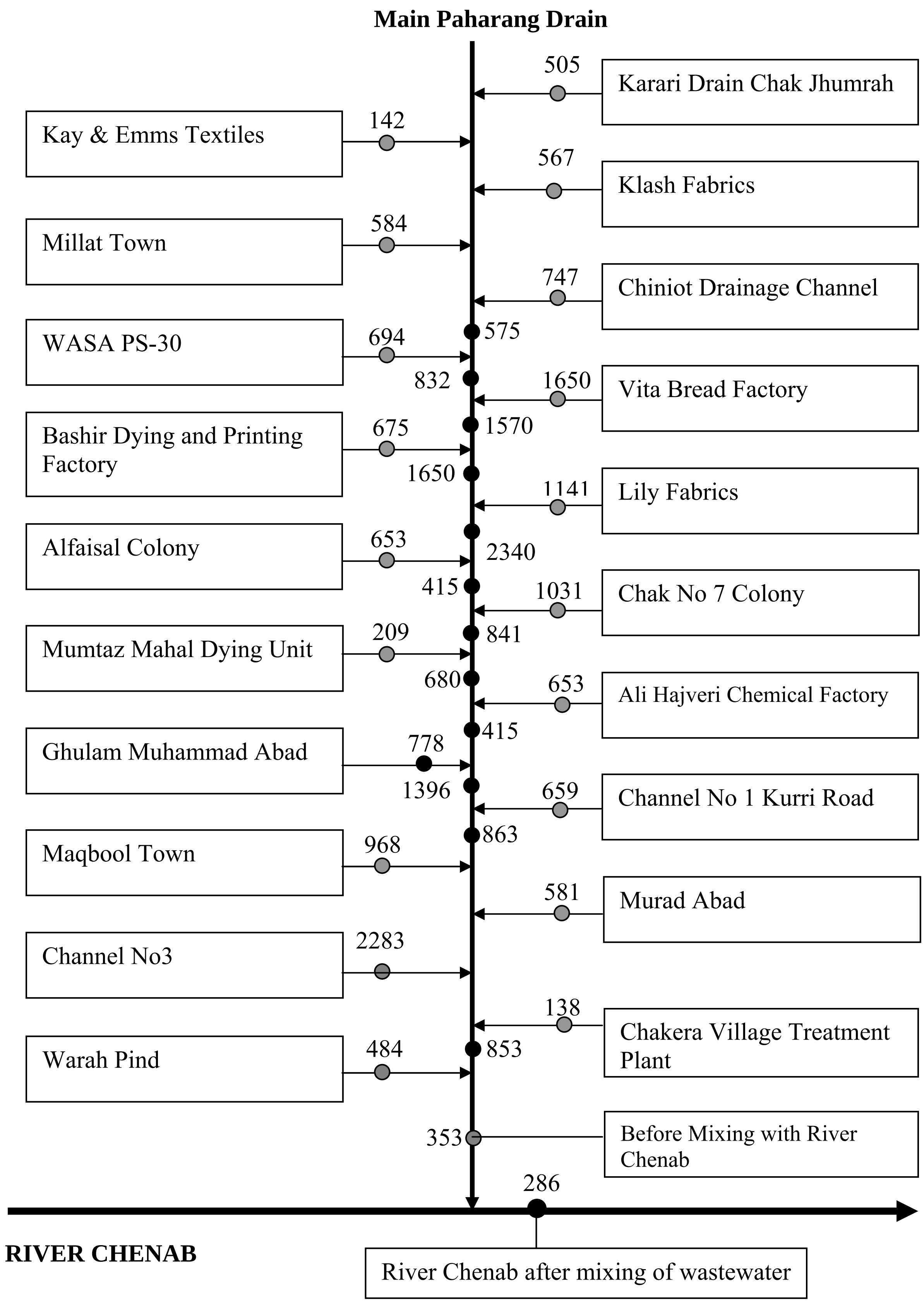


Figure 4.3: COD (mg/l) profile of Paharang drain

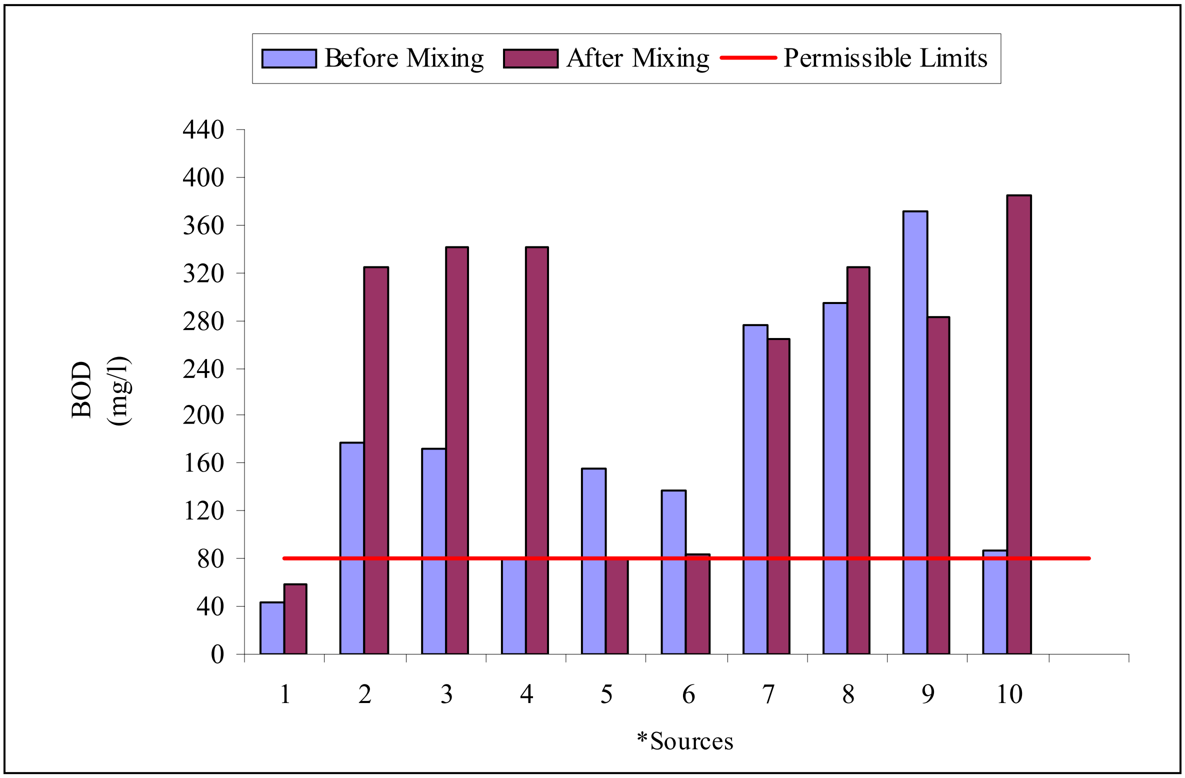
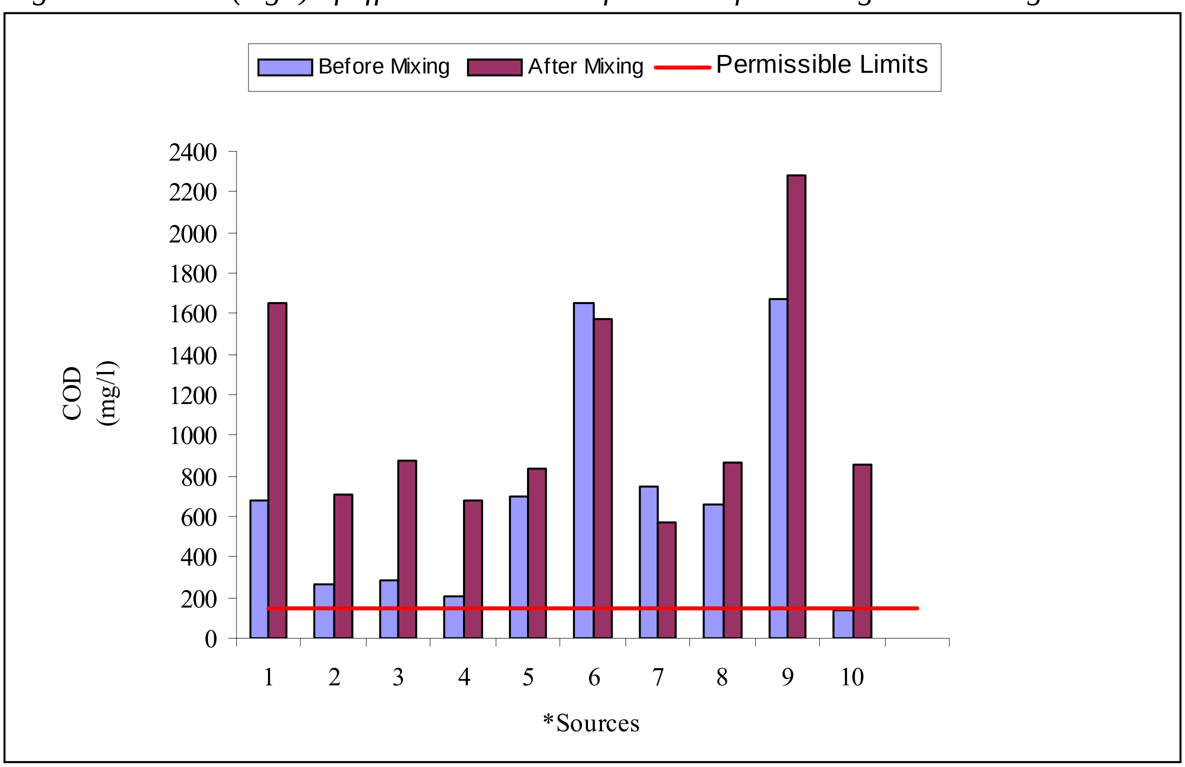


Figure 4.4: BOD (mg/l) of effluents sources before and after mixing in Paharang drain



*Sources are from 1, 2, 3…..10 as per Table 4.7

Figure 4.5: COD (mg/l) of effluents sources before and after mixing in Paharang drain

The discharge increased almost 1.5 times of average discharge of Paharang drain after the addition of drainage channel of Chiniot. This channel carries the sewerage effluent of Chiniot city as well as the effluents of all industries located along the Faisalabad-Sargodha road. The BOD and COD of Chiniot drainage channel was 276 and 747 mg/l, respectively. The same values reduced to 264 and 575 mg/l, respectively a few meters downstream from the junction. The reduction in BOD and COD may be attributed to increased flow rate and turbulence generated at junction causing aeration.

From Sargodha road to Ghulam Muhammad Abad, a number of channels carrying industrial and sewerage effluents fall into the Paharang drain. These include the effluents of WASA Pumping Station-30, Lily Fabrics, Bashir Dying and Printing Factory, Vita Bread Factory, sewerage of Alfaisal Colony, Chak No. 7, Mumtaz Mahal Dying Unit and Ali Hajveri Chemical Factory. The Vita Bread Factory and Lily Fabrics were found to be the most polluting industriesthat increased the COD of drain as high as 2340 mg/l (200 times above the permissible value). Due to subsequent fall of industrial effluents into Paharang drain, the BOD and COD values concentrates to 360 and 778 mg/l, respectively before its passage from Ghulam Muhammad Abad. In addition to Ghulam Muhammad Abad, a number of colonies are present along the Paharang drain. These colonies have high population intensity hence generate a huge quantity of wastewater which joins the Paharang drain. The span of Paharang drain along Ghualam Muhammad Abad was found highly polluted as the COD increased from 778 to 1396 mg/l.

Channel No. 3, having a BOD and COD level of 372 and 2283 mg/l, respectively, discharged on an average up to 45,000 m^3/day. The BOD and COD values reduced to 87 and 138 mg/l, respectively after treatment at WASA treatment plant. The results of WASA treatment plant were encouraging. The values of BOD and COD of WASA treated water however, increased to 387 and 857 mg/l, respectively after joining the Paharang drain. Since treated water is again discharged into Paharang drain which carried untreated flow, therefore, no benefits were being achieved from this huge investment. Moreover, these ponds were being under utilized because no pumping machinery was installed at the disposal point.

Nevertheless, it indicates that quality of surface water could be maintained biologically by disposing of the effluents after treatment. The beds of such treatment ponds should be lined in order to avoid the risks of deterioration of groundwater quality due to seepage of effluents. The WASA treatment ponds allow only primary (anaerobic) and secondary (facultative) treatments while tertiary (aerobic) treatment was missing. Few aerobic ponds (having depth of 1m) may be integrated with the existing system to further improve the quality of treated water.

BOD and COD Profile of Madhuana Drain

The Madhuana drain originates from Madhuana village and receives drainage effluents of industries located in the vicinity of Khurrarianwala (Figure 4.6). After collecting sewerage effluents of Channel No. 4 near Satiana Road, it leads to river Ravi. Major effluent sources of Madhuana drain are shown in Table 4.8. The BOD of Paharang and Madhuana drains before these fall into the rivers were 176 and 908 mg/l, respectively indicating that BOD of Madhuana was 5 times more than that of Paharang drain. The reason for high BOD of Madhuana drain was the presence of large number of industries at the upsteam whereas the presence of WASA treatment ponds on Channel No. 3 prior to its fall into Paharang drain also lowered the BOD to certain extent.

Figure 4.6: A view of drain receiving untreated effluent of Sitara Chemical Industry

The series of fall of different inflow sources of Madhuan drain and change in the BOD and COD is presented in Figures 4.7 to 4.10. Each industry was discharging effluents with a COD averagely five times more than the permissible limits. This was the reason that at the confluence of each outlet of industry, the COD increased substantially. The COD of Madhuana drain before it falls into the river Ravi was 2104 mg/l, which was about 12 times more than the permissible value. This value however, dropped down to 400 mg/l after mixing with the river water.

Table 4.8: Major influents of Madhuana drain

Sr. No	*Influent Sources*	*Chemicals Used*	*Discharge (m^3/hr)*
1	Amtex Textiles	Phosphates, Cr, Cd, halogenated hydrocarbons etc.	500
2	Alfaisal Textiles	Starch, mineral oil, polyvinyle, choloride, Cr, Cd, etc.	250
3	Interloop Textiles	Choloro-organic compounds, Cu, Sn.	500
4	Firdaus and Kausar Textiles	Alkali sulphide, formaldehyde, turpentine.	450
5	Arzoo, Magna and Kamal Dying	Cr, Cu, Sn, Cd, etc.	400
6	Aitmad and Texto Textiles	Phosphates, NaOH, polymer fluorocarbon etc.	200
7	Ashraf Zia, Rafiq and Abdur Rehman Textiles	Starch, Cr, Sn, NaOH, synthetic resin, and creasing.	200
8	M. K Processing and Weaving Units	Resin, NaOH, etc.	50
9	M. N. Chemical Industry	Pb, resins, tolven, xylen, ketones, etc.	200
10	Shamsee Gatta Factory	Raw material of sugarcane, etc.	75
11	Channel No 4	Detergents, NaOH, Cr, organic matter, etc.	1000

