Beside the microbial threat in drinking water, Total organic carbon (TOC) is another issue which should be paid attention. TOC is the amount of carbon bound in an organic compound and is often used as a non-specific indicator of water quality. TOC in source waters comes from decaying natural organic matter (NOM) especially humic acid, fulvic acid, amines, urea and from synthetic sources like detergents, pesticides and fertilizers etc. Some of the contaminants may not be completely removed by treatment processes; therefore, they could become a problem for drinking water sources. The recently issued *Disinfectants and Disinfection By-Products Rule* by the US Environmental Protection Agency specifies maximum total organic carbon levels of 2 mg/L in treated water and 4 mg/L in source water to ensure acceptable levels of disinfection byproducts. TOC value of drinking water supply with chlorination is 4 mg/L (EPD, 2001).

It is important to know the organic content in a waterway because if there is a considerably high content of organic carbon compound in the water to be processed, Trihalomethane (THMs) will develop as a result of chlorine reaction with organic carbon. But the maintenance of chlorine residue is needed at all points in the distribution system supplied with chlorine as disinfectant (Kitazawa, 2006). A quantitative assessment of the risks associated with pathogenic intrusions has shown that protection of public health by maintenance of a disinfectant residual may be insufficient (Helbling and Van Briesen, 2008) leading to regrowth of microbes or their accidental intrusion in the pipelines.

In Pakistan chlorination is practiced at most of the filtration plant as the only mean of water disinfection, and it is supplied to the public using plastic pipes via distribution network. But there is no planned regular monitoring program to assess the water quality of the surface and groundwater bodies, at the treatment plants or in the distribution system except at few major water treatment plants (WB-CWRAS, 2005) which allows episodes of serious bacteriological contamination to go undetected. Pakistan has one of the highest child mortality rates in Asia. It is estimated that water related diseases cause annual national income losses of USD 380-883 million – or approximately 0.6-1.44 percent of GDP (UNDP, 2003).

So The objective of this work was to evaluate the efficacy of free chlorine to inactivate the microbes in drinking water distribution network and bacterial contamination events in drinking water distribution systems and to evaluate their inter ralationships along side with other variables like TDS, turbidity and electrical conductivity etc.

2. Material and Methods

2.1 On field analysis of parameters:

On field, samples were analyzed for temperature and pH (Hach pH meter sension 1), turbidity (Hach 2100) and TDS and electrical conductivity by Hach meter (sension 5).

2.2 Parameters analyzed in Laboratory:

Microbial and chemical analysis of drinking water was conducted by using following test in laboratory.

2.2.1 Biological Parameters

1. MPN (Most probable Number)

The *total coliform* and *fecal coliform* counts were determined by the MPN procedure given in Standard Methods for the Examination of Water and Waste water (APHA, 2005) using lauryl tryptose broth (LTB) for the presumptive test and brilliant green lactose broth (BGLB) for confirmation.

To meet the quality standards of the U.S. Environment Protection Agency (US-EPA, 1978) recommended use of the fermentation technique with 10 replicate tubes was performed; each containing 10 ml. Sample was poured in LTB tubes and incubated at 35 ± 0.5°C. Production of an acidic reaction or gas in the tubes within 48 ± 3h constitutes a positive result. The positive tubes were shifted to BGLB and incubated at 35 ± 0.5°C. Formation of gas in any amount in the BGLB tube at any time within 48 ± 3h constitutes a positive confirmed phase. The positive tubes show the presence of *coliform*. For confirmation of *fecal coliform*, the positive BGLB tubes were shifted to EC medium and incubated for 35 ± 0.5°C for 48 ± 3h.Here if gas is produced; it is a positive test for *fecal coliform*.

2. Standard Plate Count-SPC

Standard plate counts (SPC) were also determined as per Standard Methods (APHA, 2005). It is a procedure for estimating the number of live heterotrophic bacteria in water. This test can provide useful information about water quality and supporting data on the significance of *coliform* test results. The SPC is useful in evaluating the efficiency of various treatment processes for both drinking water and swimming pools purposes, and for checking the quality of finished water in a distribution system.

The Pour Plate technique is used on any type of liquefied sample for the enumeration of bacteria. Conditions vary depending upon the type(s) of bacteria being enumerated. Agar is prepared according to standard manufacturer's instruction and then held at 44 - 46°C in molten state in a water bath. Serial dilutions of the sample are prepared (using 0.1 % peptone water) so that following incubation, one of the dilutions will yield growth of 30 - 300 colonies (the ideal counting range) on the agar plate.1.0 ml of the sample or dilution is transferred to a sterile, empty Petri dish. Approximately 15 mL of agar medium is poured into the Petri dish containing the sample. The sample and agar are mixed thoroughly by rotating the plate several times, clockwise, then counterclockwise. When the media has solidified, the plates are inverted and incubated at, 37°C ± 0.5°C for 48 - 72 ± 2 hour.

2.2.2 Chemical parameters:

1. DPD Ferrous Titrimetric Method

Chemical analysis for chlorine residual, free chlorine, monochloramine and dichloramines was carried out using DPD Ferrous Titrimetric method (APHA, 2005). For the detection of free chlorine, 5 ml of phosphate buffer and DPD were placed in a flask with 100 ml sample; development of red color was titrated against standard ferrous ammonium sulfate (FAS). Observation was recorded as soon as the color discharges giving value of free chlorine. For determination of monochloramine 0.5 g KI was added to the above sample and was titrated against FAS. The volume of FAS used gives monochloramine in mg/l. For dichloramines 1 g KI was added in the above sample and similar procedure was repeated after 2 minutes standing at room temperature. Similarly for total chlorine 5 ml of phosphate buffer and DPD was placed in a flask with 100 ml sample along with 1.5 mg KI and was noted after two minutes standing in dark.

2. TOC analysis

The drinking water samples collected were analyzed by TOC analyzer multi win N/C 30. The determination of the inorganic carbon occurs by injection of the sample into phosphoric acid. The resulting carbon dioxide is degassed from phosphoric acid with the aid of carrier gas and quantified with NDIR, according to the TC determination. The CO2 detector measures the concentration of the CO2 gas generated in the oxidation chamber. This component is critical for precise analytical results, since it directly correlates to the organic carbon content of the analyzed water.

3. Results and Discussion

The aim and objective of the study was to evaluate the efficacy of free chlorine to inactivate the microbes in drinking water distribution network and bacterial contamination events in drinking water distribution systems and to evaluate their inter relationships along side with other variables like TDS, turbidity and electrical conductivity etc.

Sampling was conducted in I-8 sector during August and September, 2008. There are two overhead tanks and a water filtration plant in the community which is supplying water to the public. The water at the over head tank was analyzed microbially and chemically to assess the status of drinking water. The analysis revealed that the water is safe for drinking with value of pH 7.10, TDS of 354 mg/L, conductivity of about 714 µS/cm and turbidity of 1.10 NTU. The value of total chlorine was estimated to be 0.13 mg/l; free chlorine was 0.09 mg/l, monochloramine of 0.04 mg/L and dichloramines of 0.03 mg/L. There was no evidence of fecal contamination in water sample collected from over head tank in all three days of sampling.

From the analysis result it is clear that the temperature of the water samples tested varied from 25.8 to 26.7 °C at *Station # 4* and 3. Water temperature is crucial for microbiological water quality. The increase in temperature enhances the disinfection efficiency of chlorine, i.e., pathogen inactivation effectiveness increases as water temperature rises. These results are inline with the study conducted by Bailey & Thompson, (1995) who found out that higher coliform counts were associated with higher water temperatures in the distribution system. It has been observed, that when water temperatures rise above 15°C, the growth of colonizing bacteria in the distribution system increases markedly (LeChevallier *et al.*, 1991; LeChevallier *et al.*, 1996; Geldreich, 1996).

