

This discussion paper is/has been under review for the journal Drinking Water Engineering and Science (DWES). Please refer to the corresponding final paper in DWES if available.

Cost and impact analysis of preventive and remedial measures for safe drinking water

M. A. Tahir¹ and H. Rasheed²

¹National Water Quality Laboratory, Pakistan Council of Research in Water Resources, Kheyaban-e-Johar, H-8/1, Islamabad, Pakistan

²Pakistan Council of Research in Water Resources, Kheyaban-e-Johar, H-8/1, Islamabad, Pakistan

Received: 3 May 2012 – Accepted: 21 May 2012 – Published: 29 January 2013

Correspondence to: M. A. Tahir (matahir2k@hotmail.com) and H. Rasheed (hifzarasheed@mailcity.com)

Published by Copernicus Publications on behalf of the Delft University of Technology.

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Abstract

Preventive measures yield much higher cost effective benefits as compared to remedial measures. To verify this hypothesis, a survey was conducted in two different regions of Rawalpindi district of Pakistan by comparing the cost on medication and mitigation expenditures for reduction in the burden of water borne diseases. Water Quality monitoring of the study areas in comparison to WHO Drinking Water Guidelines revealed the satisfactory level of physico-chemical parameters, however; significant bacteriological contamination was found at 86 % of the monitored sites in Gujar Khan and 87 % in Murree region. A field questionnaire was used to estimate the expenditures on disinfection and sanitation and concluded that 8.09 % of total income of each family were spent by the inhabitants of the study area on medication for water borne diseases. Correlation was worked out between the rate of water related diseases (V_{WRD}), unsafe drinking water (C_{DW}), poor sanitation (P_S), unhealthy personal hygiene and environment (UH_{PHE}). A simulation model "Victim's Rate Calculator" was developed to forecast the estimated number of victims within a population. Findings of the study verified the hypothesis that preventive measures are better choice than remedial measures due to cost benefit ratio (1 : 1.6) with a clear advantage of 60 %.

1 Introduction

Lack of safe drinking water and sanitation is the single largest cause of illness in the world, contributing to the death of 5 million people a year and about 5000 children every day. On the other hand, 1 billion people lack access to water and 2.6 billion people – two in five people in the world do not have access to improved sanitation, defined as a simple pit latrine or better as reported by WHO and UNICEF (2005). Safe drinking water is a basic necessity and legitimate right of all human beings irrespective of their socio-economic status. Water-borne infectious disease caused by viruses, bacteria, protozoa and other microorganisms is associated with outbreaks and background rates

DWESD

6, 1–26, 2013

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



comparatively less expensive. This research concept is highly applicable in the drinking water sector with systematic integration of preventive measures.

It is more feasible and economical to improve or optimize the water supply infrastructure by adopting the cost effective water quality treatment techniques. Otherwise, it may create an obligatory situation for the Governments and other health related agencies to make huge investments on medication of diversified water borne diseases, hospital infrastructure and man power etc. The sufferings of the patients due to water borne diseases will also have direct and indirect consequences for masses along with other socio-economic problems in the society. Considering such unwanted situations, the objectives of the study were; to investigate the water quality problems and water related diseases in the selected study area; to co-relate the health hazards to poor water quality; to develop cost relationship between preventive and remedial measures and; to develop simulation model for the prediction of victim's rate in relation to water borne diseases. The outcome of this study negates the perception of most of the policy makers of developing countries that the sufficient funds cannot be allocated to improve water quality situations being a poor nation. However, situation in case of investments in water and sanitation sector in developed countries is more attractive due to better benefit to cost ratio as proved by this study.

2 Experimental section

The target areas for this case study consisted of Gujar Khan and Murree tehsils in Rawalpindi district. The district has five tehsils i.e., Gujar Khan, Kahuta, Murree, Rawalpindi, and Taxila having three topographical categories i.e. plain, semi hilly and hilly areas (Table 1).

Two types of field proforma were used: (i) village profile, which was used during the drinking water sampling, reflects the basic information regarding the village such as: household numbers, major occupations of inhabitants, type of roads, education and health facilities, literacy rate, ratio of male and female, water supply and sanitary

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



drainage system etc., In total, 10% of households were selected randomly from each village around the basic health units for using this village profile. (ii) Household profile, which was used to collect statistics on family members, family literacy rate, basic health facilities and sanitation. The type of information for compilation of these statistics included but not limited to: average income per family per month, distance of Basic Health Units (BHU) from home, availability of doctor and medicines, medication cost, when ill, the preference of patients to go for treatment i.e. Basic Health Unit, hospital, dispensary, homoeopathic, medical store or any other, suggestion for the improvement of Basic Health Unit, frequency of visit to BHU in a year for treatment, possible reason of illness due to diseases such as; Water Borne Diseases: (Typhoid, Cholera, Infective Hepatics, Dysentery, Enteric Diarrhocas), Water Washed Diseases: (Scabies, Trachoma, Dysentery), Water Based Diseases: (Schistosomiasis, Guinea Worm), Water Related Vector Diseases: (Malaria, Yellow Fever, Onchoarciasis), Chemical Based Diseases: (Methaemoglobinaemia, Fluorosis, Toxic Metal Sickness) and Sanitation Based Diseases:(Hook Worm, Ascariasis, Trichuris, Leprospiroris), charges of treatment other than BHU, number of illness suffering days, average loss of income per day due to ailment of respondent, drinking water sources, contamination sources and treatments available to respondent, types of sanitation/drainage facilities, if any available to the respondents. Based on the information collected through village and household profiles, data analysis was done to develop a relationship between comparative economic cost of health and drinking water treatment. A summary of such information is given in Table 2.