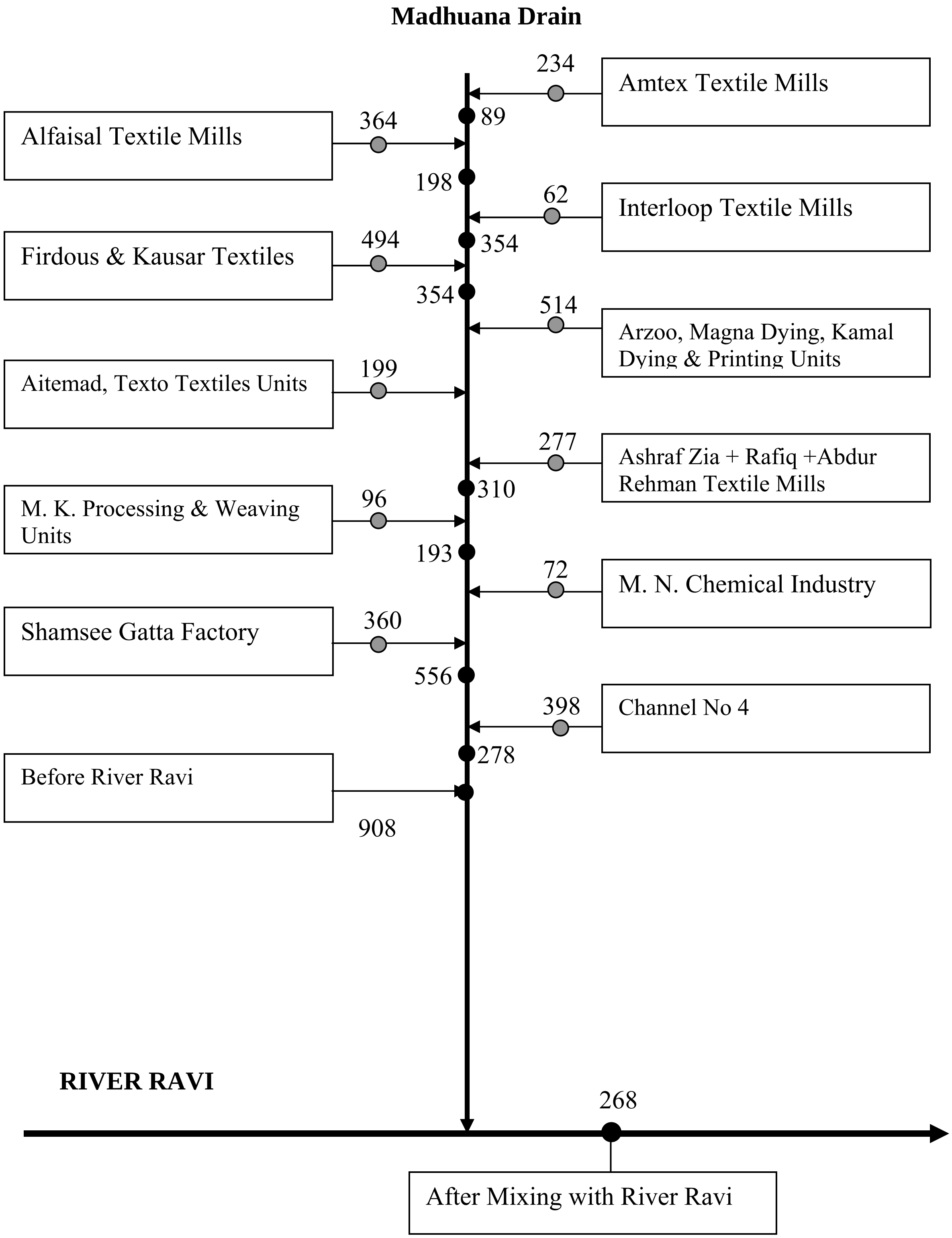


Figure 4.7: BOD (mg/l) profile of Madhuana drain

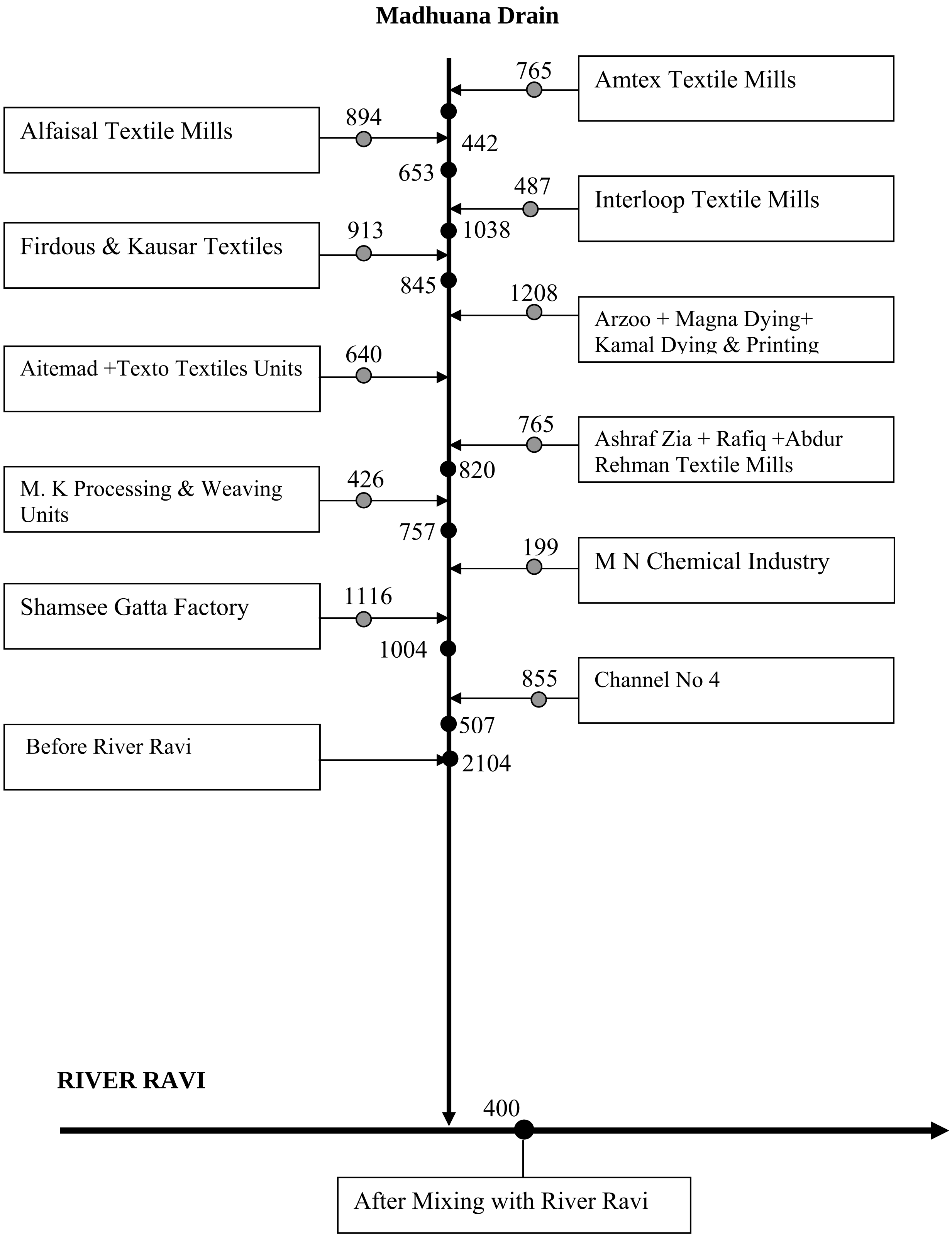


Figure 4.8: COD (mg/l) Profile of Madhuana drain

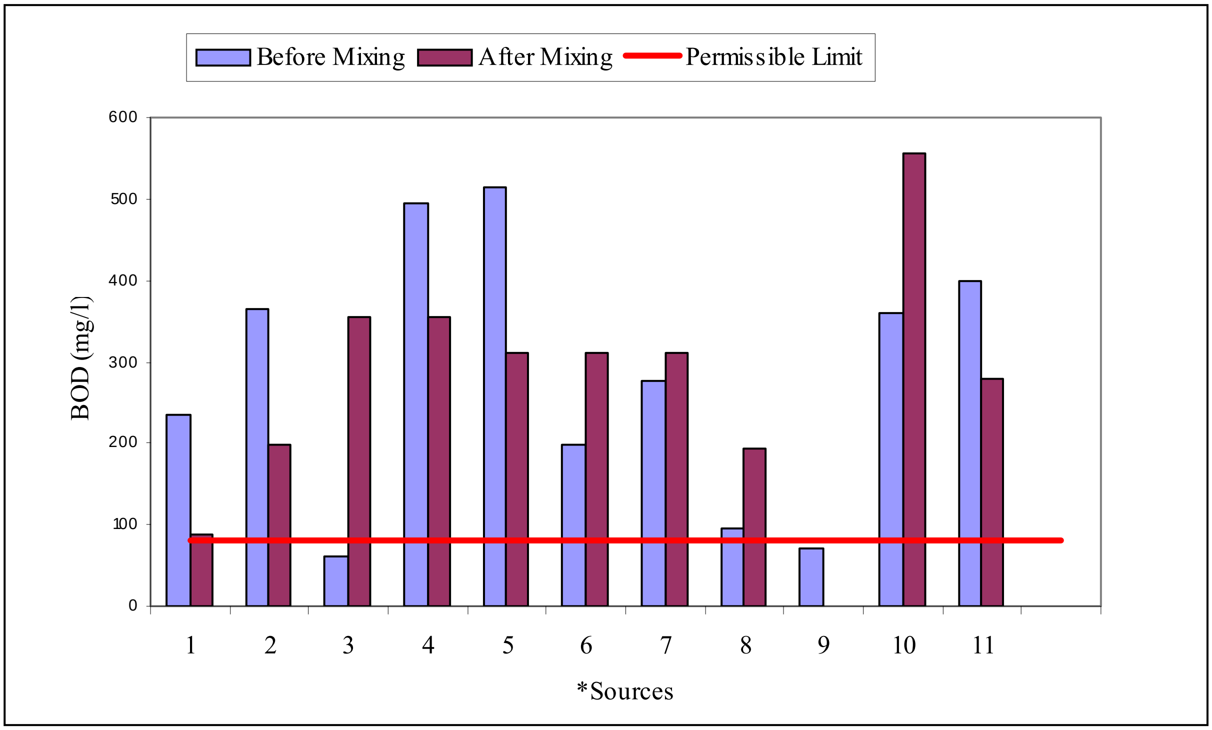
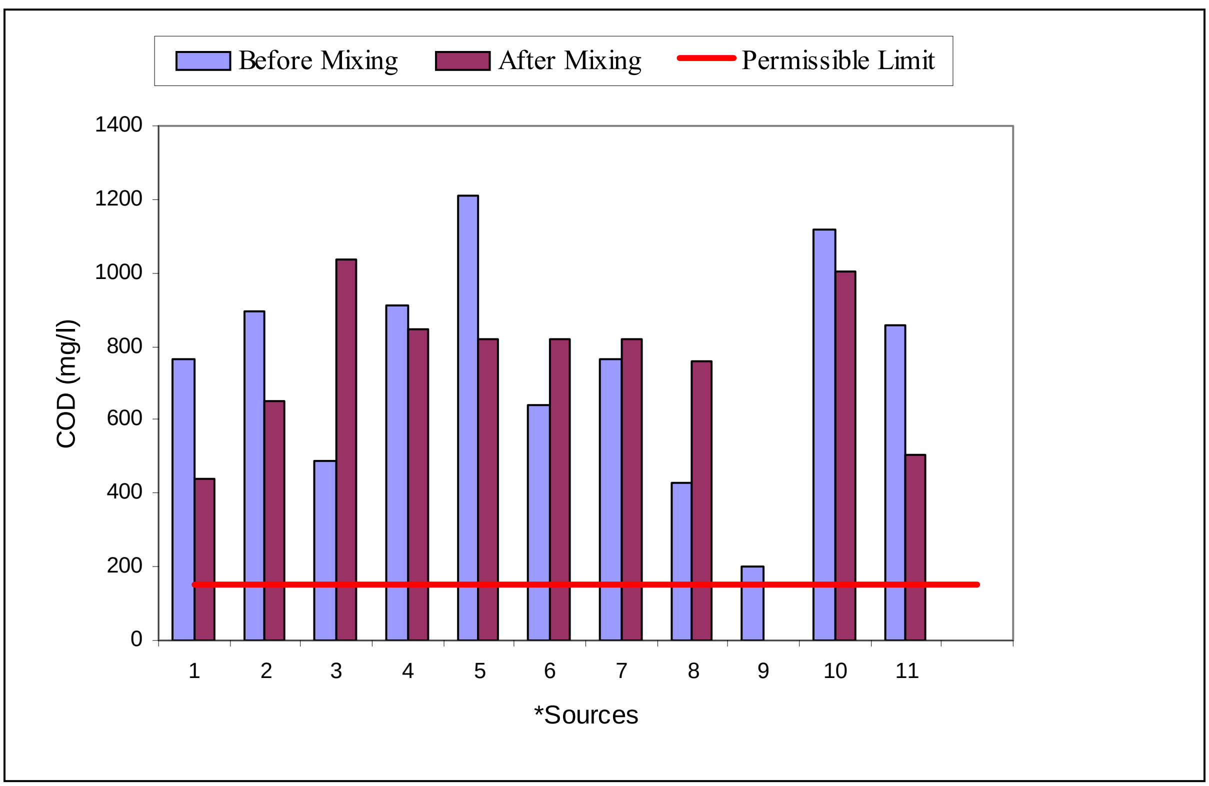


Figure 4.9: BOD (mg/l) behavior before and after mixing in Madhuana drain



*Sources are from 1, 2, 3…………11 as per Table 4.8

Figure 4.10: COD (mg/l) of different effluents before and after mixing with Madhuana drain

4.2.2 Chemical Analysis

The wastewater samples were also analyzed for the chemical parameters.

Table 4.9: Chemical analysis of wastewater samples

Parameters		*Paharang drain*	*Madhuana drain*	*Municipal drains*	*Drains before discharging into Rivers*	*Rivers after receiving effluents*
Total No. of Samples		*35*	*38*	*5*	*3*	*4*
pH	Within limit (No)	32	32	4	3	4
	Exceeding limit (No)	3	6	1	0	0
	Exceeding limit (%)	9	16	20	0	0
TDS	Within limit (No)	17	29	1	2	4
	Exceeding limit (No)	18	9	4	1	0
	Exceeding limit (%)	51	24	80	33	0
Cl	Within limit (No)	27	35	5	3	4
	Exceeding limit (No)	8	3	0	0	0
	Exceeding limit (%)	23	8	0	0	0
SO_4	Within limit (No)	27	17	2	3	4
	Exceeding limit (No)	8	21	3	0	0
	Exceeding limit (%)	23	55	60	0	0

The TDS were found higher in Paharang and Municipal drains than Madhuana drain whereas SO_4 was found higher in Madhuana and Municipal drains as compared to Paharang drain (Table 4.9). The maximum unfit samples were found for municipal drains in respect of pH, TDS and SO_4. It was due to the reason that the municipal drains were heavily loaded with different type of wastes generated within the city. The concentration of chemical parameters was high because of low flows within the city. The chemical quality of wastewater improved along its way. Turbulence, sedimentation, leaching of chemicals may be the reasons for decrease in these chemicals towards disposal points. WASA treats part of the wastewater coming from Channel 3 carrying mostly domestic wastewater. Channel 3 joins the Paharang drain partly directly and partly after treatment through aeration ponds. The chemical analysis of samples for different effluents types has been given in Table 4.10.

Table 4.10: Chemical analysis of different types of effluent samples

Parameters		*Effluent Type*			
		Industrial	*Sewerage*	*Mixed*	*WASA Treated*
Total No. of Samples		*35*	*9*	*40*	*1*
pH	Within limit (No)	29	9	36	1
	Exceeding limit (No)	6	0	4	0
	Exceeding limit (%)	17	0	10	0
TDS	Within limit (No)	21	6	25	1
	Exceeding limit (No)	14	3	15	0
	Exceeding limit (%)	40	33	37	0
Cl	Within limit (No)	26	9	37	1
	Exceeding limit (No)	9	0	3	0
	Exceeding limit (%)	25	0	7	0
SO_4	Within limit (No)	17	9	26	1
	Exceeding limit (No)	18	0	14	0
	Exceeding limit (%)	51	0	35	0

The WASA treated water was relatively better in respect of chemical quality. The sewerage effluent was found to have only excessive TDS. Sulphate was found with higher percentage in mixed and industrial types of effluent. The high sulphate content in industrial effluents was because of its being the chief constituents of the soap industry. The mean values of chemical parameter for various wastewater sources and types of effluents are given in Tables 4.11 and 4.12, respectively.

Table 4.11: Mean values of chemical parameters of samples exceeding the permissible limit for different wastewater sources (mg/l)

Parameters	*Permissible Limits*	*Paharang drain*	*Madhuana drain*	*Municipal drains*	*Drains before discharging into Rivers*	*Rivers after receiving effluents*
pH	*6-10*	11	10	13	*	*
EC (µS/cm)	*NGVS***	5689	5045	8070	4680	3477
Turbidity (NTU)	*NGVS*	307	121	132	101	162
TDS	*3500*	4498	5821	5676	3575	*
HCO_3	*NGVS*	1232	1176	1280	1292	890
CO_3	*NGVS*	13	17	0	3	7
K	*NGVS*	42	34	46	30	22
Na	*NGVS*	1075	933	1090	942	665
Ca	*NGVS*	71	94	60	67	60
Mg	*NGVS*	49	44	61	48	25
Hardness	*NGVS*	381	354	400	370	255
Cl	*1000*	1504	1519	*	*	*
SO_4	*600*	789	894	1088	*	*

* Samples found within permissible limit **No Guideline Value Set

Table 4.12: Mean values of chemical parameters of samples exceeding the permissible limit for different wastewater types (mg/l)

Parameter	*Permissible Limits*	*Effluent Type*			
		Industrial	*Sewerage*	*Mixed*	*WASA Treated*
pH	*6-10*	11	*	10	*
EC (µS/cm)	*NGVS***	5825	4844	5221	2790
Turbidity (NTU)	*NGVS*	265	133	160	75
TDS	*3500*	5865	3614	4445	*
HCO_3	*NGVS*	1105	1254	1268	780
CO_3	*NGVS*	16	3	15	0
K	*NGVS*	36	44	36	28
Na	*NGVS*	1021	918	988	400
Ca	*NGVS*	112	40	63	80
Mg	*NGVS*	53	45	41	41
Hardness	*NGVS*	418	286	332	360
Cl	*1000*	1508	*	1509	*
SO_4	*600*	858	*	906	*

* Samples found within permissible limit, **No Guideline Value Set

Highest mean value of pH was found in municipal drain but no sample was found unfit in respect of pH in drains before discharging into river and rivers after receiving effluents. The highest mean values of TDS were found in Madhuana drain but no sample was found unfit in rivers after receiving effluents. Similarly, no sample exceeded the permissible limit in drains before discharging into the rivers and after mixing of drain in river for Cl and SO_4.

It indicates that due to wastewater traveling in drains, chemicals settled/leached down and due to mixing of river water, quality of water improves. High value of pH was found in industrial effluent whereas pH, TDS, Cl and SO_4 showed that the quality of WASA treated water was relatively good.

4.2.3 Heavy Metal Analysis

Another important environmental aspect of wastewater is the heavy metal contamination as these elements enter into the food chain through drinking water (mostly groundwater), agricultural produce and fish. Depending upon nature, industries discharge heavy metals in their effluents but their concentrations are not much high due to their usage in smaller quantities. Nearly 90 percent of the industries in Faisalabad are engaged in manufacturing of textile products. It is important to study the chemicals used and processes adopted there to have an insight of textile industrial pollution and major pollutants. The detail is given in Table 4.13.