Chlorination is also effected by pH. In aqueous solutions with pH 7.0 to 8.5, HOCl reacts rapidly with ammonia to form inorganic chloramines (termed combined chlorine) (US-EPA, 1999).The values of pH fluctuated from7.10 to 7.62 at *Station # 1* and *4* respectively.

The United States Environmental Protection Agency (US-EPA, 1978) recommends treatment when TDS concentrations exceed 500 mg/L, or 500 parts per million (ppm). The TDS concentration is considered a Secondary Drinking Water Standard, which means that it is not a health hazard. However water with a high TDS concentration may indicate elevated levels of ions that do pose a health concern, such as aluminum, arsenic, copper, lead, nitrate and others. These results are also in agreement as reported by Farooq *et al.*, (2008). The value of TDS was lowest at *Station # 4* with values ranging from 332 to 354 mg/L with mean value of 339 mg/L while maximum value was obtained at *Station # 6* with mean value of 368 mg/L.

Conductivity values were found varying in between 683 to 749 µS/cm at *Station # 4* and *6*. All the parameters are within WHO standards of drinking water quality. As the concentration of dissolved salts (usually salts of sodium, calcium and magnesium, bicarbonate, chloride, and sulfate) increases in water, electrical conductivity increases (Kelin *et al*., 2005).

The microbiological quality of drinking water can be significantly affected by turbidity. Highest value of turbidity was obtained at *Station # 2* with mean value of 1.27 NTU while lowest value was observed at over head tank at I-8 with mean value of 0.34 (Figure 1). Similar results were also reported by National Water Quality Program, (PCRWR, 2005). On the other hand, Heterotrophic plate count (HPC) increases with parallel increase in turbidity as reported earlier by Snead, 1980. Similarly, Chlorine (as hypochlorous acid) reacts readily with organic matter containing unsaturated bonds, phenolic groups and nitrogen groups, giving rise to taste- and odor-producing compounds and trihalomethanes (THMs). Hence, waters with high turbidity from organic sources may give rise to a substantial chlorine demand and so is unavailable to kill pathogens (Crump, 2004). This could result in reductions in the free chlorine residual in distribution systems as protection against possible recontamination.

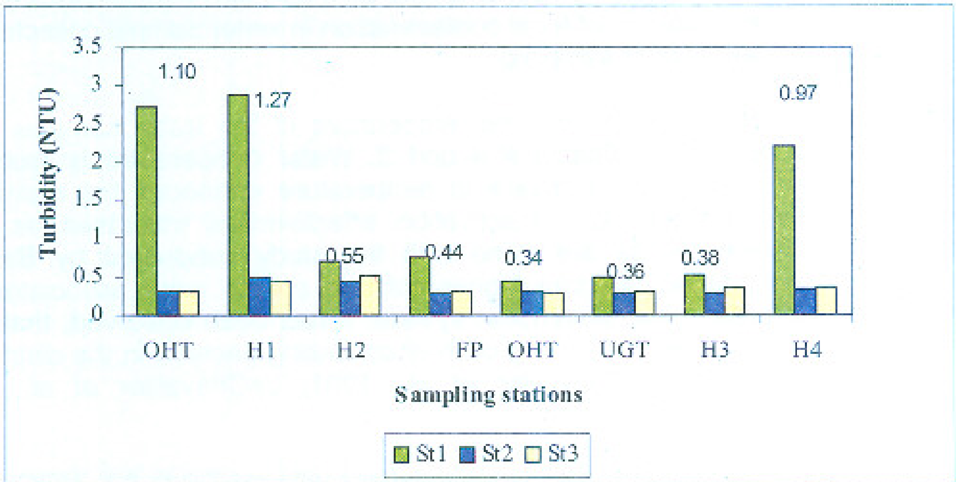

Figure 1: Values of Turbidity obtained at different sampling stations of sector I-8

The value of total residual chlorine varied from 0.05 mg/L at *Station # 3* to 0.13 at *Station # 1*. Free chlorine residual was also detected in the system with average values varying from 0.02 mg/l at *Station # 3* to 0.09 at *Station # 1*(Figure 2). Minimum level of monochloramine available at consumer end was detected at *Station # 3* with mean value of 0.01mg/L and maximum level was obtained at *Station # 6* with mean of 0.08 mg/L. Values of dichloramines ranged from 0.17 to 0.06 mg/L at *Station # 3* and *6*.

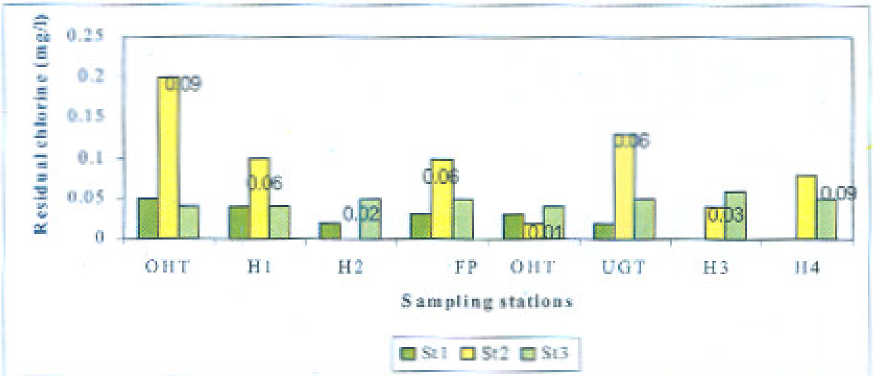

Figure 2: Values of Residual chlorine obtained at different sampling stations of Sector I-8.

Most probable number (MPN) test was conducted to determine the presence of *total coliform* and *fecal coliform* in drinking water samples. Microbial analysis of drinking water samples revealed that fecal contamination was detected at *Station # 3* with MPN /100mL of 16.1, at *Station # 5*and *7* MPN/100 mL was 6.9 and at *Station # 8* MPN/100ml was 5.1. While at the rest of the stations MPN/100 ml was <1.1 indicating that there was no presence of *fecal coliform* (Figure 3).

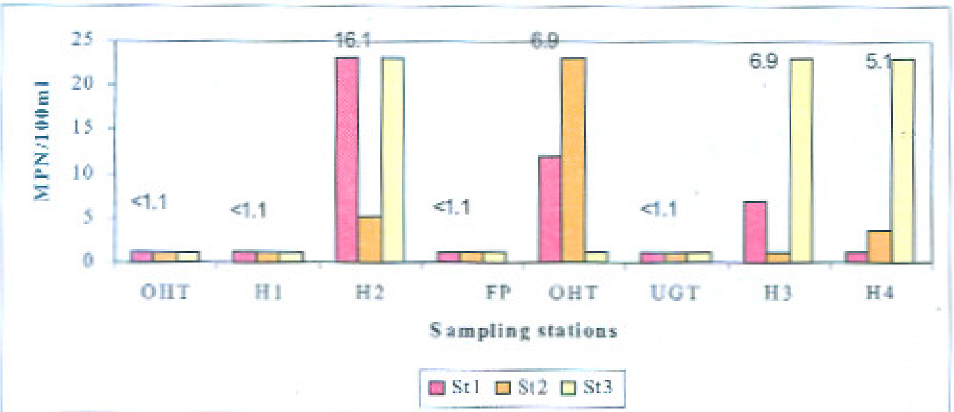

Figure 3: Values of *fecal coliform* count obtained at different sampling stations of sector I-8

The standard plate count (SPC) is considered by some scientists to be a better indicator of potable water quality than the coliform index (Geldreich, 1972).The viable count was measured by the SPC. The maximum SPC counts were observed at *Station # 3* with values ranging from 81 to 370 CU/mL with average value of 267 CFU/ml. At the rest of the stations SPC counts were below countable range. These results are in line with the study conducted by Le Chevallier *et al.*, (1980). So from the analysis it revealed that water sample from *Station # 3* was highly contaminated, this may be due to cross contamination of water supply line with sewage water and unhygienic condition of under ground storage tank (Figure 4). The cumulative values of all the parameters are given in Table-1.