Table 4.13: Textile processes with possible pollutants and impacts

Process	*Chemicals used*	*Possible impacts*
Washing	Phosphates	Fatal for fisheries
Sizing	Starch, polyvinyl chlorides, poly acrylate and mineral oil.	High concentrations of organic substances with scum formation.
Dying	Synthetic dyestuff, Cr, Cu, Sn and Cd.	Not readily degradable and enters into the food chain.
Preservation	Chloro organic compounds	Toxic pollutants
Bleaching & dying	Sulphites, hydrosulphites and thiosulphites.	Toxic for aquatic life
Delustring	Phenol, turpentine, pine, barium chloride, Cr salts, alkali sulphides, resins and formaldehydes.	Induction of allergy
Mercerization	Sodium hydroxide and ammonia.	Fatal for aquatic life
Antistatic finish	Urea derivatives, biphenyl ether and chlorinated sulphonamide.	Skin diseases
Dirt repellent finish	Polymeric fluorocarbon resins.	Dangerous for the nervous system.
Flame proof finish	Halogenated hydrocarbons, Phosphorous compounds.	Allergenic substances
Deodorization	Perfume, synthetic resinsking and creasing.	Skin diseases

The collected wastewater samples were analyzed for 9 elements. The concentration of heavy metals in drains and different types of effluent samples did not show significant violation of permissible limits. No industry in Faisalabad was found to be disposing excessive heavy metals as per NEQS, because water being a cheap commodity in Pakistan is being used abundantly in industrial processes resultantly decreasing the heavy metal concentrations in the effluents. Also, some major industries have started to use environment-friendly substances in different industrial process under WTO regime of ISO certification.

4.3 DRINKING WATER QUALITY

The drinking water samples were analyzed to determine their fitness with respect to the microbiological, chemical and heavy metal parameters as discussed below:

4.3.1 Microbiological Analysis

A drinking water sample is considered safe for human consumption if it does not have any coliforms per 100 ml (WHO, 2004). The microbiological results of the drinking water samples collected from different sources and zones are given in Table 4.14. The unfit samples of WASA were 62, 25, 65, 25 and 18 percent for W-I, W-II, W-III, W-IV, W-V zones, respectively (see Table 3.3 for zoning). The mean values of CFU for W-I, W-II, W-

III, W-IV and W-V were 9500, 3000, 504, 100 and 23 CFU/ml, respectively. As CFU should be zero for microbiologically safe drinking water, it can therefore, be concluded that most of the samples of zones W-I and W-III were the worst contaminated whereas those of zones W-II, W-IV and W-V have shown comparatively less contamination.

The unfit drinking water samples of groundwater in the city were 85, 73, 83, 71 and 57 percent for zones CG-I, CG-II, CG-III, CG-IV and CG-V, respectively. The mean values of CFU for these zones were 952, 1926, 2025, 116, 1116 CFU/ml. It can therefore, be concluded that microbiological quality of groundwater was the worst in all the zones and was microbiologically unfit for drinking.

Table 4.14: Microbiological analysis of drinking water samples from different sources

Source	*Zone*	*Samples (No)*	*Within limit (No)*	*Exceeding limit (No)*	*Exceeding limit (%)*	*Mean CFU/ml*
Public water supply	W-I	*34*	13	21	62	9500
	W-II	*4*	3	1	25	3000
	W-III	*23*	8	15	65	504
	W-IV	*12*	9	3	25	100
	W-V	*17*	14	3	18	23
Groundwater in the city.	CG-I	*61*	9	52	85	952
	CG-II	*11*	3	8	73	1926
	CG-III	*18*	3	15	83	2025
	CG-IV	*38*	11	27	71	116
	CG-V	*33*	14	19	57	1116
Groundwater near drains.	D-I	*21*	2	19	90	44496
	D-II	*10*	8	2	20	142
	D-III	*34*	10	24	70	2948
Groundwater near canal.	CW-I	*23*	7	16	70	13483
	CW-II	*14*	4	10	71	505
	CW-III	*3*	2	1	33	560

The unfit samples were 90, 20 and 70 percent for zones D-I, D-II and D-III, respectively (for zoning see Table 3.5). The mean values were 44496, 142 and 2948 CFU/ml, respectively. It is evident from these results that groundwater pumped near Paharang drain was the worst from microbiological point of view. High fecal contamination of D-I was attributed to high recharges from Paharang drain, as it is located on a higher altitude of the hydro-geological divide. Substantial seepage also takes place from the treatment ponds leading to further groundwater contamination. The presence of coliforms at various locations of different zones has also been depicted in Figure 4.11.

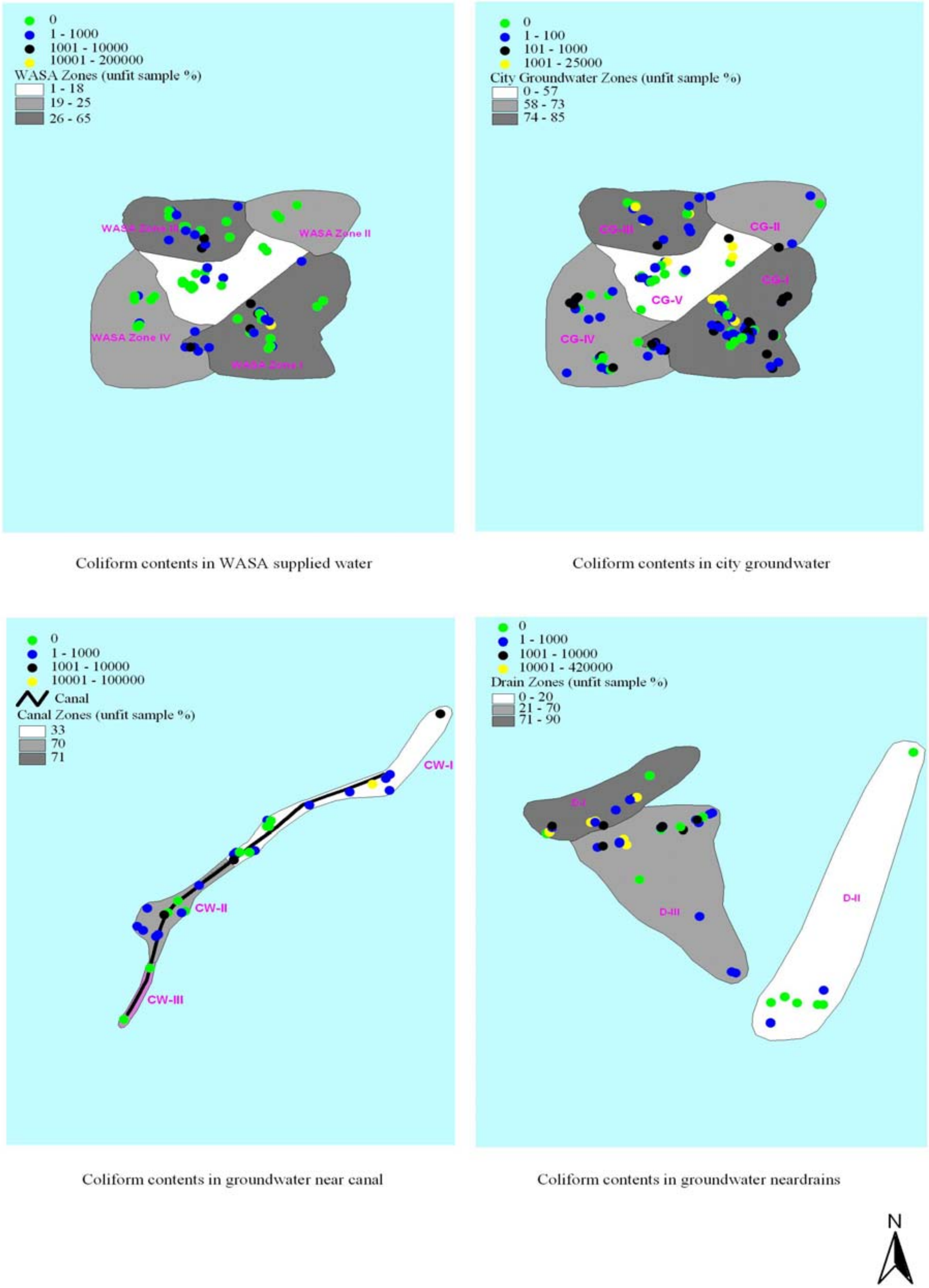


Figure 4.11: Coliforms status in drinking water of Faisalabad (CFU/ml)

Mostly shallow hand pumps were used to get groundwater in the zone D-I; therefore it was tapped from comparatively shallower depths, which was the direct recharge from the unlined drain. The unfit samples were 70, 71 and 33 percent for CW-I, CW-II and CW-III zones, respectively whereas the mean values were 13483, 505 and 560 CFU/ ml (see Table 3.6 for zoning). Most of the pumpage along Rakh Branch canal was done in the zones CW-I and CW-II. The groundwater in this zone was in a dynamic state due to more pumping and recharge from the canal. The process leads to a freshwater supply to the consumers of zones CW-I and CW-II. Since, most of the CFU could be killed at temperature of $105^{o}C$, boiling of drinking water for about ten minutes is suggested for safe drinking water.

4.3.2 Chemical Analysis

The results of the chemical analysis of the drinking water samples are given in Tables 4.15 and 4.16. As for as the water supplied by the WASA is concerned, the chemical quality of water has been found satisfactory. Except drinking water supplied by WASA, 85 percent samples in terms of Na concentration exceeded the permissible limit for groundwater in the city and groundwater close to drains. High sodium intake increased blood pressure of human body beyond desired levels that may lead to a number of cardiovascular diseases. Similarly, potassium is needed for growth of body, building muscles, transmission of nerve impulses and heart activity etc. Potassium, together with sodium (potassium inside the cell and sodium in the fluid surrounding the cell) work together for the nervous system to transmit messages, regulates the contraction of muscles and regulates the heart beating. Kidneys normally excrete excessive potassium from body through urine and perspiration. Excessive potassium may cause kidney failure in most severe conditions. Nearly 83 percent samples exceeded the permissible limit of K in groundwater close to drain and city groundwater in the city. Excessive TDS in drinking water is dangerous for health although most of these are eliminated through excretory channels. But some of these stay in the body, causing stiffness in the joints, hardening of the arteries, kidney stones, gallstones and blockages of arteries. Eighty two percent samples were found exceeding the permissible limit of TDS in groundwater in the city and close to drain. Like sodium and potassium, 71 and 76 percent samples of chloride and sulphate, respectively exceeded the permissible limit in city groundwater and groundwater close to drain, respectively.

Groundwater pumped in the city for drinking was very poor for chemical quality as almost all samples exceeded the maximum permissible limits for Na, K, TDS, Cl, and SO_4. Seepage of industrial waste may be the main reason for such high concentrations of these contaminants. Consumption of such low quality drinking water is dangerous and may cause cardiovascular diseases, blood pressure, saline imbalance of blood and malfunction of nervous system.

The quality of groundwater pumped near drains for drinking was found the worst as on average 90 percent samples were found unfit with respect to TDS, Na, K, Cl, and SO_4. However, pH and turbidity were found within permissible limits. Drinking such water increases concentration of these chemicals in the blood resulting in abnormal saline composition. This may cause high blood pressure and a number of cardiovascular problems to the consumers. The concentrations of different chemicals like TDS, K, Na, Ca, Mg, hardness, Cl, and SO_4 at various locations of different zones have been shown in Figures 4.12 to 4.19.

Table 4.15: Chemical analysis of drinking water samples exceeding the permissible limits (percent)

Zone	*Samples (No)*	*pH*	*Turbidity*	*TDS*	*K*	*Na*	*Ca*	*Mg*	*Hardness*	*Cl*	*SO_4*
W-I	*34*	0	3	23	21	26	3	6	9	21	26
W-III	*23*	0	4	17	22	17	0	0	0	13	17
CG-I	*61*	0	11	92	87	92	29	20	61	85	85
CG-II	*11*	0	0	73	91	82	18	0	45	55	64
CG-III	*18*	0	11	83	83	83	5	0	5	72	67
CG-IV	*37*	3	11	81	86	84	38	16	51	81	81
CG-V	*33*	0	3	70	88	73	27	3	12	58	61
D-I	*21*	0	0	95	57	95	38	0	14	86	95
D-II	*10*	0	30	90	100	90	60	0	20	70	90
D-III	*34*	0	12	79	74	79	26	0	26	59	68
CW-I	*23*	0	0	30	22	35	13	0	0	9	26
CW-II	*14*	0	0	43	43	43	21	0	28	36	43
CW-III	*3*	0	0	0	0	0	33	0	0	0	0

Table 4.16: Mean values of chemical parameters of drinking water samples exceeding the permissible limit (mg/l)

Zone	*pH*	*Turbidity (NTU)*	*TDS*	*HCO_3*	*Alkalinity*	*K*	*Na*	*Ca*	*Mg*	*Hardness*	*Cl*	*SO_4*
Permissible Limits	*(6.5-8.5)*	*5*	*1000*	*NGVS***	*NGVS*	*12*	*200*	*75*	*150*	*500*	*250*	*250*
W-I	*	48	2867	256	5.11	24	828	80	161	720	821	871
W-III	*	6.7	2638	285	5.69	20	830	*	*	*	1031	540
CG-I	*	55	3288	480	9.61	37	974	108	167	730	816	1135
CG-II	*	*	3016	429	8.57	25	731	82	*	662	821	1088
CG-III	*	7.9	2724	466	9.32	21	771	84	*	700	933	555
CG-IV	6.4	19	3106	382	7.64	31	806	116	198	786	854	736
CG-V	*	12	2739	520	10.39	26	789	91	184	730	821	692
D-I	*	*	2414	600	12	25	717	120	*	623	543	590
D-II	*	34	2665	675	13.48	28	710	107	*	620	536	699
D-III	*	19	2685	505	10.11	25	784	110	*	921	867	648
CW-I	*	*	1406	316	6.37	18	374	83	*	*	383	447
CW-II	*	*	2960	410	8.19	27	877	152	*	707	738	952
CW-III	*	*	*	228	4.57	*	*	80	*	*	*	*

* Samples found within permissible limit

**No Guideline Value Set

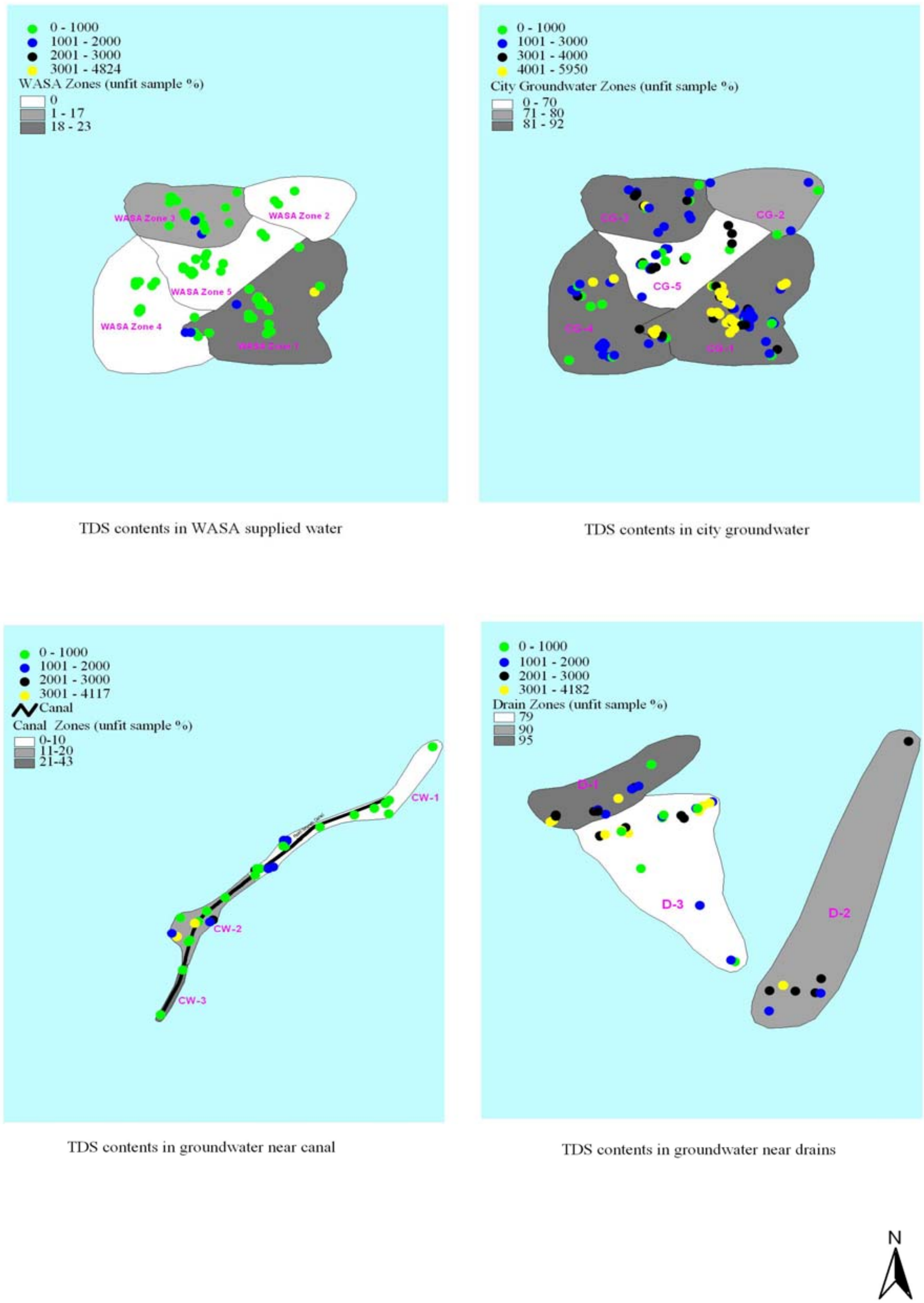
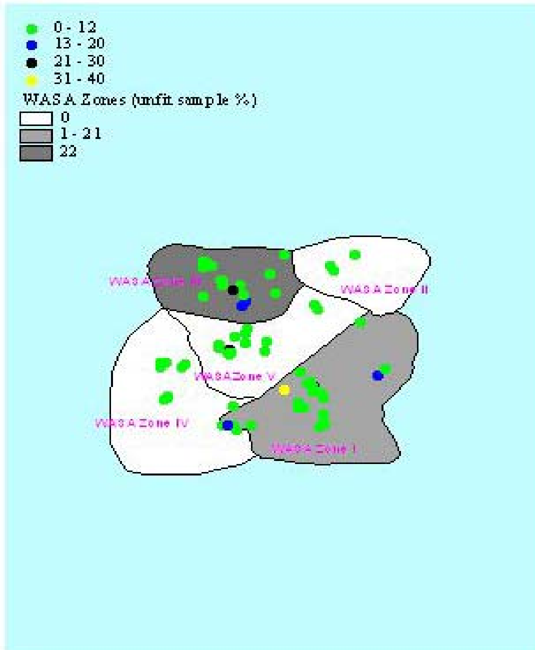
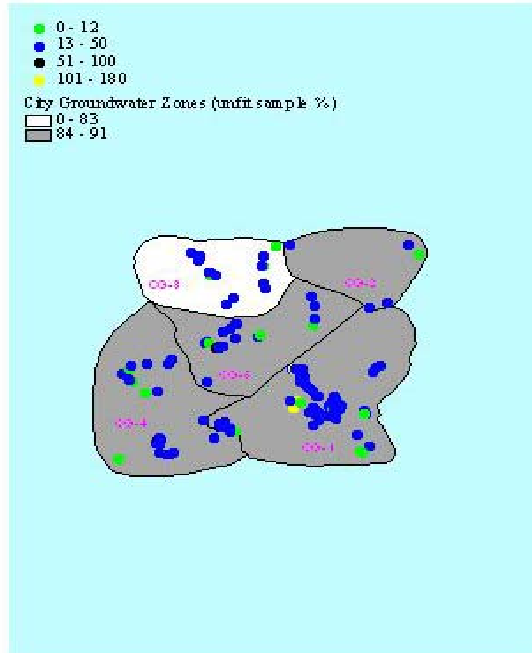


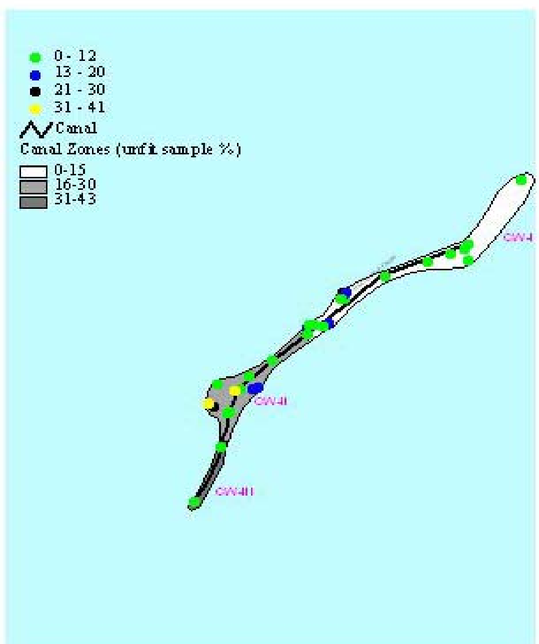
Figure 4.12: TDS contents in drinking water of Faisalabad (mg/l)



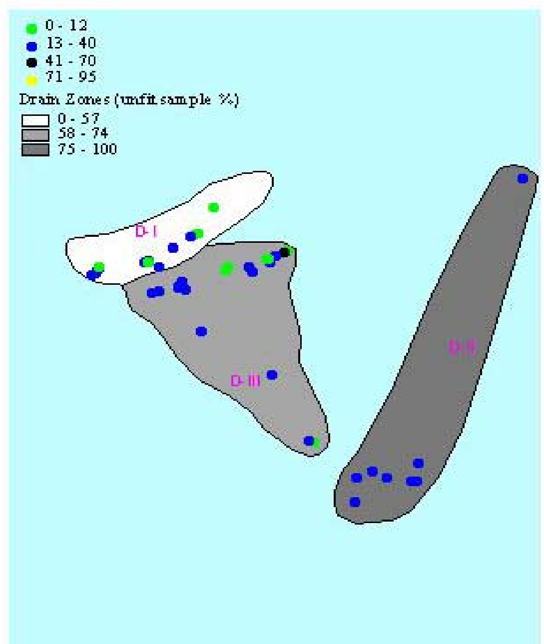
Potassium contents in WASA supplied water



Potasium contents in city groundwater



Potasium contents in groundwater near canal



Potasium contents in groundwater near drains

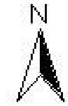


Figure 4.13: Potassium contents in drinking water of Faisalabad (mg/l)

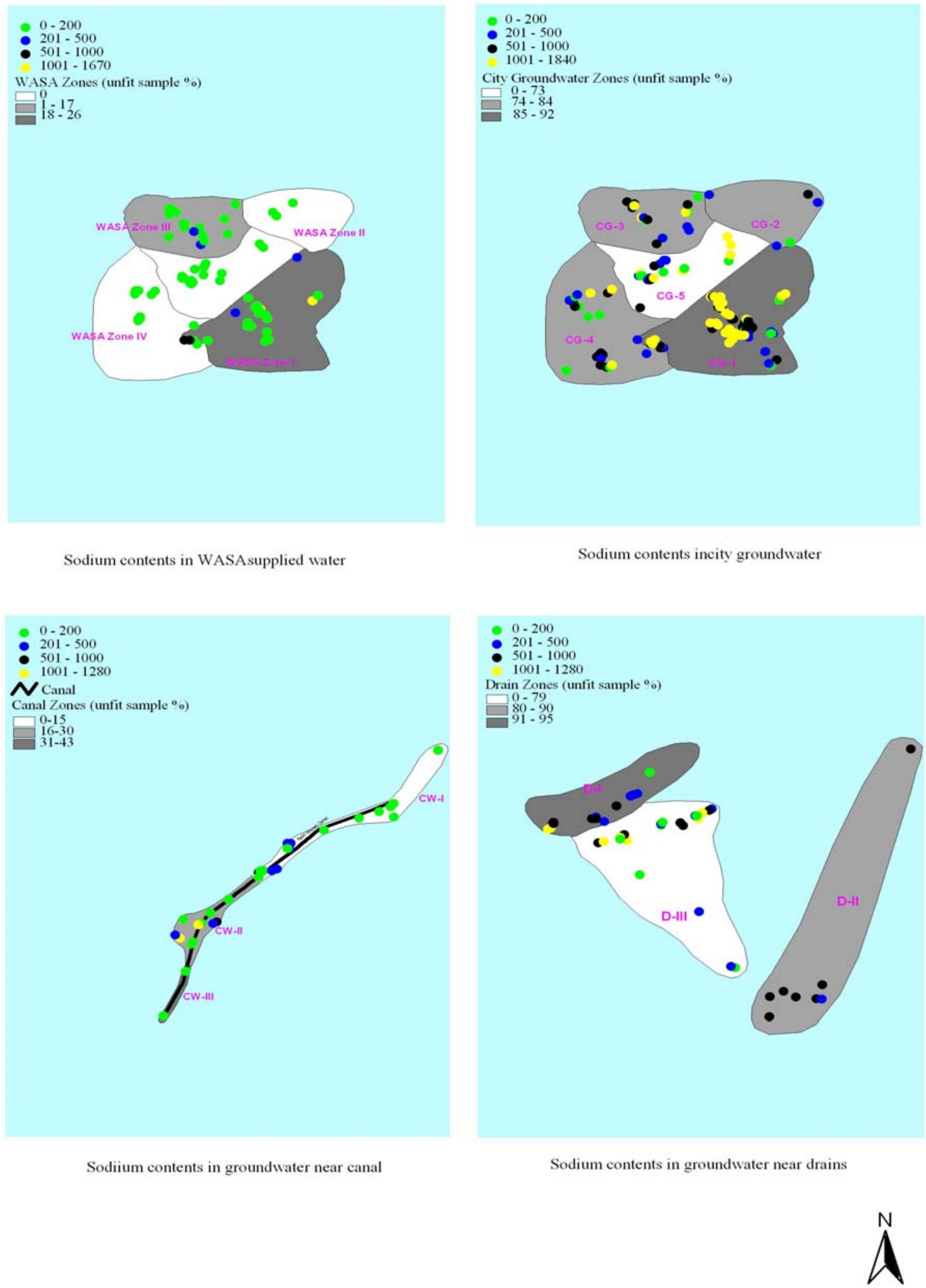
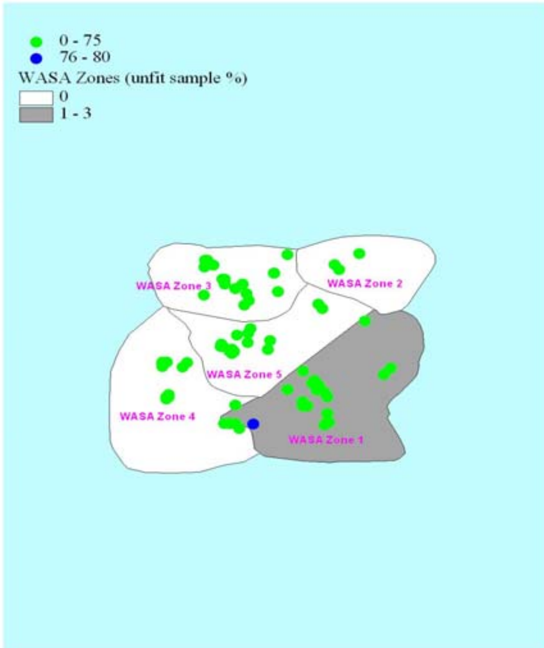
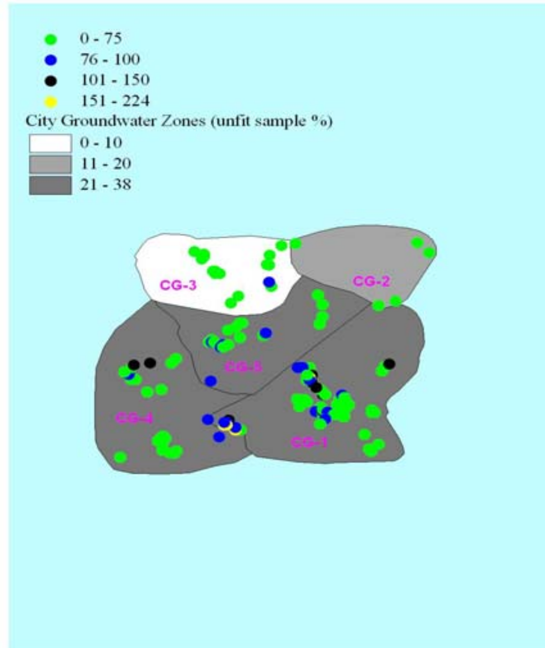


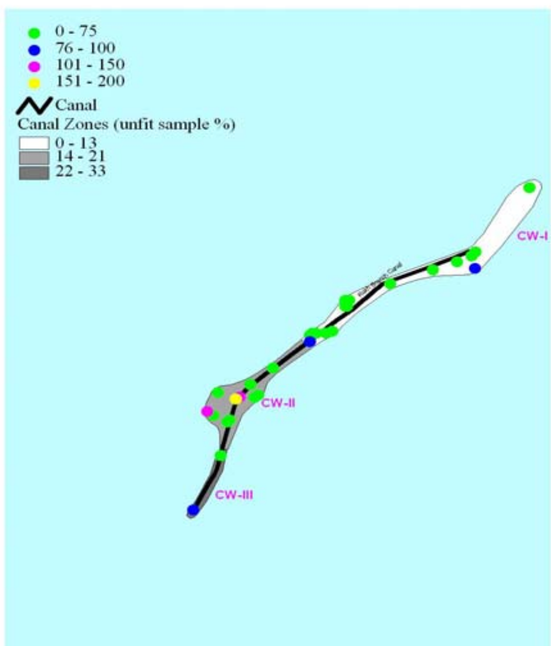
Figure 4.14: Sodium contents in drinking water of Faisalabad (mg/l)



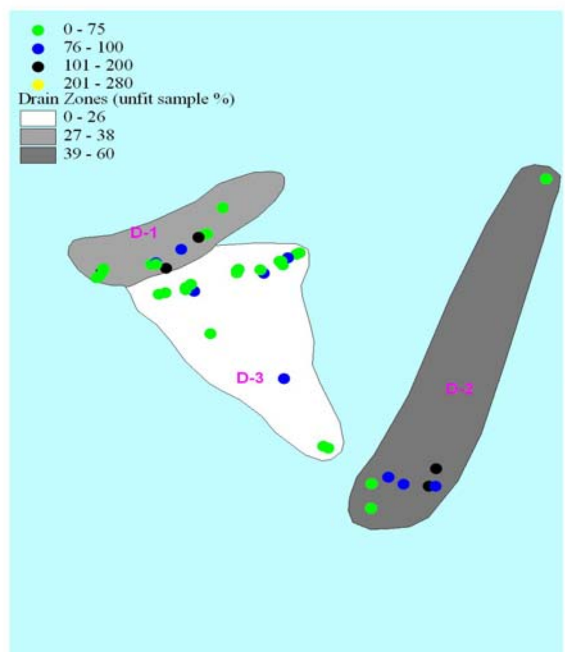
Calcium contents in WASA supplied water



Calcium contents in city groundwater



Calcium contents in groundwater near canal



Calcium contents in groundwater near drains

N

Figure 4.15: Calcium contents in drinking water of Faisalabad (mg/l)

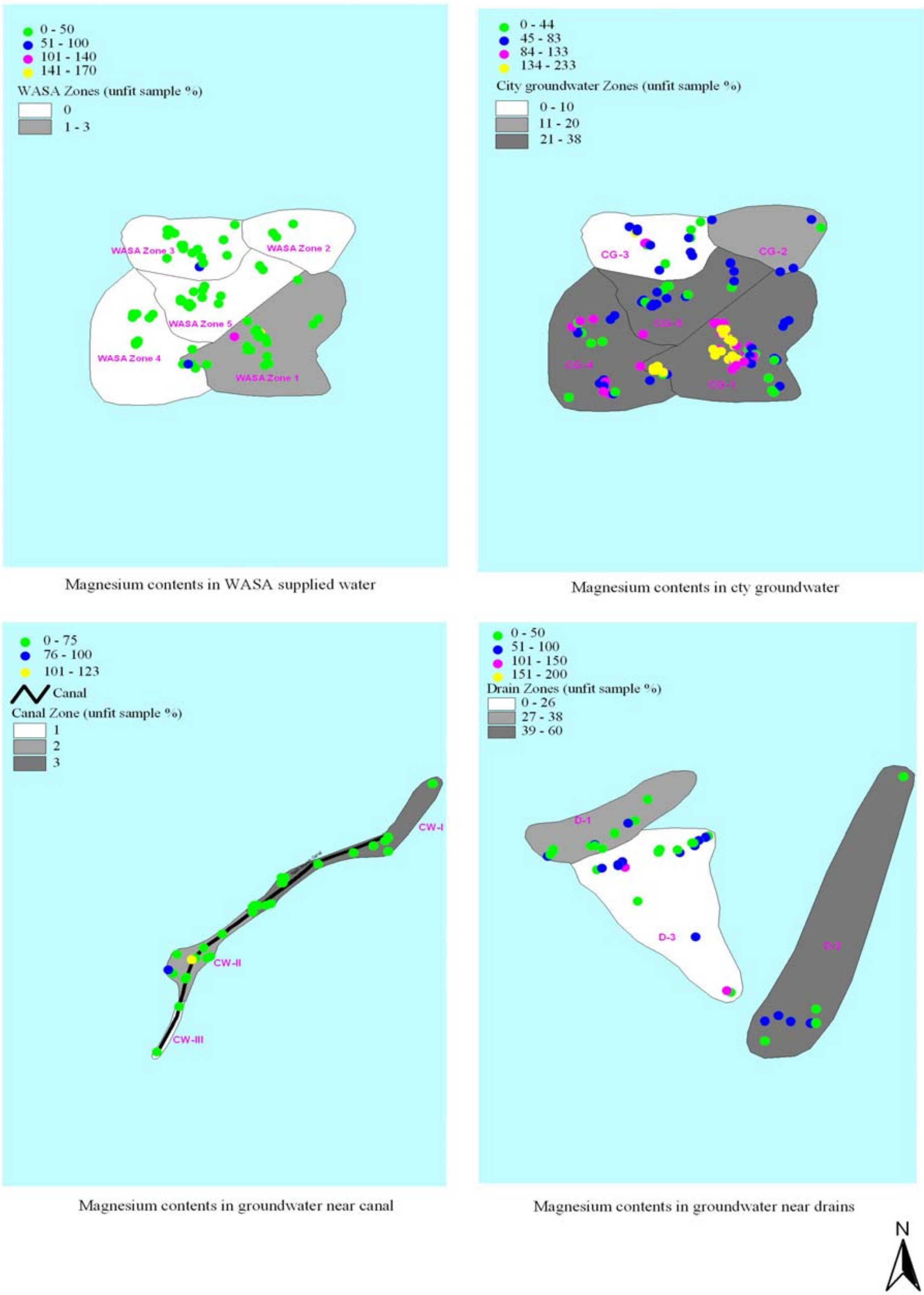
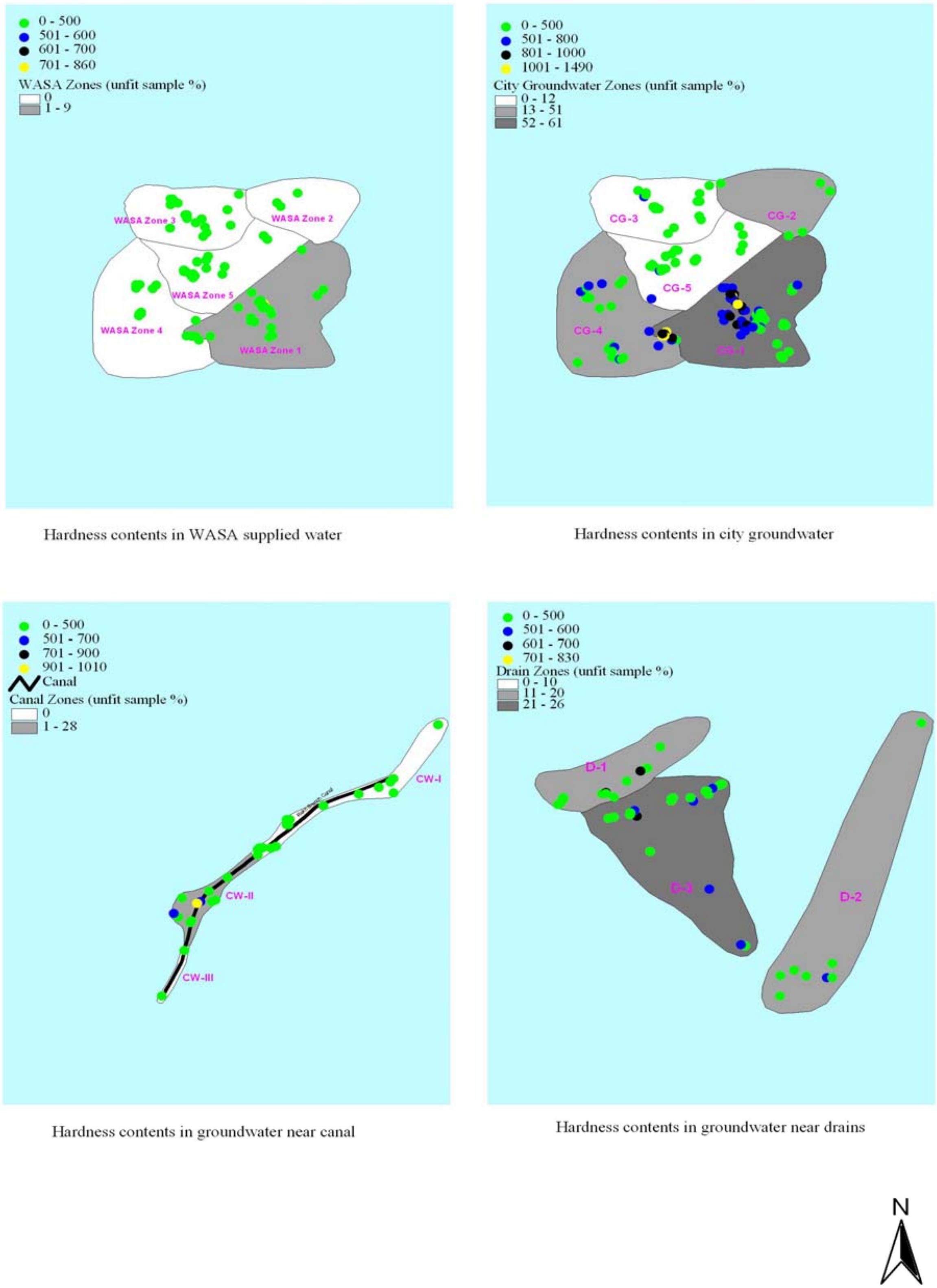