Table 1: Mean value of Microbial and Chemical Analysis of Water Samples Collected from Residential area of I-8 during July & August 08*

Water Parameters	Station Numbers							
	1	2	3	4	5	6	7	8.
Station Name	UGT	H1	H2	H3	H4	H5	H6	H7
Temp in °C	25.6	26.2	26.7	25.8	26.13	5.8	25.76	20.06
pH	7.10	7.26	7.6	7.62	7.41	7.24	7.56	7.21
TDS (mg/l)	354	353	343.3	339	362.3	368	363	357
Conductivity(μS/cm)	714	718	689.6	683.6	737	749	739	726
Turbidity (NTU)	1.10	1.27	0.55	0.45	0.34	0.36	0.38	0.97
Total Chlorine (ppm)	0.13	0.093	0.05	0.27	0.06	0.12	0.12	0.06
Free chlorine	0.09	0.06	0.023	0.06	0.03	0.06	0.033	0.043
Monochloramine	0.04	0.033	0.016	0.02	0.023	0.05	0.07	0.06
Dichloramines	0.03	0.006	0.05	0.05	0.04	0.06	0.046	0.053
Total Coliform (MPN index/100ml)	<1.1	<1.1	12.0	<1.1	9.2	<1.1	6.9	5.1
Fecal Coliform (MPN index/100ml)	<1.1	<1.1	12.0	<1.1	9.2	<1.1	6.9	5.1
Range 95% Probability	0-3.0	0-3.0	4.3-27.1	0-3.0	3.1-21.1	0-3.0	2.1-16.8	1.3-13.4
CFU /ml	5	12	267	2	36.3	0	3	2

NTU=Nephlometric turbidity units, **CFU**=Colony Forming Units, **UGT**=Underground tank, **H (1, 2, 3, 4, 5, 6,7)** = Consumer houses

* Based on mean of three replicates (Dated: 20/08/08, 02/09/08, 11/09/08)

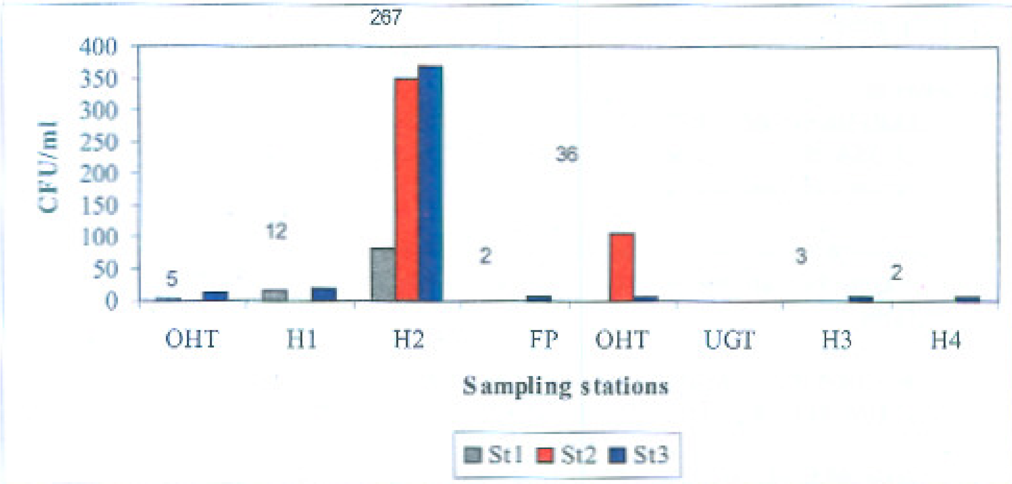

Figure 4: Values of SPC counts obtained at different sampling stations of sector I-8

The water samples collected were also analyzed for TOC. The analysis results were alarming as high amount of TOC was observed at all of the sampling stations which were above standards of treated drinking water i.e., above 2 mg/L. The values were found to be ranging from 7.67 to 22.57 mg/L. The main water supply had a TOC value of 11.22 mg/l. These are in line with the study conducted by Wallace *et al.*, (2002) (Figure 5). According to their study, TOC monitoring is required monthly for one source water and one treated water sample. If the TOC levels of the source water average less than 2mg/L^{-1} C for two consecutive years, or the treated water average is less than 1mgL^{-1} C

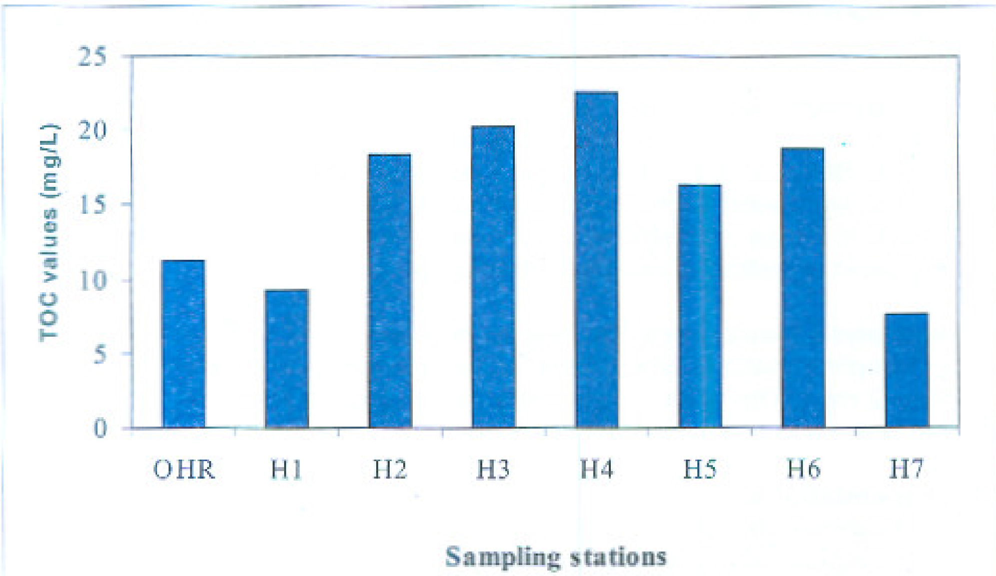

Figure 5: Average values of TOC obtained at different sampling stations of sector I-8

for 1 year, then a public water system would qualify for reduced monitoring to one pair of samples per quarter.

4. Conclusions

1. The analysis revealed that the water is safe for drinking with value of pH 7.10, TDS of 354 mg/l, conductivity of about 714 µS/cm and turbidity of 1.10 NTU in water from overhead tank.

2. The value of total chlorine was estimated to be 0.13 mg/l; free chlorine was 0.09 mg/l, monochloramine of 0.04 mg/l and dichloramines of 0.03 mg/l in the over head tank.