Figure 4.16: Magnesium contents in drinking water of Faisalabad (mg/l)



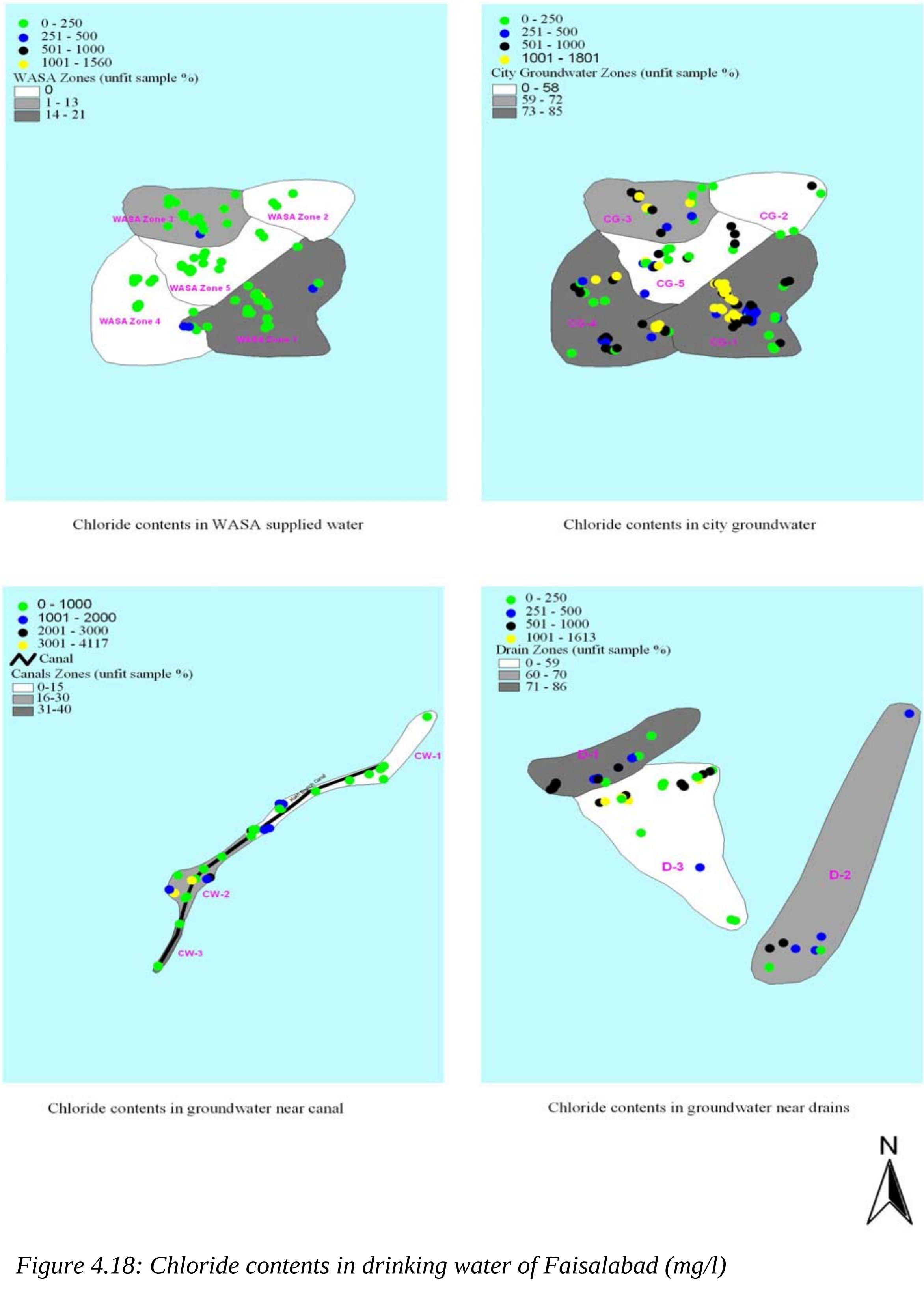
Hardness contents in WASA supplied water

Hardness contents in city groundwater

Hardness contents in groundwater near canal

Hardness contents in groundwater near drains

Figure 4.17: Hardness in drinking water of Faisalabad (mg/l)



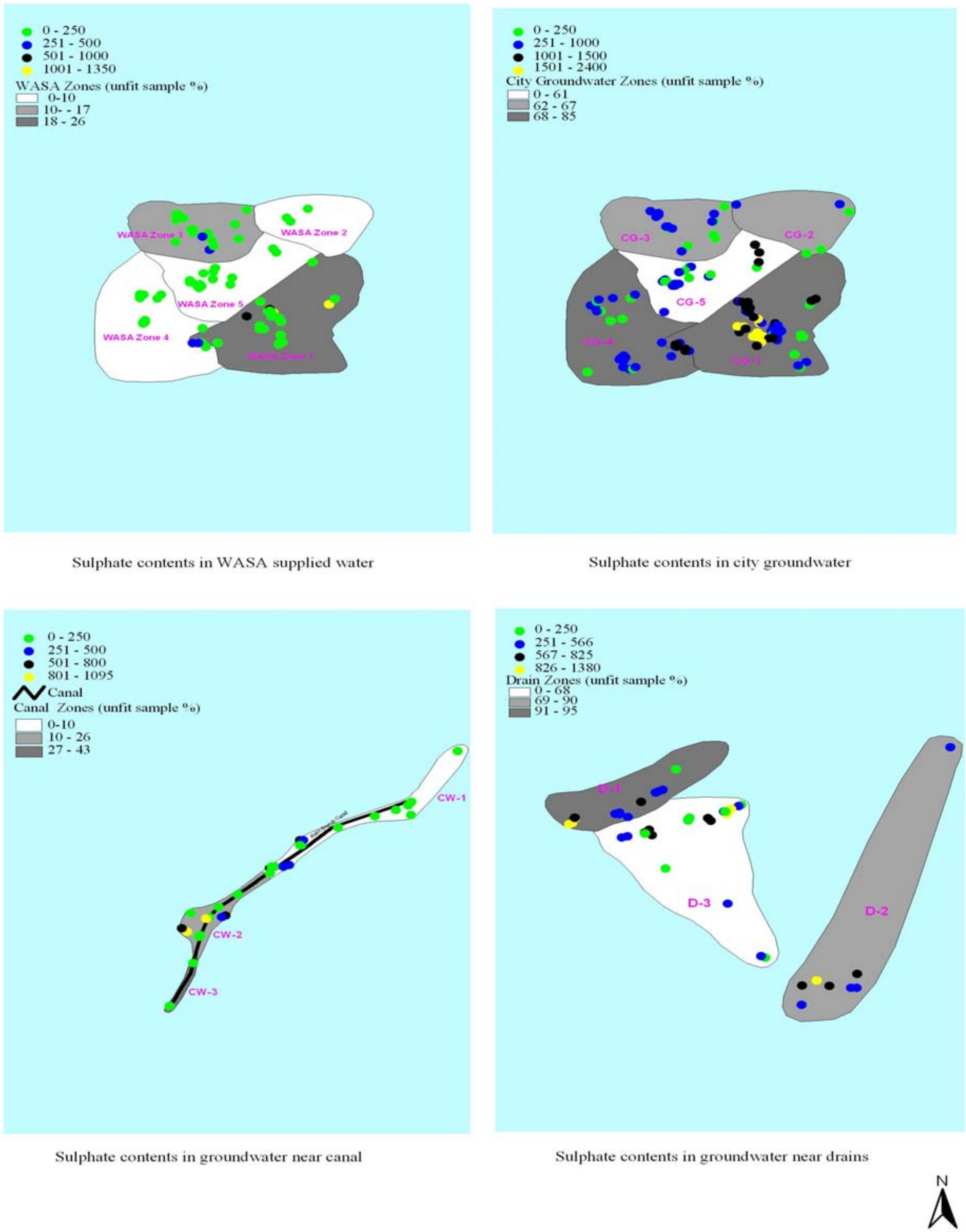
Chloride contents in WASA supplied water

Chloride contents in city groundwater

Chloride contents in groundwater near canal

Chloride contents in groundwater near drains

Figure 4.18: Chloride contents in drinking water of Faisalabad (mg/l)



Sulphate contents in WASA supplied water

Sulphate contents in city groundwater

Sulphate contents in groundwater near canal

Sulphate contents in groundwater near drains

Figure 4.19: Sulphate contents in drinking water of Faisalabad

The chemical quality of groundwater pumped near canals (can water) was found better, although 30-40 percent of these samples were also found unfit for drinking. The sodium and potassium concentrations were not very high in can water. The chemical quality of can water improves along the flow of canal due to increased pumpage and recharge.

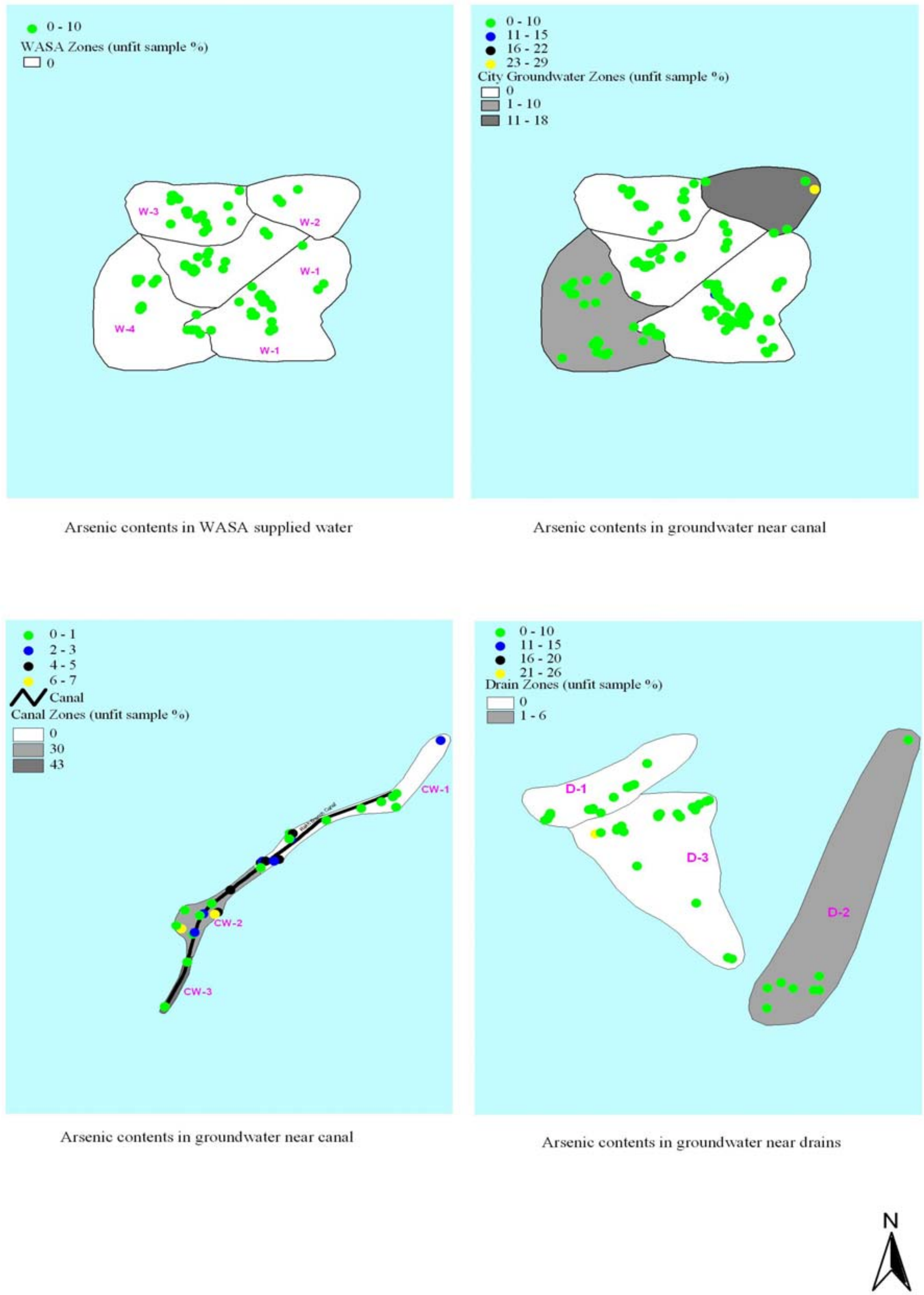
However, it was noted that the can water was being transported in blue cans. These blue cans are actually used for the transportation of chemicals to industries. These chemicals may contaminate the drinking water quality of can water. Similarly, blue cans are not transparent and any contaminant inside is not visible. It is suggested to use transparent cans so that safe drinking water quality could be maintained.

4.3.3 Heavy Metal Analysis

The results of drinking water samples analyzed for heavy metals are given in Tables 4.17 and 4.18. The concentrations of heavy metals except arsenic, mercury and manganese were found within permissible limits for all types of drinking water samples. Mercury concentrations exceeded the permissible limit in 9, 9, 5, 6 and 13 percent of the samples of zones W-I, W-III, CG-IV, CG-III and CG-I, respectively. Mercury is one of the most toxic elements of nature therefore; consumption of such water is extremely hazardous for human health. Excessive mercury intake would lead to mental impairment, retarded mental growth and blindness (Alloway, 1990). Similarly, excessive concentrations of As were also found in 18, 3 and 6 percent of the samples of the zones CG-II, CG-IV and D-III, respectively. Drinking arsenic contaminated water would lead to violent stomach pains, vomiting and delirium. Problems like skin cancer, keratoses of feet and kidney failure may result from drinking such water. Usually, if continued it results in death (Wikipedia, 2006). The zone D-III has shown excessive Mn content in only 3 percent of its samples. Manganese toxicity causes lack of facial expression, shaky movements, weakness and tiredness etc (Monheit, 2006). The occurrence of different heavy metals like As, Hg and Mn at various locations of different zones are given in Figures 4.20, 4.21 and 4.22, respectively.

Table 4.17: Heavy metal analysis of drinking water samples exceeding the permissible limit for different zones (percent)

Zone	*Samples (No)*	*As*	*Hg*	*Mn*
W-I	*34*	0	9	0
W-III	*23*	0	9	0
CG-I	*61*	0	5	0
CG-II	*11*	18	0	0
CG-III	*18*	0	6	0
CG-IV	*38*	3	13	0
D-III	*34*	6	0	3



Arsenic contents in WASA supplied water

Arsenic contents in groundwater near canal

Arsenic contents in groundwater near canal

Arsenic contents in groundwater near drains

Figure 4.20: Arsenic contents in drinking water of Faisalabad (µg/l)

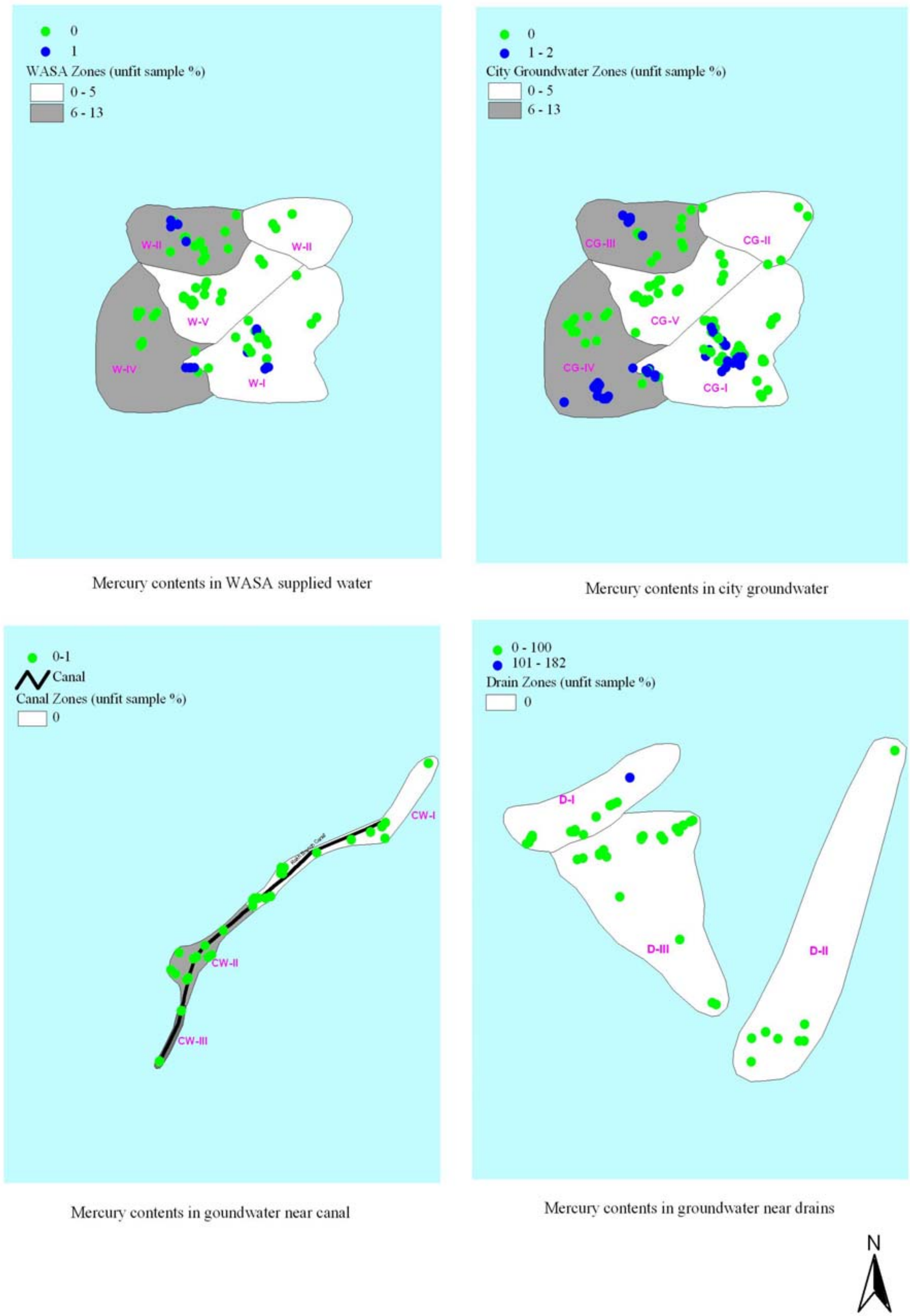


Figure 4.21: Mercury contents in drinking water of Faisalabad (µg/l)

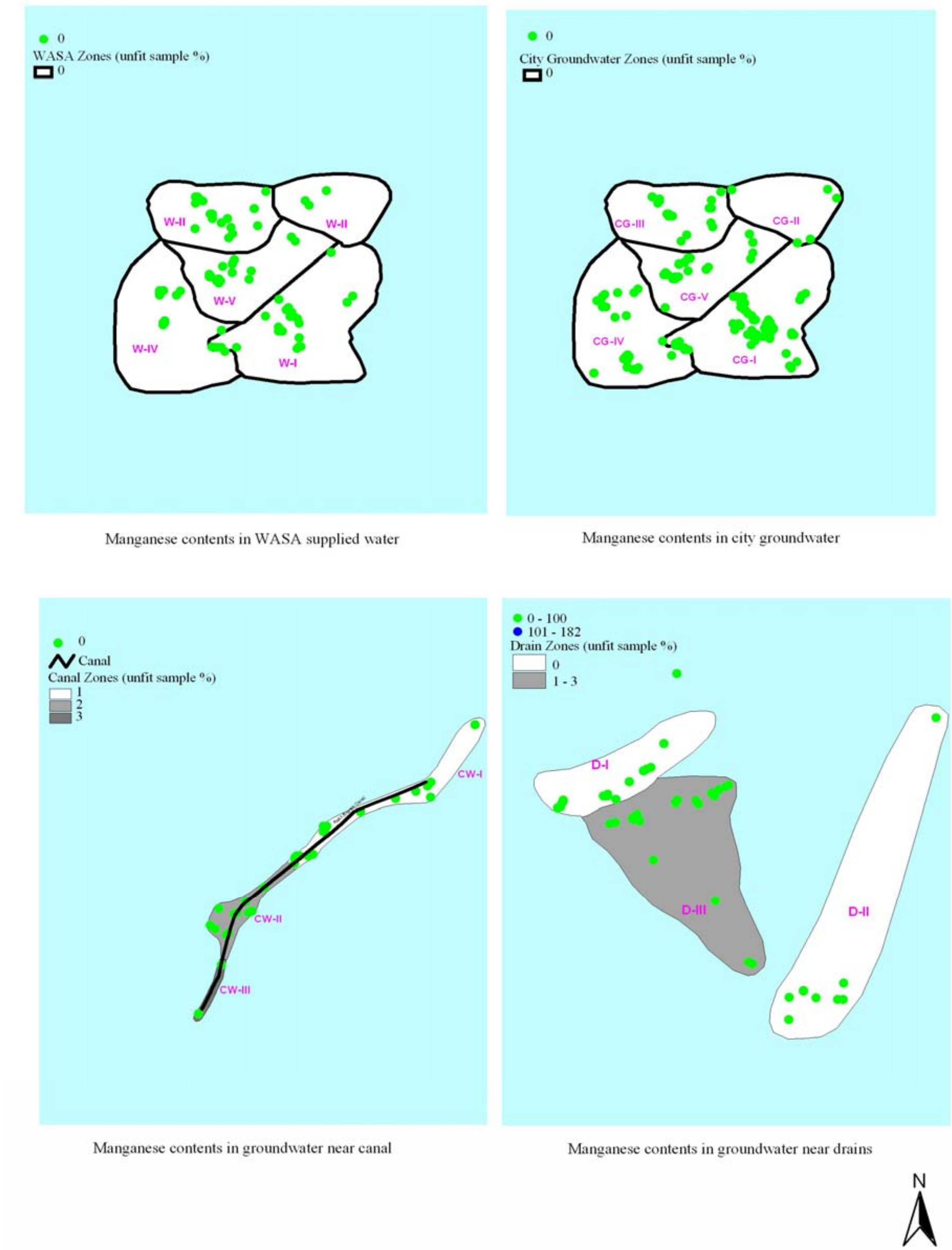


Figure 4.22: Manganese contents in drinking water of Faisalabad (μg/l)

Table 4.18: Mean concentrations of heavy metals of drinking water samples exceeding the permissible limit for various zones (μg/l)

Zone	*As*	*Hg*	*Mn*
	10	*1*	*100*
	*	1.29	
W-III	*	1.3	*
CG-I	*	1.47	*
CG-II	20.86		*
CG-III	*	1.2	*
CG-IV	11.86	1.22	*
D-III	19	*	143

*Samples found within permissible limit

The sources of Hg for drinking water may be coal-fired brick kilns. Coal is naturally contaminated with mercury. Its burning releases a lot of Hg into the atmosphere. Incineration of automobile scrap (light switches) is another source of mercury. The source of arsenic in drinking water may be due to the use of arsenic based chemicals in the area. High concentration of Mn found in some samples of groundwater pumped near city drains might be from industrial disposal. It can be concluded that most of heavy metals in the drinking water samples were within permissible limits except a few samples of Hg, As and Mn. Therefore, the threat of heavy metal contamination was not severe, as these were not being used extensively in industries situated in Faisalabad.

4.4 IRRIGATION WATER QUALITY

The wastewater samples used for irrigation (Figure 4.23) were analyzed for chemical and heavy metal concentrations. The results of chemical and heavy metal analysis are discussed below:

4.4.1 Chemical Analysis

Tables 4.19 to 4.22 present percentages of samples exceeding the permissible limit and mean values of chemical parameters, respectively for different wastewater irrigation sources and types.

Figure 4.23: Wastewater pumped for irrigation

Table 4.19: Chemical analysis of irrigation samples exceeding permissible limit for different wastewater sources (percent)

Source	*TDS*	*HCO_3*	*Na*	*Mg*	*Cl*	*SO_4*
Paharang drain	80	100	100	0	80	0
Madhuana drain	100	100	100	0	50	50
Municipal drains	89	67	100	17	94	39

Table 4.20: Chemical analysis of irrigation samples exceeding permissible limit for different wastewater types (percent)

Effluent Type	*TDS*	*HCO_3*	*Na*	*Mg*	*Cl*	*SO_4*
Industrial	100	0	100	100	100	100
Sewerage	100	89	100	0	100	22
Mixed	80	73	100	13	80	33

Table 4.21: Mean values of chemical parameters of irrigation samples exceeding the permissible limit for different wastewater sources (mg/l)

Parameters	*Permissible Limits*	*Paharang drain*	*Madhuana drain*	*Municipal drains*
TDS	*1500*	1921	3481	3105
HCO_3	*400*	784	1100	1111
Na	*230*	396	1060	816
Mg	*100*	*	*	117
Cl	*400*	466	1243	919
SO_4	*500*	*	1121	766
SAR	*6-9*	9	30	20

* Samples found within permissible limit

Table 4.22: Mean values of chemical parameters of irrigation samples exceeding the permissible limit for different wastewater types (mg/l)

Parameters	*Permissible Limits*	*Industrial*	*Sewerage*	*Mixed*
TDS	*1500*	4020	2812	2918
HCO_3	*400*	784	1056	1000
Na	*230*	530	824	723
Mg	*100*	123	*	113
Cl	*400*	1060	792	879
SO_4	*500*	820	742	836
SAR	*6-9*	22	7	6.5

*Samples found within permissible limit

The chemical quality of irrigation water in respect of TDS, Na, HCO_3, Cl and SO_4 was found unfit as per international irrigation water quality standards. Exceeding concentrations of TDS were found in all wastewater sources and types. The wastewater of industrial origin especially of Madhuana drain was found with high TDS. Irrigation water having high TDS leads to accumulation of salts in the soils and makes those less productive subsequently reduces the crop yields. Excessive sodium reacts with carbonate and bicarbonate farming Na_2CO_3 or $NaHCO_3$. Both are insoluble and accumulate in the pores of the soil thus reducing the permeability of soil. Bicarbonate was the highest (1111 mg/l) in the Municipal drain. In all the drains and wastewater types, its concentration exceeded the permissible limits. Excessive Na contents were found in all sources and types of wastewater, whereas no sample exceeded permissible limit for Ca. Similarly, Mg was found within permissible limit in most of the samples except a few belonging to industrial drain. Calcium and Mg, if present in large quantities, counter the effects of the sodium and help maintain good soil properties. High concentrations of Na and low Ca & Mg contents results in very high SAR values for irrigation water. Continuous use of water having a high SAR leads to a breakdown in the physical structure of the soil. Na is adsorbed and becomes attached to soil particles. The soil then becomes hard and compact when dry and increasingly impervious to water penetration. Fine-textured soils, especially those high in clay, are mostly affected by this action.

The effluent of Paharang drain possesses less quantity of Cl as compared to other two irrigation water sources. Irrigation with high Cl water leads to reduction in the crops yields. The SO_4 contents exceeded the permissible limits in Madhuana and Municipal drains. High concentration of TDS (4020 mg/l) was observed in industrial effluents as compared to sewerage (2812 mg/l) and mixed effluents (2918 mg/l). All types were found to have excessive TDS more than the permissible value of 1500 mg/l. HCO_3 exceeded the permissible limit in sewerage effluents (1056 mg/l) and mixed effluents (1000 mg/l). The HCO_3 ion in soil solution harms the mineral nutrition of the plant through its effect on the uptake and metabolism of nutrients. Na concentration was more in sewerage water (824 mg/l), mixed effluents (723 mg/l) and industrial type of effluents (530 mg/l) against the permissible limits of 230 mg/l. Magnesium was slightly high in industrial type of effluents. Cl was more in industrial type of effluents (1060 mg/l) as compared with sewrage (792 mg/l) and mixed type of effluents (879 mg/l) against permissible limits of 400 mg/l. SO_4 (820 mg/l) and SAR (22 mg/l) exceeded the permissible limits in industrial type of effluents. SO_4 salts affect sensitive crops by limiting the uptake of Ca and increasing the absorption of Na and K, resulting in a disturbance in the cationic balance within the plant. Wastewater irrigation of vegetables containing higher amount of Na and Cl may also have a negative effect on the human health.

4.4.2 Heavy Metal Analysis

The irrigation water samples have been analyzed for heavy metals. The mean concentrations of heavy metals in all wastewater samples irrespective of its source and type were within the permissible levels. However, its use for longer period of time might be injurious to soil and crop health.

4.5 WASTEWATER IRRIGATED SOILS

Eighty-nine agricultural soil samples irrigated with wastewater were collected in order to determine the effect of wastewater irrigation on their fertility and productivity (Figure 4.24). Each sample was a homogeneous mixture of samples collected from five different locations of the field, four from each corners and one from the centre of the field. The soil samples were collected up to 45 cm depths at 15 cm interval. These soil samples were analyzed for chemical and heavy metals.

Figure 4.24: Diversion of wastewater from an effluent channel to agricultural fields

4.5.1 Chemical Analysis

Mean values of chemical parameters of soil samples not falling within the permissible limit for different irrigation sources, types and horizons of soils are shown in Tables 4.23 to 4.25.

Table 4.23: Mean values of chemical parameters of soil samples not falling within the permissible limit for different wastewater irrigation sources

Parameters	*Permissible Limits*	*Paharang drain*	*Madhuana drain*	*Municipal drains*
pH	*4-8.5*	*	*	8.6
OM (% w/w)	*>0.86*	0.11	0.19	0.27
EC (µs/cm)	*4000*	8140	8070	5220
P (mg/kg)	*>7*	5	*	5
K (mg/kg)	*>80*	42	78	17

* Samples found within permissible limit

Table 4.24: Mean values of chemical parameters of soil not falling within the permissible limit for different wastewater irrigation types

Parameters	*Permissible Limits*	*Industrial*	*Sewerage*	*Mixed*
pH	*4-8.5*	8.61	8.6	*
OM (% w/w)	*>0.86*	0.23	0.30	0.21
EC (µs/cm)	*4000*	*	5220	8117
P (mg/kg)	*>7*	*	*	5
K (mg/kg)	*>80*	16	62	25

* Samples found within permissible limit

Table 4.25: Mean values of chemical parameters of samples not falling within the permissible limit for different soil depths

Parameters	*Permissible Limits*	*0-15 cm*	*15-30 cm*	*30-45 cm*
pH	*4-8.5*	8.61	8.6	8.6
OM (% w/w)	*>0.86*	0.31	0.21	0.18
EC (µs/cm)	*4000*	8070	6530	6830
P (mg/kg)	*>7*	4	6	5
K (mg/kg)	*>80*	20	21	30

The pH exceeded the permissible limit in soils irrigated with municipal drains and it also exceeded in all soil horizons irrigated with industrial and sewerage types effluents. Normally farmers believe that wastewater is rich in nutrients. However, the organic matter content has been found deficient in all soil samples irrespective of its source and type of irrigation and most of the values were much below the minimum desired level. The deficiency of organic matter contents increased with depth. This is due to lack of organic matter and chemical fertilizer applied to the soils. The soils irrigated with the wastewater of Paharang and

Municipal drains were found to be deficient in P content. Potassium was also deficient in all soil samples irrespective of sources/types indicating that wastewater was deficient in macronutrients.

4.5.2 Heavy Metal Analysis

Samples exceeding the permissible limit have been shown in Tables 4.26 to 4.28 whereas mean values of heavy metals of soil samples exceeding the permissible limit for different irrigation sources, types and depths are given in Tables 4.29 to 4.31.