3. All the chemical parameters were within WHO standards of drinking water quality. But turbidity was highest with mean value of 1.27 NTU at *Station # 2.*

4. The value of total chlorine varied from 0.05 mg/l at *Station # 3* to 0.13 at *Station # 1*. Free chlorine residual was also detected in the system with average values varying from 0.02 mg/l at *Station # 3* to 0.09 at *Station # 1.*

5. Microbial analysis of drinking water samples revealed that fecal contamination was detected at *Station # 3* with MPN /100ml of 16.1, at *Station # 5*and 7 MPN/100 ml was 6.9 and at *Station # 8* MPN/100ml was 5.1

6. In light of the increasing concerns over pathogenic contamination in distribution systems and the documented deficiencies in the efficacy of the disinfectant barrier, an additional monitoring is required to protect public health and provide early warning of accidental pathogenic contamination events. While at the rest of the stations MPN/100 ml was <1.1 indicating that there was no presence of *fecal coliform*

7. The maximum SPC counts were observed at *Station # 3* with values ranging from 81 to 370 CU/ml with average value of 267 CFU/ml. At the rest of the stations SPC counts were below countable range. So from the analysis it revealed that water sample from *Station # 3* was highly contaminated, this may be due to cross contamination of water supply line with sewage water and unhygienic condition of underground storage tank.

8. The analysis results were alarming as high amount of TOC was observed at all of the sampling stations which were above standards of treated drinking water i.e. above 2 mg/l. The values were found to be ranging from 7.67 to 22.57 mg/l. The main water supply had a TOC value of 11.22 mg/L.

5. Recommendations

1. It is recommended that there should be regular monitoring of physical, chemical and biological quality of drinking water being treated at any treatment facility in order to ensure good water quality provision to the community.

2. A regular monitoring of residual chlorine concentration and microbiological contamination of water in the distribution system is recommended to ensure that after travelling a long distance the water supplied to the community, considerable amount of residual chlorine should still be present to combat the microbes which accidentally enter the distribution network.

3. Optimization of chlorine dosage according to the requirement because if the dosing rate of chlorine is too low, there may be insufficient residual chlorine at the end of the distribution system, resulting in bacterial regrowth. On the other hand, the addition too much chlorine can lead to customer complaints about taste and odor, corrosion of the pipe network.

4. It is recommended that the departments responsible for water supply in urban areas in particular should replace age-old leaking pipes in their water supply systems because they are a major cause of bacterial contamination even in treated water in the distribution.

6. **Acknowledgement:** We gratefully acknowledge the financial support of Higher Education Commission (No. 20-874/HEC/R&D/07/379), Pakistan to carry out this research and the support of staff from Khanpur Filtration Plant, Islamabad, Pakistan.

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"SAFE DRINKING WATER AND SANITATION IN PUNJAB"

By

Salman Yusuf [1]

Introduction

This paper is with regard to the challenge of providing safe drinking water & sanitation in villages and small towns in the Punjab. This paper provides a general review of the existing situation in Punjab Province, covering water supply, sanitation and drainage and institutions. Given its general nature, seeks to provide an overview of the existing situation for the province as a whole.

Four different conditions of water availability in Punjab, namely : (Figure 1)

- Sweet water areas
- Brackish water areas
- Water scarce areas
- Areas in which water is both scarce and brackish.

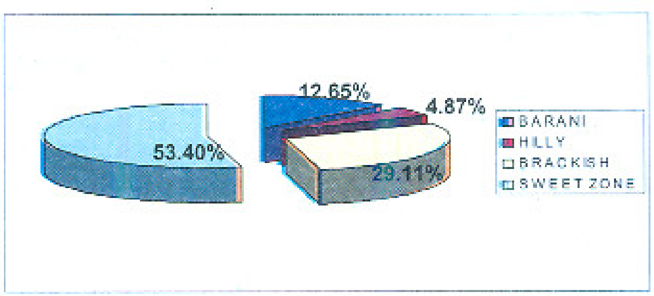

Figure 1 : Different Conditions of Water Availability in Punjab

1. Deputy Secretary (Technical) Housing Urban Development & Public Health Engineering Department.

These classifications mainly relate to groundwater and sweet water is normally available from surface sources in areas with brackish groundwater. As a general rule, it can be said that sweet and brackish water areas occupy the central Punjab plains that are watered by the five rivers while water scarce areas, including those in which groundwater is brackish, are found in the Salt Range/Potohar Plateau and Southern Punjab desert areas.

The water supply section contains sub-sections dealing with water sources, completed and ongoing initiatives, water supply coverage and water system management arrangements. The sanitation and drainage section contains sub-sections dealing with sanitation, drainage and waste water treatment coverage, institutional arrangements and innovative initiatives. An overview of existing water quality, water supply and drainage related norms and standards.

1. Water Supply

1.1. Water Sources

Possible sources of water for human consumption include:

- Rainwater
- Surface water (in streams, rivers and lakes)
- Springs
- Groundwater

Rainwater can be collected from roofs, normally by individual households, or from protected ground level catchments. Collection from roofs is not widely practiced in Pakistan, partly because rainfall is highly seasonal and partly because houses are mostly built with flat roofs rather than the sloping roofs that are most suitable for rainwater collection. Ground level catchments are possible in hilly areas. Indeed, some towns collect water from dammed catchments. However, water collected in this way normally has to be treated. Given the difficulty in ensuring effective treatment of contaminated water and the large catchments required to provide water at the village level, ground level rainwater catchments will not normally be a preferred water source option.

Surface water is available throughout the Punjab plains in irrigation canals and the five major rivers. As indicated in the previous paragraph, it is subject to contamination and must be treated to remove pathogens before it can be considered fit for drinking. In the 1980s, a number of PHED village water supply schemes in brackish groundwater areas relied on water drawn from minor irrigation canals and treated by sedimentation and slow sand filtration. Few if any of the slow sand filter works have been operated and maintained properly and those that are still operational are mostly by-passed.

Springs are a possible source of water in hilly areas and a few spring-fed schemes exist in the Potohar Plateau area and in the Districts that lie west of the Indus. Where springs exist, they can provide good quality water as long as they are properly protected. However, they will be an option in only a small number of cases.

Most people in Punjab obtain water from groundwater sources. In sweetwater areas, most households access shallow groundwater through shallow wells and relatively shallow tubewells fitted with handpumps or, for richer households, electrically powered pumps. Where village schemes exist, they obtain water from tubewells, which draw from deeper depths than most individual household wells and tubewells.

In brackish water areas, many villages located close to larger canals and rivers rely on seepage water, tapped by relatively shallow tubewells located close to the banks of the canal or river. This approach can also be used for villages situated some distance from the canal or river, provided that a transmission main is provided between the well or wells and the village.


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In hilly and relatively dry areas, water is obtained from shallow aquifers, normally consisting of alluvial sands and gravels located beneath seasonal water courses. Such sources are normally located some distance from the village or villages to be served. In such circumstances, multi-village systems might be considered but the normal practice at present is to provide each village with its own system, even though several village systems may rely on the same aquifer.

Percolation wells from several villages - Chakwal District

Percolation wells, are commonly used to access water from shallow gravel/sand aquifers. Another option, which may be combined with a percolation well, is to construct infiltration galleries under the bed of the watercourse. The dam blocks the flow of groundwater, leading to increased groundwater depth and greater yield from an infiltration gallery located upstream of the dam. This system will only be economical where the width of the valley and the depth to impervious rock or clay are both limited so that the sub-surface dam can be built fairly cheaply.