Table 4.26: Heavy metal analysis of soil samples exceeding the permissible limit for different wastewater sources (percent)

Parameters	*Paharang drain*	*Madhuana drain*	*Municipal drains*
Cd	20	0	62
Ni	87	100	49
Zn	20	28	3

Table 4.27: Heavy metal analysis of soil samples exceeding the permissible limit for different wastewater types (percent)

Parameters	*Industrial*	*Sewerage*	*Mixed*
Cd	67	57	46
Ni	100	53	60
Zn	0	0	12

Table 4.28: Heavy metal analysis of soil samples exceeding the permissible limit for different depths (percent)

Parameters	*0-15 cm*	*15-30 cm*	*30-45 cm*
Cd	56	45	50
Ni	60	58	61
Zn	10	6	7

Table 4.29: Mean values of heavy metals of soil samples exceeding the permissible limit irrigated with different wastewater sources (mg/kg)

Parameters	*Permissible Limits*	*Paharang drain*	*Madhuana drain*	*Municipal drains*
Cd	*1*	4.53	*	3.95
Ni	*20*	59.15	41.93	76.24
Zn	*250*	331.33	653.25	662.25

* Samples found within permissible limit

Table 4.30: Mean values of heavy metals of soil samples exceeding the permissible limit irrigated with different wastewater types (mg/kg)

Parameters	*Permissible Limits*	*Industrial*	*Sewerage*	*Mixed*
Cd	*1*	1.58	4.69	3.74
Ni	*20*	76	56	71.63
Zn	*250*	*	*	517.86

* Samples found within permissible limit

Table 4.31: Mean values of heavy metals of samples exceeding the permissible limit for different soil depths (mg/kg)

Parameters	*Permissible Limits*	*0-15 cm*	*15-30 cm*	*30-45 cm*
Cd	*1*	4.42	3.14	4.30
Ni	*20*	78.60	49.67	74.69
Zn	*250*	666.80	471.50	3.41

The concentrations of heavy metals were found within permissible limits for all types of soils except Cd, Ni and Zn. Cadmium was found in all soil samples irrigated with different wastewater types and in different soil horizon. The sources of Cd were dyes used in the dying units operating within municipal area. An excessive Ni was also found in all soil samples irrigated with different wastewater sources, types and in all the soil layers. These high nickel contents of soils may be attributed to the diesel engine exhausts; ghee and soap industries. OEHHA (1998) reported that diesel exhaust and many individual substances contained in it (including arsenic, benzene, formaldehyde and nickel) have the potential to contribute to transformations in cells that can lead to cancer. Nickle is also used as catalyst in the hydrogenation process of oil to ghee. The presence of excessive Zn concentrations was found in the top horizon of the soil indicating its low leaching ability. The reason might be its use in many light and household industries as raw material like electroplating and cell manufacturing etc. Though heavy metals were within permissible limit in all wastewater-irrigated sources however, continuous use of wastewater may cause an increase in heavy metal in the soil particularly at shallow depths.

4.6 VEGETABLES/CROPS GROWN WITH WASTEWATER

4.6.1 Chemical Analysis

Mean values of macronutrients in vegetables grown with different wastewater sources and are given in Tables 4.32 and 4.33.

Table 4.32: Mean values of macronutrients in vegetables grown with different wastewater sources (g/kg)

Parameter	*Optimum Range*	*Paharang drain*	*Madhuana drain*	*Municipal drains*
N	*10-50*	15.00	19.86	8.92
P	*10-40*	4.67	1.28	1.45
K	*10-40*	4.34	5.82	4.50

Table 4.33: Mean values of macronutrients in vegetables grown with different wastewater types (g/kg)

Parameter	*Optimum Range*	*Industrial*	*Sewerage*	*Mixed*
N	*10-50*	11.60	9.75	12.55
P	*10-40*	0.98	2.11	2.38
K	*10-40*	2.65	4.64	4.61

It is evident from these tables that vegetables grown from wastewater were deficient in essential macronutrients irrespective of the source of irrigation and type of wastewater. Lack of natural and chemical manuring may be one of the reasons for such low contents of N, P and K. In few cases, nitrogen was found in permissible limits in industrial water of Paharang and Madhuana drains. Farmers believe that wastewater is rich in nutrients and they avoid to use NPK for growing crops and vegetables. But it is found that wastewaters do not contain appreciable quantities of these elements. As a result, soils and vegetables grown with wastewater remained deficient in macronutrients. Therefore, green manuring and use of natural and chemical fertilizers is necessary to grow vegetables and crops with wastewater.

Table 4.34 gives mean values of macronutrients for different crops and vegetables. The result shows that almost all crops do not having sufficient contents of these elements.

Table 4.34: Mean values of macronutrients for different crops/vegetables (g/kg)

Crops/ Vegetable	*N (g/kg)*	*P (g/kg)*	*K (g/kg)*
Optimum Range	*10-50*	*10-40*	*10-40*
Wheat	16.2	2.6	5.5
Radish	9.1	2.4	3.8
Cauliflower	13.9	3.4	4.1
Sugarcane	4.6	0.5	5.4
Turnip	14.6	4.2	3.3
Mustard	7.7	1.8	4.6
Carrot	9.2	0.9	4.2
Tomato	21.7	2.1	4.9
Brinjal	25.7	2.4	4.4
Berseem	15.9	4.0	2.4
Maize	6.2	1.9	5.4
Chili	8.5	2.0	4.8
Sorghum	11.7	2.4	2.8
Sugar beat	2.4	0.1	6.2
Garlic	3.3	0.1	6.3
Potato	4.3	0.7	5.2
Spinach	11.4	2.1	4.1
Lettuce	1.7	0.2	4.6
Mint	5.9	3.3	5.4
Barely	0.9	0.3	4.4
Bitter Gourd	8.7	4.0	5.0
Beans	3.4	0.9	5.7

4.6.2 Heavy Metal Analysis

The vegetables and crops were also analyzed for heavy metals. The samples exceeding the permissible limit for heavy metals are shown in Tables 4.35 and 4.36 whereas mean values of heavy metals in crops and vegetables grown with different irrigation sources and types are given in Tables 4.37 and 4.38.

Table 4.35: Samples exceeding permissible limit for heavy metals in crops and vegetable grown with different wastewater sources (percent)

Parameter	*Paharang drain*	*Madhuana drain*	*Municipal drains*
Cd	100	100	91
Cu	0	0	3
Cr	100	100	91
Fe	61	100	61
Ni	46	0	48
Pb	100	100	100
Zn	23	0	6

Table 4.36: Samples exceeding permissible limit for heavy metals in crops and vegetable grown with different wastewater types (percent)

Parameter	*Industrial*	*Sewerage*	*Mixed*
Cd	100	89	97
Cu	0	0	3
Cr	100	89	97
Fe	100	67	62
Ni	100	44	41
Pb	100	100	100
Zn	0	0	15

Table 4.37: Mean values of heavy metals in crops and vegetable grown with different wastewater sources exceeding the permissible limit (mg/kg)

Parameter	*Permissible Limits*	*Paharang drain*	*Madhuana drain*	*Municipal drains*
Cd	*0.2*	13	5	9
Cu	*73.3*	*	*	130
Cr	*2.3*	35	20	30
Fe	*425.5*	1664	2449	187
Ni	*67.9*	146	*	153
Pb	*0.3*	136	34	148
Zn	*99.4*	206	*	147

* Samples found within permissible limit

Table 4.38: Mean values of heavy metals in crops and vegetable grown with different wastewater types exceeding the permissible limit (mg/kg)

Parameter	*Permissible Limits*	*Industrial*	*Sewerage*	*Mixed*
Cd	*0.20*	2	8	11
Cu	*73.30*	*	*	131
Cr	*2.30*	61	29	31
Fe	*425.50*	7374	1812	1700
Ni	*67.90*	79	156	153
Pb	*0.30*	185	218	84
Zn	*99.40*	*	*	182

* Samples found within permissible limit

The vegetables were found highly contaminated with Cd, Cr, Fe and Pb irrespective of its source and types. The irrigation water and rainfall carry these contaminants to soils and are readily taken up by the plants. Vegetables irrigated with wastewater of industrial origin showed evidence of higher concentrations of these elements. Similarly, Ni concentration was found more in vegetables irrigated with effluents of Paharang and Municipal drains as compared to Madhuana drain. Mean values of heavy metals of samples exceeding the permissible limit for different crops and vegetables are given in Table 4.39.

Table 4.39: Mean values of heavy metals for different crops/vegetables exceeding the permissible limit (mg/kg)

Crops/ vegetables	*Cd*	*Cr*	*Fe*	*Pb*	*NI*	*ZN*
Permissible Limit	*0.2*	*2.3*	*425.5*	*0.3*	*67.9*	*99.4*
Wheat	10.3	35.3	2812	96	139	108
Radish	9.7	21.9	*	105	119	144
Cauliflower	13.6	38.3	1461	133	115	*
Sugarcane	3.6	16.0	*	20.5	*	*
Turnip	14.5	44.5	579	131	222	365
Mustard	9.6	22.8	786	56	159	*
Carrot	18.4	24.2	769	63	176	*
Tomato	3.8	31.9	*	39.8	124	*
Brinjal	15.7	33.9	*	41	220	*
Berseem	1.8	19.1	577	21	*	149
Maize	2.5	35.0	711	523	*	144
Chili	3.4	19.4	1018	225	*	*
Sorghum	1.4	50.0	5198	204	79	*
Sugar beat	8.0	20.2	*	103	120	*
Garlic	11.7	43.3	1879	57	145	*
Potato	17.3	18.2	803	47	308	*
Spinach	10.4	31.9	905	345	107	*
Lettuce	7.0	11.3	1318	122	68	*
Mint	8.0	29.7	3967	51	98	*
Barley	1.3	21.0	*	143	*	*
Bitter Gourd	2.1	45.4	1915	860	*	*
Beans	40.0	31.7	*	49	143	*

* Samples found within permissible limit

The Cd concentrations were higher in beans and lower in barley. Excessive Cr concentrations were found in sorghum. Wheat, sorghum and mint were highly contaminated with Fe. Nickle was found in excessive quantity in turnips. The Pb concentration was also found higher in bitter gourd and lower in sugarcane. The concentrations of Zn were found higher in berseem and turnips. Overall, the vegetables namely, wheat, sorghum, berseem, lettuce, mint and turnips showed more contamination whereas sugarcane and barley showed relatively less contamination.

4.7 FISH FARM WATER

Thirteen fish samples belonging to 5 commercially important species were collected from six fish farms alongwith their water samples for chemical and heavy metal analysis.

Table 4.40 shows that all heavy metals except Cd and Mn were present in the fish upto toxic levels. The concentration of Pb was particularly very high. The high levels of heavy metals in the fish were not specific to particular fish specie or age. All the species in all ages were carrying high heavy metal contents in which Pb was the most prominent. The higher concentrations of Pb in the fish may be attributed to the air pollution carrying Pb from the exhaust of petrol engine and vehicles. It is transported to fish by rainfall, as it absorbs lead from the atmosphere, brings it down and carried to the fish farms. The other reason may be the direct absorption by the open water surface of farms from atmosphere. Higher concentration of trace elements in the edible muscle of fish species and the relevant water was due to placement of fish farms near drains (Figure 4.25) and use of low quality groundwater for fish rearing.

Figure 4.25: Fish farm very close to drain

Fish were found to have outstanding capability to absorb heavy metals. Such high concentration of heavy metals in fish leads to heavy metal poisoning to the consumers. Regular intake of contaminated fish may cause irreversible damage of brain nervous system particularly in the young children resulting in poor intelligent quotient (IQ) level and may also cause cancers in the elders. The chemical analysis of fish farm water is given in Table 4. 41.

Table 4.40: Heavy metal contents of fish harvested from farms (mg/kg)

S.No	*Location*	*Source*	*Specie*	*Weight (kg)*	*Age*	*Cd*	*Cu*	*Cr*	*Fe*	*Mn*	*Ni*	*Pb*	*Zn*
1	Satiana Hetchery Farm Chack No 38 GB	Groundwater	Grass Corp	1.5	1 year	*BDL	9.136	31.48	18.37	BDL	14.10	72.39	11.92
2	Satiana Hetchery Farm Chack No 38 GB	Groundwater	Rahoo	1	1 year	BDL	10.05	32.44	15.42	BDL	8.46	68.86	59.40
3	Satiana Hetchery Farm Chack No 38 GB	Groundwater	Mori	1	1 year	BDL	18.08	47.71	53.96	BDL	23.64	120.17	43.53
4	Chack No 107 RB	Groundwater	Hybrid	0.5	6 months	BDL	13.37	36.73	64.07	BDL	13.97	122.95	29.95
5	Chack No 73 RB Jaranwala	Groundwater	Gross Corp	1.5	1 year	BDL	12.7	37.6	18.41	BDL	11.20	132.00	32.60
6	Chack No 73 RB Jaranwala	Groundwater	Mori	1	1 year	BDL	11.91	35.12	15.77	BDL	17.16	127.38	17.96
7	Chak No 73. RB Khurrianwala	Groundwater	Gross Corp	1.25	1 year	BDL	10.48	37.23	10.68	BDL	26.45	152.50	30.84
8	Chak No 73. RB Khurrianwala	Groundwater	Gross Corp	1.25	1 year	BDL	13.09	38.16	11.89	BDL	23.98	140.56	54.15
9	Khurrianwala	Groundwater	Mori	0.5	1 year	BDL	9.65	37.41	9.95	BDL	26.67	159.20	23.78
10	Khurrianwala	Groundwater	Rahoo	0.5	1 year	BDL	12.18	41.32	20.16	BDL	42.61	178.94	18.16
11	Government Fish, Himat Pura	Groundwater	Mori	1	6 months	BDL	13.99	75.89	45.73	BDL	27.88	144.44	23.51
12	Government Fish, Himat Pura	Groundwater	Mori	1	6 months	BDL	23.93	139.03	6.74	BDL	29.1	149.75	21.15
13	Government Fish, Himat Pura	Groundwater	Gulfam	0.75	6 months	BDL	12.67	37.03	21.06	BDL	20.76	140.72	7.684

*BDL: Below detection level

Table 4.41: Chemical analysis of fish farm water

S. No	*Location*	*pH*	*TDS (mg/l)*	*HCO_3 (mg/l)*	*Alkalinity (mg/l)*	*CO_3 (mg/l)*	*Ca (mg/l)*	*Hardness (mg/l)*	*Cl (mg/l)*
Permissible Limits		*7-8.5*	*50-1000*	*50-400*	*50-400*	*0-100*	*10-160*	*50-400*	*40-1000*
1	Satiana Hetchery Chack # 38 GB	8.2	1782	800	16	Nil	16	110	156
2	Chack # 107 RB	8.1	3150	1220	24.4	Nil	44	100	347
3	Chack # 73 RB	7.3	3171	440	8.8	Nil	40	400	667
4	Chak # 73 RB	8.3	4494	1000	20	Nil	20	200	737
5	Khurrianwala	7.9	5418	460	9.2	Nil	60	470	1617
6	Government Fish Farm, Himatpura	8.3	4081	815	16.3	Nil	24	360	510

Hundred percent farm water samples exceeded the permissible limit of TDS, indicating presence of dissolved solids in the fish farms. This would cause inconvenient breathing environment for the fish reducing its growth. Similarly, HCO_3 was found exceeding the permissible limit in farm water samples ultimately harming the nutrition of the fish through its uptake. CO_3 was not found in all samples. Alkalinity was found within the permissible range. Water with low alkalinity is very susceptible for fish. The heavy metal analysis of fish farm water is given in Table 4.42.

Table 4.42: Mean values of heavy metals of fish farm water (µg/l)

S. No	*Location*	*As*	*Pb*	*Cd*	*Cu*	*Hg*	*Cr*	*Mn*	*Ni*	*Zn*
1	Satiana Hetchery Chack # 38 GB	65	0.45	0	5	0.01	0.05	0	0.01	482
2	Chack # 107 RB	46	0.63	0	5	0	0.08	0	0.15	0
3	Chack # 73 RB	33	0.24	0	6	0.01	0.04	0	0.03	0
4	Chak # 73 RB	17	1.4	0	9	0.03	0.01	0	0.01	350
5	Khurrianwala	7	0.3	0	12	0.05	0.07	0	0.08	0
6	Government Fish Farm, Himatpura	45	1.6	0	4	0	0.05	0	0.02	407

Mean values of heavy metals of fish farm water shows the same situation as for fish. All heavy metals excluding Cd and Mn were present in the fish farm water. Copper, Lead and zinc was found with higher concentration in fish farm water. Up take of lead in fish may lead to damage of brain nervous system.

4.8 HUMAN BLOOD SAMPLES

The human blood samples were analyzed for various water-born and water-related diseases to assess the impact of environmental contamination on human health. The results are given in Table 4.43.

Table 4.43: Human blood sampling analysis for water-borne and water-related diseases

Drinking Water Source	*Parameter*	*Negative*	*Positive*
Pumped near drains	Malaria	25	0
	Widal Test	25	0
	Hepatitis A	25	0
	Enteric Pathogenic Ecoli	25	0
	Salmonella	25	0
	Hepatitis E	24	1
Pumped near canals	Malaria	25	0
	Widal Test	25	0
	Hepatitis A	25	0
	Enteric Pathogenic Ecoli	25	0
	Salmonella	25	0
	Hepatitis E	24	1
Groundwater in the city	Malaria	25	0
	Widal Test	25	0
	Hepatitis A	25	0
	Enteric Pathogenic Ecoli	25	0
	Salmonella	25	0
	Hepatitis E	23	2
WASA supplied water	Malaria	25	0
	Widal Test	24	1
	Hepatitis A	25	0
	Enteric Pathogenic Ecoli	25	0
	Salmonella	25	0
	Hepatitis E	23	2

Six blood samples were found to have reactive Hepatitis E, out of which 4 were women. The only person found to have positive typhoid were using WASA supplied drinking water. The diseases causing bacterium like salmonella and E.coli were not found in human blood, which happens in most severe conditions leading to death due to enteric fever. Therefore, water borne and water related diseases were not common in the human blood of the area. The human blood sampling was done on only 100 peoples due to financial constraints. However, there is need for a detailed blood sampling analysis before reaching to a general conclusion.