1.2. Completed and Ongoing Initiatives

In the 1980s and early 1990s, the PHED constructed a large number of rural water supply schemes, most of which relied on either treated canal water or tubewells. More recently, the most important initiatives have been the Punjab Rural Water Supply and Sanitation Project (PRWSSP) and Punjab Community Water Supply and Sanitation Project (PCWSSP), both of which were funded by the Asian Development Bank (ADB). PRWSSP ran from 1995 to 2002. It covered seven districts, mainly in relatively water-scarce areas and including Chakwal District and resulted in the implementation of about 335 schemes.

PCWSSP, which ran from 2002 to 2007, built on the PRWSSP experience, extending the remit to cover 30 districts and paying increased attention to social mobilization. The Project Completion Report on the second phase of PCWSSP states that 778 subprojects were implemented, providing 161,132 household connections and serving a population of 2,621,192. These figures suggest an average of just over 206 household connections per scheme and about 16 users per connection. In addition, about 100 schemes that had been wholly or partially prepared by the PCWSSP team are said to have been implemented by the PHED with government funds.

The National Ministry of Environment initiated a 'Clean Water for All' programme in 2005. Under this programme, which was included in the 2005 – 2010 Mid Term Development Framework, water treatment plants were to be provided in 6035 locations throughout Pakistan, one plant for one union council. The water treatment plants come in three standard designs with capacities of 500, 1000 and 2000 gallons per hour, approximately 2.25, 4.5 and 9 cubic metres per hour respectively. It appears that they incorporate ultrafiltration membranes and disinfection using ultra-violet light although details have not been confirmed. The programme became part of the Government's Khushal Pakistan Programme. Preliminary calculations suggest that 10 hours operation of the 9 cubic metres per hour plant would provide approximately 10 litres per person per day to a village with a population of 9000, sufficient to provide drinking water but insufficient for all potable water needs.. The approach has several serious drawbacks. First, it provides water at a central point within each Union Council and is only easily accessible to people living close to this central point. Second, it requires that people carry water from the delivery point to their houses. Given that research has shown that the greatest possibilities of contamination occur during transport to and storage in the home, this means that the claimed health benefits are unlikely to be achieved in practice. Third, there must be considerable doubt about its sustainability. Membrane filtration systems require regular maintenance and cleaning, without which their capacity reduces so that they fail to produce much water after only a few months. For all these reasons, the small water treatment plant option, as implemented in the Clean Water for All programme, will not be considered further as a model to be replicated throughout Punjab.

1.3. Water Supply Coverage

According to the Multiple Indicators Cluster Survey (MICS) 2003–2004, access to improved drinking water sources is consistently high across all districts of Punjab. Indeed, the MICS estimates a provincial average of 97%. These are overall figures and include many people who obtain their water from self-financed shallow wells and tubewells. Most of these sources draw on relatively shallow water sources, some of which may be contaminated. In addition, information on water quality in piped water schemes suggests that many are subject to pollution in the distribution system. Taken together, these points suggest that considerably less than 97% of the population has access to an adequately improved water source.

1.4. Water Quality

PCRWR has conducted a survey of water resources throughout Pakistan. This survey has involved the collection and testing of one or two water samples from water sources in every union council. Parameters tested include bacteriological contamination (+ve or –ve), colour, odour, taste, total dissolved solids (TDS – a measure of salinity), arsenic, hardness, nitrate (an indicator of organic pollution and potential cause of 'blue baby' syndrome) and fluoride.

The 2009 ADB Impact Evaluation on PRWSSP and PCWSSP reports that 45% of samples taken at source and 72% taken in the distribution system were contaminated with coliform bacteria. The increased percentage of contaminated samples from the distribution system is not surprising but the 45% figure for samples taken at source is higher than might be expected, given the depth to the aquifer and the nature of the subsoil. This requires further investigation. None of the 115 schemes assessed had problems with high arsenic concentrations and only three had fluoride concentrations in excess of the recommended standard.

A summary report by the PCRWR states that Total Dissolved Solids (TDS) concentrations in groundwater range from less than 1000 mg/l near the major rivers to over 3000 mg/l, indicating highly saline conditions, in the areas between the rivers. Cholistan Desert in the Southern Punjab and covering part of Bahawalnagar District is underlain by highly brackish waters which cannot be used for drinking purposes.

Arsenic contamination occurs in some areas of Punjab. Muzzafargarh, one of the study Districts, is one of the affected areas. A study conducted by researchers from UNICEF and other institutions[1] found that 58% of 49 samples taken from both shallow and deep groundwater exceeded the WHO guideline standard of 10 µg/l. No samples taken from shallow aquifers had arsenic levels above 25 µg/l but all seven samples taken from deeper groundwater had arsenic levels above 50µg/l, the figure that is accepted as the absolute maximum limit by several countries, including India and in some Pakistan

[1] See Nixon R, McArthur J, Shrestha B, Kyaw Myint T and Lowry D (2004), Arsenic and other drinking water quality issues, Muzzafargarh District, Pakistan, *Applied Chemistry*,Elsevier

guidelines[2]. The report suggests that the arsenic contamination in shallow groundwater may be at least partly due to the release of arsenic following the reduction of hydrous ferric oxide (HFO) driven by pollutant organics contained in sewage and other anthropogenic pollutants. Overall, the study found that the greatest problems were likely to occur close to industrial towns. UNICEF also tested for arsenic in other Districts, including Chakwal and Gujrat, Its first survey found that 90% of samples had arsenic concentrations within WHO limits and that only 2% were above 50µg/l. The percentage above this figure was 5% for Gujrat and zero for Chakwal. There is little epidemiological evidence for arsenic poisoning in Punjab but UNICEF nevertheless recommended that potential water sources should be tested for arsenic.

There are also reports of high fluoride content, ranging from 65 to 12 mg/l in groundwater in Bahawalpur area. A report by the British Geological Survey (BGS) found some evidence of fluoride contamination in groundwater, most of which appeared to be occurring around cities and industrial areas.

Nitrate contamination, particularly of shallow groundwater, could be a problem where either unsealed waste water ponds or excessive use of nitrogen-based fertilizers results in percolation of nitrogen-rich water into the ground. However, the available evidence suggests that nitrate levels in groundwater are generally within the PSQCA standard of 10mg/l. A WaterAid document[3] reports the findings of Chandio (1999) that concentrations of nitrate (NO_3-N) were mostly less than 6 mg/l in dug wells and tubewells from canal-irrigated areas of Pakistan, although concentrations up to 210 mg/l (as N) were found where directly contaminated by sewage.

Institutional Responsibilities and Management Arrangements

Prior to devolution, the PHED and Local Government, Elections and Rural Development Department (LG&CDD) were responsible for implementing water supply & sanitation schemes. Their responsibilities were as follows:

- LG&CDD - small-scale water and sanitation schemes in rural communities, including hand pump installations, and promotion of household sanitation

- PHED - relatively large and complex water supply and drainage schemes in larger settlements.

Most of the systems implemented by the PHED were groundwater-based but those in areas with brackish groundwater relied on canal water treated by sedimentation and slow sand filtration. Most PHED systems had three staff, an operator, a valve man and a watchman, all of whom were PHED employees. Each system had its own bank

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[2] See Section 2.4.13 of PDSSP Technical and Service Delivery Standards for Water Supply and Sanitation Sectors (2008).

[3] Information Sheet on Groundwater Quality in Pakistan, produced for WaterAid by British Geological Survey –(http://www.wateraid.org/documents/plugin_documents/pakistangroundwater_1.pdf)

account, which was managed by the PHED Sub-Divisional Officer (SDO), who was the signatory for the account. Customer payments were deposited into this account and salaries, electricity bills and other bills incurred in operating the system were paid from it. In 1993, Government in Pakistan adopted a Uniform Policy, which stated that operation and maintenance of rural water supply schemes should henceforth be the responsibility of beneficiary communities. The Government of Punjab enacted legislation to implement this policy in late 1993. The policy required PHED to mobilise communities to form water users committees (WUCs) to take over schemes after completion according to the terms of a Memorandum of Understanding (MOU) between the PHED and the WUC. Funds were to be deposited in a joint account, in the names of the SDO PHED and a member of the WUC. The PHED would continue to be responsible for the planning and design of new schemes and also undertook to train community personnel in the technical and financial skills required to operate schemes.

In 2001, the Punjab Local Government Ordinance (PLGO) assigned responsibility for water supply and sewerage services to Tehsil and Town Municipal Administrations (TMAs). PHED's role was initially restricted to monitoring although more recently it has reclaimed most of its responsibilities for planning, design and implementation. The PLGO makes no direct reference to the options for community management. It does state that a TMA can assign or contract out any of its functions to any public-private, public or private organisation, subject to the approval of the Tehsil Council and after inviting public objections. In practice, investigations in Jaranwala Tehsil suggest that schemes previously operated by the PHED were left with little support. By 2004, around 35% of existing schemes in the tehsil were non-operational. The situation was worse for systems based on slow sand filter treatment of canal water. Of about four schemes investigated, only one was operational and even this was barely functioning with no the slow sand filters effectively by-passed.

An evaluation of the two projects was recently carried out by the Asian Development Bank's Independent Evaluation Department (ADB 2009). The study covered 115 villages, representing about 10% of all the schemes covered by the two projects. It revealed that 68% of PRWSSP schemes and 89% of PCWSSP schemes remained functional, giving an average of 80% functional overall. The higher percentage of failed PRWSSP schemes does suggest a negative relationship between age of scheme and operability. This impression is reinforced by another study finding, that only 43% of the community organisations formed to manage rural water supply schemes under the two projects were still partly or fully functional. The study report identified a positive relationship between scheme functionality and a lack of alternative water resources. Our initial investigations provide qualitative confirmation of this conclusion. It seems that most water supply schemes in Chakwal District, a water scarce area, are operating well with good cost recovery and a strong likelihood that services will be sustained.

While the majority of functional schemes are managed by community organisations, as required by Government policy, the management arrangements for the schemes serving Balkasar and four other villages in Chakwal District are in reality closer to those that might be found in a small private sector water company. Further information on the management arrangements for the Balkasar schemes is given in Box 1.

The Punjab Local Government Ordinance (PLGO) does not specifically mention the policy of community management. It assigns responsibility for planning and providing water supply and drainage schemes to Tehsil Municipal Administrations (TMAs). In practice, TMA investment in water supply since 2001 has been limited and what investment there has been has generally been small-scale, involving piecemeal extension of existing systems. The ADB evaluation of 115 schemes executed under PRWSSP and PCWSSP found no systematic arrangements for recording income and expenditure. In contrast to this general finding, visits to two metered systems in Chakwal District revealed well maintained records of water use, billing and payments. In Balkasar, accounts have been computerized.

Box 1 The Balkasar Initiative

The water supply scheme serving Balkasar was commissioned in 1983 and a Water User Committee took responsibility for operation in 1988. The WUC operated the scheme for a number of years but began to face problems as unequal distribution of water, resulting from the varied topography of the supply area, led to many households ceasing to pay their bills. Poor cost recovery resulted in losses, which were met from maintenance funds handed over by PHED when the WUC took over responsibility for the system. Efforts to improve the situation by dividing the system into different supply zones and raising the tariff proved to be ineffective. Cleary this situation could not be sustained. In 1997, a decision was taken to install meters and all supplies were metered by 2001.

The number of connections has increased over the years from around 300 in the late 1990s to around 1100 today. Water is drawn from three linked percolation wells located about 2km from the village. From the central well, it is pumped to a ground level service reservoir located in the centre of the village. From this reservoir, which provides approximately 24 hours storage at the average daily demand, it is pumped to two elevated service reservoirs, from which water gravitates to the village on a continuous 24/7 basis. Supply to private sector and bulk users located some distance from the village is by a separate main, and is not continuous. Rather continuity of supply is achieved through the storage capacity provided in-house by the various customers.

The system has been upgraded and improved over the years. For instance, the ground level reservoir was not included in the original scheme and the second elevated service reservoir has been constructed fairly recently. A second supply main has recently been laid from the source to the ground level reservoir. Mr Moussadeq, the Chairman of the Balkassar WUC (and in effect operator of the scheme), says that the funds for these improvements and extensions, including the extension to serve commercial areas close to the motorway, have been raised by the organisation itself. However, it seems that Rs 458,000 in CCB funds provided by Chakwal TMA was used to fund the second supply main and it may be that the WUC has also sought funding for some other improvements from external sources.

In addition to the Balkasar scheme, Mr Moussadeq's organisation is also operating four smaller village schemes in the vicinity of Balkasar. The organisation currently employs seventeen staff. An accountant, three meter readers and three complaints resolution staff divide their time between all five schemes while the remaining 10 staff are pump operators, who work 8 hour shifts in the five villages.

Current tariffs are:

- Rs7 per cubic metre for domestic connections.
- Rs13 per cubic metre for commercial connections.
- Rs 6 per cubic metre for bulk supplies to institutional customers.

Sanitation and Drainage

1.1 Sanitation, Drainage and Waste water Treatment Coverage

Figures on sanitation coverage in Punjab vary, reflecting the difficulty of determining what exactly constitutes good sanitation. The Pakistan Social and Living Conditions Measurement Survey (PSLM) for 2006-7 gives overall sanitation coverage, urban and rural, as 73%. Corresponding figures from the 2006 Human Development Report and Joint Management Programme survey 2008 are 59% and 58% respectively, reflecting the fact that the last two are rather stricter in determining what constitutes satisfactory sanitation. Percentage coverage for rural areas is generally much lower than that for towns, the rural figure for the PSLM being only 56% for instance. These figures are averages and there are likely to be great varieties between Districts. The PSLM survey found that the average sanitation coverage figure for Rajanpur District, one of the study Districts, was only 28%.

Regardless of the situation with regard to toilet coverage, the drainage situation is generally unsatisfactory. Few villages have any form of sewerage and most rely on open drains. Pour-flush WCs may be connected to these drains directly or may discharge indirectly via septic-tanks. Figure 2 show a typical situation in the centre of a village, with open drains running down either side of a brick-soled lane.

Figure 2 : Open drains in Kotla Arab Ali Khan, Gujrat District

There are a few exceptions to the general rule. In Lodhran District, some villages have piped sewerage, provided by householders themselves with support from the Lodhran Pilot Project, a non-government organisation that follows the approach pioneered by the Orangi Pilot Project (OPP). Similarly, in the area around Faisalabad City, Anjuman Samaji Behbood, an NGO led by Mr Ahmed Nazir Wattoo, has implemented some rural sewerage schemes following the OPP approach. Other than these initiatives, which are small in the overall scheme of things, the PHED does cover some collector drains.