4.9 PARTICIPATORY RURAL APPRAISAL

The participatory rural appraisal was conducted to get views and perceptions of common masses, farmers, industrialists and doctors about different water-related parameters and issues.

4.9.1 Common Masses Survey

The common masses were interviewed about the sources and quality of different drinking water sources, existence and effectiveness of the sewerage system, mixing of wastewater with public water supply, presence of pathogens in the drinking water and the incidence of water-borne diseases. The responses of peoples are summarized as:

Sources and Quality of Drinking Water

Out of 90 respondents, 67 percent were using groundwater pumped directly by the ejecto pumps. The remaining 33 percent were using public water supplies. The persons using groundwater were complaining of its poor quality. They were forced to use it due to unavailability of public water supplies. The most of the community was aware of the deteriorating drinking water quality whereas 90 percent respondent recorded that quality of can water was good. The respondents using public water supply also complained about its poor quality. One of the reasons for poor public water supply was its contamination during conveyance due to rusting of water supply pipes lines and intermittent water supply.

Existence and Performance of Sewerage System

Sewerage system existed at most of the places in the city but performance of the system and its ability to cope with huge quantities of wastes generated was very poor. Overflow of sewerage wastes occurs frequently, particularly in the rainy seasons (Figure 4.26). The overflow of surface drains was due to the reason that most of the drains in the city were uncovered and lot of solid waste was being thrown into it, eventually choking them. Overflow of drains, was lying in the streets and roads. In 70 percent cases, the respondents complained of inefficient and overloaded sewerage system.

Figure 4.26: Wastewater overflows in Nishatabad

Mixing Sewerage Water with Public Water Supplies

Mixing of sewerage water with public supply water was also evidenced in some parts of the city due to improper maintenance of supply lines. Twenty seven respondents reported mixing of sewerage water with the public supply. It was causing serious threat to human health.

Presence of Pathogens in Drinking Water

Respondents of the survey were questioned about the evidence of any pathogenic organisms in the drinking water causing water-borne diseases. Most of the respondents were unaware of the water-borne diseases due to lack of awareness, education and medical check up.

Water-borne Diseases

Nearly 90 percent of the respondents complained about the bad quality of water consequently giving rise to many diseases like enteric fever, gastroenteritis, rashes, diarrhea, vomiting, stomach and digestive problem etc. It was also reported by the respondents that quality of water has been deteriorated extensively during the last couple of decades due to unprecedented and unchecked growth of industries within and out side the city. The respondents complained that the industries did not have efficient drainage systems. Similarly, the unmanaged city solid wastes were also sources of groundwater contamination (Figure 4.27). Water-borne diseases were reported mostly by the people using pumped groundwater as compared to those using public supply or can water.

4.9.2 Industrial Survey

The industries were visited to determine the quantity of effluents generated, chemical used and the existence of effluent treatment systems.

Effluent Management System

Nearly 75 percent of the respondent claimed to have proper effluent management systems whereas 25 percent of those reported deficiency in effluent management system. Due to lack of effluent management system, the effluents were directed to the low-lying areas providing favorable conditions for the growth of pathogens (Figure 4.28). The city sewerage system was unable to cope with the huge quantities of wastes generated from these industries resulting in overflowing of sewerage water.

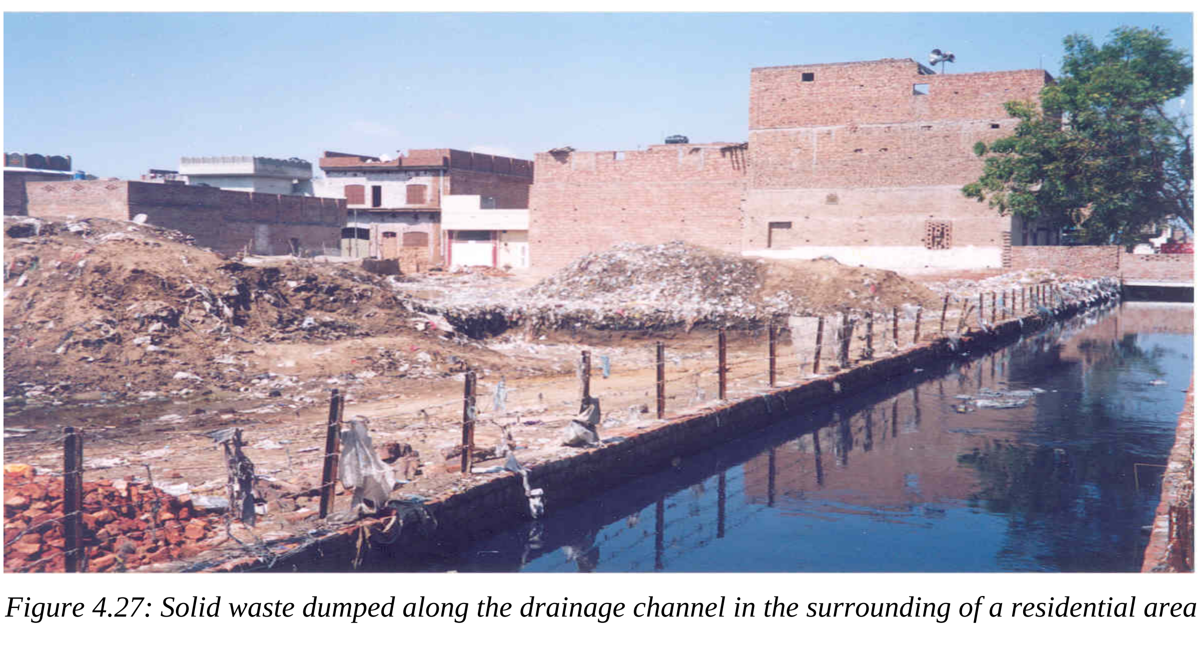


Figure 4.27: Solid waste dumped along the drainage channel in the surrounding of a residential area

Major constituents of effluents in most of the industries were different chemicals, caustic soda, starch, waxes, soda ash, sulphuric acid, ammonia, sodium phosphate, organic substances, dyes, pigments, phosphorus, polymers, silicon, sodium hydroxide, bleach etc. The disposal source of most of these industries was Paharang and Madhuana drains. Out of 30 industries visited, only 2 industries have their wastewater treatment plants whereas only two 2 industries have settling tanks.

Figure 4.28: Unmanaged drainage effluent

4.9.3 Farmers Survey

There is rising trend among farmers for wastewater irrigation during the last couple of years due to shortage of canal water. Farmers were interviewed about the wastewater use and its effects on the fertility and productivity of the soils, health of farmers, crop quality and yield.

Wastewater Utilization and Impacts on Crops, Soils and Human Health

A few farmers receiving mostly the city sewerage with some industrial effluents reported an increase in the agricultural productivity and fertility of the soils. But at the same time, they were unaware of the hygienic quality of the produce. Most of the farmers reported that conjunctive use of wastewater and canal water was good for the crops without harmful effects.

Sixty five percent farmers reported that in the period of water scarcity, they use wastewater and due to wastewater application, the soil becomes hard and some time crops are burnt. The land becomes barren within two to three years with bad quality water. In Daata Chowk Muzzafar Colony, the farmers reported that they paid water charges to the councilor for wastewater at the rate of Rs. 600 to 800 per crop. Forty five percent farmers said that they obtained good yield especially for vegetables due to wastewater application. They reported that except sugarcane and rice, wastewater is very good for rest of the crops/vegetables. They also reported that due to eating of wastewater-irrigated crops animals become ill reducing milk yields.

4.9.4 Hospitals and Clinics Survey

Hospital outdoors, public health units and private clinics were visited to document the common water-borne/water-related diseases, their causes and remedial measures. The diseases found in Faisalabad bear a lot of spatial and social variation. The diseases were more common amongst the poor (Figure 4.29) and illiterate segments of society particularly the people living in areas with improper drainage system like Rashidabad, Nishatabad and Hajiabad.

Figure 4.29: Poor children trying to find some thing out of solid waste

Most of the doctors were of the view that lack of sanitation, financial constraints and unawareness (Figure 4.30) were the main causes of diseases in the society. Doctors reported that 30-40 percent patients were suffering from water-born diseases whereas some doctors reported it as high as 80 percent. Among the water-borne diseases, gastroenteritis was the most common followed by Hepatitis A, liver malfunction, digestive and renal problems.

Figure 4.30: Youth taking bath in the polluted canal water close to Paharang drain

The usage of low quality water was resulting in heart diseases and brain hemorrhage as it contains high Na contents, which increases the blood pressure causing damage to the heart muscles and arteries. Blood cancer was also caused by the use of bad quality water. The low quality water contains a lot of heavy metals like As and Pb. Continuous usage of such water causes accumulation of metals in the body ultimately giving rise to physiological disorders and malicious cancers.

CHAPTER 5

MITIGATION PLAN

A number of mitigation measures are suggested as follows:

5.1 WASTE WATER

- About 7.29 m^3/sec wastewater is disposed off into the rivers from Faisalabad. This huge volume of water could be used for irrigation after proper treatment to reduce the gap between water demand and supply.
- Drainage channels should be lined to prevent seepage from drains to avoid groundwater pollution.
- WASA should design and install system to avoid overflow of drainage effluent.
- Seepage occurring from WASA treatment ponds should be controlled. Similarly, pumping unit should be installed to enhance the efficiency of the system. The water after treatment should be used for irrigation instead of again disposing into the drain.
- Wastewater must be disposed off after proper treatment. Any violation in this regard must be delt strictly. Facilities analysis of wastewater may be provided to monitor wastewater regularly.

5.2 DRINKING WATER

- Groundwater quality of the city was very poor and necessary efforts should be made to extend regular supplies of water through WASA to the entire residential areas of the city.
- The WASA should regularly monitor the quality of pipelines and water supply lines should be laid away from the sewerage pipes so that mixing of water supply with sewerage lines may be avoided.
- Installation of water filtration plants at appropriate distribution points alongwith the regular monitoring of drinking water is very important.
- Pumpage of groundwater near drains for drinking purpose must be avoided.
- Blue cans are being used to transport water pumped from the canal banks. These cans were earlier used for chemicals. Any contamination inside is not visible. It is therefore, suggested to use transparent cans for transporting water.

5.3 WASTEWATER IRRIGATION

- Due to scarcity of canal water, wastewater irrigation is preferred due to its reliable supply and nutrient contents. But on the other hand, the quality of crops and vegetables is highly contaminated and ultimately affecting the human health. Therefore, wastewater must be treated before using for irrigation

5.4 FISH FARMING

- Heavy metal contamination of fish was alarming and necessary efforts should be made to encourage the conjuctive use of canal and tubewell water. However, rearing of fish in the peri-urban areas may be avoided.

CHAPTER 6

CONCLUSIONS, RECOMMENDATIONS AND FUTURE STRATEGIES

6.1 CONCLUSIONS

- Wastewater of the city was 5.28 m^3/sec and after the addition of effluent from other towns and villages it was about 7.29 m^3/sec which is finally being discharged into the rivers. The seepage from Paharang and Madhuana drains were 140 lps/100 m and 47 lps/100 m, respectively.
- Hundred percent wastewater samples exceeded the permissible limits for BOD and COD in all drains. Highest mean value of BOD (425 mg/l) and COD (980 mg/l) was recorded at a point of drains just before falling into rivers. Samples exceeding the permissible limit for BOD were 83, 89 and 95 percent in industrial, sewerage and mixed (industrial + sewerage) water samples, respectively. Similarly, samples exceeding the permissible limit for COD were 94, 100 and 97 percent for industrial, sewerage, and mixed wastewater, respectively.
- The chemical quality of wastewater was found worst for municipal drains in terms of pH, TDS, and SO_4. Highest mean values of TDS (5821 mg/l) were found for Madhuana drain whereas high mean value of pH (13) was found for city municipal drains. Whereas, no sample exceeded the permissible limit of TDS for WASA treated water indicating improvement in the chemical quality of water. The concentration of heavy metals in all wastewater samples showed that these were below the permissible limit.
- For drinking water microbiologically, unfit samples of WASA were 62, 25, 65, 25 and 18 percent for W-I, W-II, W-III, W-IV and W-V zones, respectively. The mean values of CFU for W-I, W-II, W-III, W-IV and W-V were 9500, 3000, 504, 100 and 23 CFU/ml, respectively. The microbiologically unfit water samples of groundwater in the city were 85, 73, 83, 71 and 57 percent for zones CG-I, CG-II, CG-III, CG-IV and CG-V, respectively. The mean values of CFU for city groundwater zones were 952, 1926, 2025, 116 and 1116 CFU/ml, respectively. The unfit water sample were 90, 20 and 70 percent for zones D-I, D-II and D-III (groundwater pumped near drains), respectively with the mean values of 44496, 142 and 2948 CFU/ml, respectively. The D-I zone showed highest CFU. Microbiological quality of can water was relatively good.
- Chemical quality of the WASA samples was found satisfactory. The chemical quality of groundwater pumped in the city was found very poor. Nearly 80 percent of the samples showed excessive TDS, Na, K, Cl, and SO_4 for all zones of the city.
- The quality of groundwater pumped near drains was found to be the worst as on average 90 percent samples were found unfit with respect to TDS, Na, K, Cl and SO_4, The chemical quality of groundwater was better near the canal banks (i.e. can water) particularly in Abdullahpur area.
- Excessive Hg concentration was found in 9, 9, 5, 6 and 13 percent samples drinking water of zones W-I, W-III, CG-IV, CG-III and CG-I, respectively. Similarly, concentrations of As exceeding permissible limit were found in 18, 3 and 6 percent of

the samples collected from the zones CG-II, CG-IV and D-III, respectively. The zone D-III has also shown excessive manganese contents in 3 percent of its samples.

- The chemical quality of irrigation with wastewater in respect of TDS, Na, HCO_3 and Cl was found completely unfit. The SO_4 contents were found higher in Madhuana and Municipal drains. Heavy metal concentration in irrigation water was found within permissible limit. The WASA treated water was found fit for irrigation. However, this water was not being used rather was again allowed to mix with Paharang drain.

- Contrary to the general perceptions, the soils irrigated with wastewater were found significantly deficient in organic matter content. The deficiency of organic matter contents increased with depth. The soils irrigated with the wastewater of Paharang and Municipal drains were found to be deficient in phosphorus content. Potassium was also found deficient in all soil samples irrigated with different sources and types. An excessive Ni was found in soils irrigated with Madhuana drains and excessive Cd was seen in the soils irrigated with wastewater of Municipal drains.

- The mean values of N, P and K showed that vegetables grown from wastewater were deficient in these elements. The vegetables were found contaminated with Cr, Pb, Cd and Fe. The heavy metal contamination of vegetables was more with industrial wastewater irrigation. Wheat, sorghum, berseem, lettuce, mint and turnips were found to have more contaminant uptake capability.

- All heavy metals except Cd and Mn were present in the farm fish up to toxic levels. The concentration of Pb was particularly very high. Higher concentration of trace elements in fish was due to use of low quality groundwater for fish farms. The fish farm water was found to be completely unfit as all these samples were exceeding the permissible limits of TDS and HCO_3.

- In human blood screening few cases of Hepatitis E were found. The percentage of common masses found to suffer from water-borne and water-related diseases was almost negligible.

- The PRA revealed that nearly 67 percent people are using groundwater for drinking however, small number fetch water in cans pumped from the banks of Rakh Branch Canal. About 33 percent are using WASA supplied water. Nearly 90 percent of the respondents complained of bad quality of water consequently giving rise to certain diseases. The industries with inefficient and unmanaged drainage systems were the main cause of deteriorated water quality as nearly 75 percent of the industries were without proper effluent management systems.

- Few farmers reported an increase in the agricultural productivity and fertility of the soils with the wastewater irrigation but they were unaware of the hygienic quality of the produce. According to doctors, 30 to 40 percent patients were having water-borne diseases and few reported it as high as 80 percent.

Keeping in view the gravity of situation, a crash program may be initiated for installation of wastewater treatment plants in the industries. Strict enforcement of environmental standards must be ensured to keep the ecosystem safe from pollution.

6.2 RECOMMENDATIONS

- Wastewater must be disposed off after suitable treatment. Any violation in this regards must be dealt strictly. Drainage channels should be lined to prevent seepage from drains.
- Seepage control measures should be undertaken to avoid seepage from WASA treatment ponds. WASA should regularly monitor the quality of the pipelines and water supply lines should be laid away from the sewerage pipes so that mixing of water supply with sewerage lines may be avoided.
- Stream lining of chlorination process should be carried throughout the city. Installation of water filtration plants at appropriate distribution points along with the regular monitoring of drinking water is recommended.
- Pumpage of groundwater near drains for drinking purpose must be avoided.
- Transparent cans should be used instead of blue cans for transporting the drinking water.
- Due to scarcity of canal water, wastewater is used for irrigation due to its reliable supply. However, the soils, crops/vegetables irrigated with wastewater are highly contaminated. Wastewater must be treated before irrigation.
- Heavy metal contamination of fish was alarming and necessary efforts should be made to encourage the conjunctive use of canal and tubewell water. Moreover, rearing of fish in the peri-urban areas may be avoided.

6.3 FUTURE STRATEGIES

The following strategies/options are suggested to overcome the issue of mismanagement of wastewater:

- Wastewater should be considered as a resource
- Development and promotion of site specific wastewater treatment plants
- Provision of subsidized wastewater treatment machinery and equipment
- Linkages between research and development agencies should be developed
- Guidelines should be developed for reuse of wastewater
- A national wastewater monitoring program should be initiated
- Pilot projects should be implemented for the management of wastewater
- Proper operation and maintenance of the sewage system must be ensure
- Ban should be imposed on the use of polythene bag
- Implementation of Sanitation Policy should be ensure
- Mass awareness through media campaign and curriculum.
- Capacity building of implementing agencies for effective enforcement of rules and regulations.

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