Few drainage schemes incorporate pumping and virtually no waste water from villages and small towns is treated. A significant percentage of waste water finds its way to ponds, from which it may drain and evaporate away although it is probably more common for waste water to overflow out of the pond or be pumped out of the pond for irrigation purposes. Studies by the International Water Management Institute (IWMI) suggest that 26% of all Pakistan's vegetable production relies on irrigation with waste water. Waste water may also be used to irrigate wheat although farmers in Gujrat District report that waste water irrigation has an adverse effect on rice cultivation. (Irrigation of rice paddy is also likely to have high health risks for workers). Although waste water irrigation occurs widely around larger towns and cities, there is no doubt that it is also found around villages. Some waste stabilisation ponds were provided under PCWSSP. Anecdotal evidence suggests that effluent disposal can be particularly problematic during the monsoon months and at harvesting times, when farmers do not want waste water and may block sewers and drains to prevent it from reaching their fields. (Figure 3)

1.6. Institutional Responsibilities for Sanitation

Responsibilities for sanitation are less clear than those for water supply. Until 2001, the LG&CDD was theoretically responsible for promoting improved household sanitation but the reality seems to be that its promotional activities were very limited. In practice, most households with sanitation have provided their own facilities, which normally consist of a pour-flush toilet discharging to an open drain.

The Punjab Local Government Ordinance (PLGO) requires Union Councils to maintain public sources of drinking water, including wells and ponds, and presumably by this token requires them to keep such sources free of contamination. However, there is no specific reference to promoting better sanitation. Similarly, TMAs are required to provide sewerage and sewage disposal infrastructure but the PLGO makes no reference to sanitation promotion. The PLGO says nothing on the specific responsibilities of District (Zilla) Councils.

Levels of Service and Standards

1.7. Drinking Water Quality Standards

The PDSSP Technical and Service Delivery Standards for Water Supply and Sanitation provide a wide range of information on different water quality standards. For planning and design of the proposed model water supply schemes, the Pakistan Standards Quality Control Authority (PSQCA) standards may be taken. These are generally based on WHO standards. PHED also has its own standards and where these are more stringent than the PSQCA standards, they should be followed. Standards with particular relevance to work on model schemes are listed in Table 1 below:

Table 1 - Some key drinking water quality standards

		PSQCA		PHED	
Pollutant	Unit	Desirable limit	Permissible limit	Desirable limit	Permissible limit
Total dissolved solids	mg/l	1000	1500	500	1500
Total hardness (CaCO3)	mg/l	20	500	100	500
Ph		7 – 8.5	6.5 – 9.2	7 – 8.5	6.5 – 9.2
Fluoride	mg/l	1.0	1.5	Not given	
Iron	mg/l	0.3	1.0	0.1	1.0
Manganese	mg/l		0.5	0.05	0.5
Nitrate (NO3)	Mg/l		10	Not given	
Arsenic	µg/l	10	50	Not given	
E.Coli		0/250ml		Not given but PHED aims to follow WHO standard (See below)	
Total coliform		0/250ml			

In some Districts, arsenic concentrations in shallow groundwater may exceed the 10 µg/l figure. It appears that this is generally considered acceptable, if not desirable, so long as the concentration does not exceed 25 µg/l. Indeed, the PWSSP Technical and Sewerage Delivery Standards note that many countries, including India and china, arsenic concentrations up to 50 µg/l are accepted in drinking water and suggest this figure as a permissible upper limit for Punjab. (1 µg/l is equivalent to 0.001mg/l).

The WHO bacteriological standards require that in 95% of the samples collected over a one year period, coliforms should be absent from 100ml of the sample. No sample should contain more than 10 coliforms per 100ml and no sample should contain escherachia coli (e.coli) in a 100ml. Coliform bacteria should not be detectable in two consecutive samples. The available information suggests that these standards are not being met by many rural water supply schemes at present. The aim should normally be to achieve the standards at the source and ensure that schemes are planned, designed and constructed in a way that minimises the risk of pollution occurring in the distribution system. This will require that pipes are durable and joints and connections are made in a way that ensures that the system is watertight.

1.8. Water Supply Technical Standards

The water supply technical standards as set out in the PDSSP Technical and Service Delivery Standards document are generally appropriate. However, some aspects of the standards should be reviewed. These are discussed below.

Assumed design life The design lives adopted for tubewells and water treatment facilities are based on the perceived operational life of those facilities. So, a design life of 15 years is adopted for tubewells on the basis that 15 year old tubewells are still operating satisfactorily while that for slow sand filters has been taken as 20 years on the basis that slow sand filters commissioned in the mid 1970s remained operative until the mid 1990s. This reasoning pays insufficient attention to the fact that the performance of a facility depends to a large extent on the way in which it is operated and maintained. Slow sand filters have been operating in London for over 100 years and continue to operate today. A distinction needs to be made between mechanical machinery, which should normally be designed for a life of 10 or at most 15 years, and civil works, which if properly designed and constructed may have a design life of 50 years or more. In the case of water mains, the design life depends on the material used. The PDSSP standard of a 20 year design life for distribution mains may be appropriate for galvanised steel mains but the design life of uPVC and particularly high density polyethylene (HDPE) mains should be longer, up to 50 years in the case of HDPE although it may be appropriate to take 30 years for financial comparison purposes. This is important as it will influence the economic calculations on which pipe material decisions are made.

Per-capita consumption The current PHED standards suggest that the design figure used for per-capita water consumption should increase with increasing design population in accordance with the following norms:

Design Population	Per-capita consumption - gals per day (including allowance for unaccounted for water)
Up to 5000	10 gallons
5,000 – 10,000	15 gallons
10,000 – 25,000 (without sewerage)	20 gallons
10,000- 25,000 (with sewerage)	30 gallons
25,000 – 100,000 (without sewerage)	40 gallons
25,000 – 100,000 (with sewerage)	50 gallons

The PDSSP standards propose that these norms should be replaced with one standard, that all schemes should be designed to achieve 50 gpcd. In principle, the PDSSP approach is sound. There is no reason in theory why people in a village of 4000 people should use less water than those in a town of 30,000, assuming that water is freely available in each case. Similarly, there is no theoretical or practical reason why water consumption in households with sewer connections should be greater than that of households served by pucca open drains. However, the figure of 50 gpcd is arguably much too high. It would mean that per-capita water production for domestic purposes will be higher than in many European countries and would require huge investment in water production facilities in order to meet the water supply needs of all of the population.

Actual average water consumption for metered schemes is much less. For instance, taking the average bill for Balkasar as Rs80 per month and the current domestic rate of Rs7 per cubic metre, average water-use is about 11.5 cubic metres per month. This equates to about 1500 litres per person for an average household size of 7.5, which in turn equates to an average daily demand of 50 litres (11.2 gallons) per person per day. This figure is only slightly above the current PHED design figure for villages with a population of less than 5000. This figure does not include allowance for leakage. The leakage figure for Balkasar is said not to exceed 5% but even allowing for a higher percentage leakage, say 20%, per-capita consumption will still be less than the 15 gpcd figure allowed by the PHED for schemes serving a population of up to 10,000.

Bearing these points in mind, it is suggested that the design standards for 'model' schemes should be 20 gpcd for metered schemes and 25 gpcd for unmetered schemes.

These standards allow for some increase in consumption over the average currently measured for metered schemes.

Peak factors The PDSSP standards propose that the peak daily demand should be taken as 1.5 times the average daily demand and that the peak hour factor should be taken as 1.5 times the peak daily demand, giving a combined peak factor of 2.25. These are fairly standard figures and are likely to be appropriate for schemes that deliver water 24/7. It will normally be necessary to use higher peak factors for schemes that deliver water intermittently. For instance, the peak hour factor for a scheme that delivers water for 4 hours a day will be at least 6[4]. If the peak day factor is still taken as 1.5, mains will have to be designed for an overall peak factor of 9. This illustrates one of the key disadvantages of intermittent schemes.

Minimum pipe diameter and cover The PDSSP standards follow the PHED standards in proposing a 3" (80mm) minimum pipe diameter for distribution and transmission mains, apart from in hilly areas where a 1½" (38mm) minimum diameter is recommended. In practice, there appears to be no technical reason why a minimum 50mm internal diameter should not be allowed for HDPE mains. PDSSP and PHED recommend a 3ft (900mm) minimum cover over water mains. While this is appropriate for trafficked roads, it may be possible and indeed desirable to reduce the cover in pedestrian lanes to perhaps half this figure, depending on the pipe material and diameter.

Overhead Reservoirs PHED's existing design guidelines state that overhead reservoirs should be provided where needed, with a capacity of 1/6th of the average daily demand, subject to a minimum size of 5000 gallons. The stipulation 'where needed' provides some discretion and many PHED engineers now design schemes that rely on direct pumping and do not include overhead reservoirs. The PDSSP standards state that overhead reservoirs are essential, except where the topography is such that they can be replaced by an appropriately located ground storage tank or tanks. They suggest a minimum capacity of 1/10th of the average day demand and a minimum capacity of 10,000 gallons. The PHED engineers are right to observe that overhead reservoirs may have limited utility on schemes that provide a limited intermittent supply. However, the ultimate aim should always be to provide water on a 24/7 basis and for a 24/7 scheme, overhead storage will be essential. The amount of storage provided will depend on the pattern of supply and demand. Storage equivalent to about 1/4th of the average daily demand is required to balance supply and demand when demand fluctuates over a 24 hour period and the supply is constant over that perriod. Rather less storage is required if the supply capacity is greater than the average daily demand so that supply does not have to be continuous but can be matched to demand. So, the minimum overhead capacity should be decided on the basis of analysis of demand patterns and supply arrangements.

[4] Although little evidence is available, it is probably reasonable to assume that flow variations during supply periods are limited for systems that provide water for short periods. So, in the case given, the peak hour factor can probably be taken as 6.

1.9. Sewerage Design Norms and Standards

PDSSP's recommended design lives for civil and electrical/mechanical works, 25 years and 10 years respectively, are reasonable. The design approach for sewers could usefully be reviewed. The peak factors given in both the PHED and PDSSP standards are fairly conventional, following an approach originally developed in the United states. However, measurements of actual flows in European conditions suggest that dry weather flow peak factors are likely to be rather lower, perhaps 2 – 3 for a population up to 5000, reducing to perhaps 1.5 for a population of over 100,000. Conversely, it is unrealistic to allow no provision for storm water ingress in rural areas[5]. In practice, infiltration should not be significant for sewers laid above the water table and can generally be ignored. The PHED and PDSSP manhole standards are almost identical and provide a good basis for manhole sizing. The possibility of using small inspection chambers on shallow branch mains should be further explored. PDSSP and the PHED recommend 3' and 2.5' earth cover respectively over sewers. While the PDSSP figure may be appropriate for sewers laid under trafficked roads, a reduced cover will often be appropriate in narrow non-trafficked lanes. The key point to note here is that the sewer should normally be deeper than the water main. All technical agencies in Pakistan recommend a 9" (228mm) minimum sewer diameter. There is no clear technical reason for this. A 6" (152mm) diameter sewer will provide more than enough capacity for branch mains, even for sewers designed to carry some storm water[6]. The reason normally given for specifying a larger minimum diameter is that smaller diameter sewers are more likely to block or will block more quickly. In fact, the smaller the diameter of the sewer, the greater will be its hydraulic efficiency for a given flow. It will be worthwhile to consider a revised approach to sewer design, starting from first principles and laying special emphasis on the need to keep unwanted materials and objects out of the sewers. This will require:

- careful attention to manhole and chamber cover design (in order to ensure that extraneous material cannot enter the sewer through broken or missing manhole covers)
- Exploration of alternatives to the presently used reinforced concrete pipes; and
- Consideration of sewer connection arrangements.

A pilot sewerage project is currently being planned and will shortly be executed in two lanes in Lahore's Walled City. This will use 6" diameter uPVC pipes, with 4" uPVC house connections, connected to the main sewer via 'Y' connections rather than at manholes. In the past, 'Y' connections have been considered inappropriate for sewers in Pakistan, partly because they are difficult to fabricate in reinforced concrete. However, they are used widely elsewhere and provide a smoother entry into the sewer and thus better

[5] Both sets of Guidelines are contradictory on this point, stating that sewers will be designed as partially combine and then saying that no allowance will be made for storm water for rural schemes.

[6] Indeed, 100mm (4") diameter sewers are routinely provided in schemes to serve low income areas in Brazil. These schemes are designed on the assumption that sewers will be separate, carrying only foul water, which is unlikely to be appropriate for Pakistan.

hydraulics than connections at manholes. The performance of the Walled City pilot system should be monitored and, if appropriate, it may be considered for branch mains in rural schemes, perhaps on a pilot basis in the first instance, provided that PVC pipes are used for both sewers and connections.

Institutions

1.10. PHED Operational Structure

The PHED operates in a partly centralised and partly decentralised way. Technical sanction powers of Executive Engineers working at the District level are limited and so final decisions on all bur fairly small schemes can only be made by higher level officials. There is a design section at the headquarters in Lahore and functioning water quality testing laboratories in Lahore, Rawalpindi and Multan. In all these respects, the organisation is centralised, although there have recently been moves to devolve water quality testing to District offices. However, in its day to day operations, the PHED appears to act in an essentially decentralised way. New schemes are identified and prepared at the District level and as such are the direct responsibility of the Executive Engineer and his staff. Once complete, they have to be checked and sanctioned at higher levels of the organisation but this does not alter the fact that responsibilities for scheme preparation lie at the Executive Engineer level.

Prior to 2001, the PHED was responsible for operation of all water supply schemes that had not been taken over by a WUC. In practice this seems to have meant the majority of schemes. Most systems had three staff, an operator, a valve man and a watchman, all of whom were PHED employees. Each system had its own bank account, which was managed by the PHED Sub-Divisional Officer (SDO), who was the signatory for the account. Customer payments were collected by the pump operator and valve man and remitted to the SDO, who paid them into the account. Salaries, electricity bills and other bills incurred in operating the system were paid from the account. As with design, operational systems thus operated in an essentially decentralised way. The number of failed schemes recorded in the 1990s suggests that this system did not work particularly well.

Since 2001, the PHED has had not remit for operation and maintenance and there are no posts within the structure that deal specifically with operational issues. Whatever the role of the PHED should be in the future, there is arguably a need to develop effective systems and procedures to provide support and oversight to local water supply and drainage system operators.

1.11. Limited Capacity of TMAs

One point to be taken into account when considering possible management arrangements for waste water dispoal, and indeed for water supply, is the limited technical capacity of TMAs. Most TMA staff are untrained and employed at low grades. For instance, only 1% and 3.3% of the staff employed by Rawalpindi TMA in 2004 were above grade 17 and in the range 11 – 16 respectively. No less than 92% of the TMA's staff were at grade 5 or below[i]. This situation is typical and is unlikely to have changed significantly since 2004. The key point is that TMAs do not have capacity to either manage or provide support and oversight for rural and peri-urban water supply schemes. A related point is that TMAs are financially dependent on transfers from higher levels of government and do not have the resources to support operation of village level water supply and sanitation schemes.

[i] Source – Rawalpindi Environmental Improvement Program (REIP), Institutional Development Sector Paper, Supplementary Paper 06, prepared by Izhar Ul Haq, April 2004.