The information collected through this survey was utilized to develop correlation between water quality, expenditure to be incurred due to water-related diseases and expenditure to be needed for preventive measures. Based on this correlation, a simulation model in Microsoft Visual Basic backed by a Database built in Microsoft Access was developed to forecast the possible number of victims of water borne diseases within a given community.

DWESD

6, 1–26, 2013

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

[Title Page](#)

[Abstract](#)

[Introduction](#)

[Conclusions](#)

[References](#)

[Tables](#)

[Figures](#)



[Back](#)

[Close](#)

[Full Screen / Esc](#)

[Printer-friendly Version](#)

[Interactive Discussion](#)



3 Results and discussion

In total, 300 drinking water samples were collected from the study areas and analyzed for 22 basic physico-chemical and microbiological parameters (alkalinity, aluminum, bicarbonates, carbonates, calcium, chloride, copper, electrical conductivity, free CO₂, hardness, iron, magnesium, manganese, nitrate (N), pH, phosphate, potassium, sodium, Total Dissolved Solids, zinc, Total Coliforms and *E-coli*) in National Water Quality Laboratory of PCRWR. Analytical findings were compared with World Health Organization Drinking Water Guideline values (WHO, 2006) to conclude the contamination load.

There was no significant problem of chemical contamination in both the tehsils except slightly excessive Nitrate (N) in Gujar Khan and iron contents in Murree tehsil (Table 3), however; the bacteriological quality of drinking water in 06 villages (i.e Rajoha, Banote, Jajja, Jungal, Gojra and Baghana) of Tehsil Gujar Khan and in 04 villages (Jugial, Dhol Koni Dana, Durrah Gali, and Phagwari) of Tehsil Murree was evaluated as unsafe due to presence of Total Coliforms and *E-coli* (Figs. 1 and 2).

An analysis of data collected using field questionnaire on socio-economic aspects from households and basic health units revealed that 32.84 % populations were suffering from water borne and water related diseases in the area. The percentage distribution of water related cases included dysentery (23.79 %), diarrhea (5.37 %), scabies (21.48 %), malaria (20.46 %), hookworm (9.21 %), cholera (6.91 %), and goiter (6.65 %) and other water related diseases such as typhoid (1.79 %), ascariases (0.51 %) as detailed in Table 4.

Findings were actualized in respect of economic facts due to contaminated water supply on the basis of collected information. It was concluded that 8.09 % of total income of each family in Pakistan is being spent on medication of water related diseases based on correlation between expenditure incurred on medicine and total income of the family per month. The precise digest of this analysis is presented in Table 5.

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



For estimating the water treatment expenditures, water demand per capita was required. Minimum water quantity per capita is the estimate to be needed for maintaining human survival. Basic human requirements of water are given in Table 6 according to recommendations of Gleick (1999).

A review of studies from developed and developing countries (Howard and Bartram, 2003; Chenoweth, 2007; NRC, 1999; UNESCO, 2003; WHO, 2006) have suggested that an average of 10 to 20 l per person will meet basic needs. Minimum drinking water requirements have been estimated at about three liters per day under average temperature climate conditions. With changing climate and levels of activity, these daily minimum water requirements can also increase. However, domestic water requirement of many countries has been estimated below 100 L per person per day and is also assumed sufficient for domestic water requirement. Keeping in view of water quality data, estimates were calculated assuming 100 L water requirements per capita per day on the basis of low-cost, simple and dependable water treatment i.e., appropriate chlorination for the provision of safe drinking water to the inhabitants of the study area. Tri-Chloro-Iso-Cyanuric Acid (TCICA) is water-soluble (12 gram per liter at 25 °C) having 90% active Chlorine and is best for effective disinfection. Summing up, the overall water requirement 43 471 cubic meters per year is needed, 277 kg of TCICA for Chlorination of 1191 family members (155 families @ > 7 members per family) of study area at the rate of 100 L per capita per day. The details of expenditure to be spent for the disinfection process are as given in Table 7.

To improve 100% sanitation conditions, 155 toilets (one per each family) were required in that area. An amount of Rs. 11 574 (USD 178.00) was calculated for one low cost toilet with life span of 40 yr and having width and length of 4 × 4 feet, height of 7 feet with walls of 4.5 inches brick masonry (1 : 6 cement mortars), roof of 3 or 4 inches thick concrete slabs cover the whole toilet with WC ceramic. As the concrete structures have an average service life of 60 yr (Lemay and Leed, 2011), however, calculations are made on the basis of 40 yr life span depending on several environmental

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

[Title Page](#)

[Abstract](#)

[Introduction](#)

[Conclusions](#)

[References](#)

[Tables](#)

[Figures](#)



[Back](#)

[Close](#)

[Full Screen / Esc](#)

[Printer-friendly Version](#)

[Interactive Discussion](#)



and other factors. Horizontal and vertical X-sections of toilet are shown in Figs. 3 and 4, respectively. The cost of improved sanitation for 155 families is calculated as following:

i. Expenditure on 155 units = $11\,574 \times 155 = \text{Rs. } 1\,793\,970 \cong \text{USD } 27\,599.00$

ii. Cost per year for sanitation system = $1\,793\,970/40 = \text{Rs. } 44\,849 \cong \text{USD } 690$

Therefore, total cost to improve water and sanitation conditions in study area was Table 8.

In view of the above actualities regarding economic statistics collected through field questionnaire, it is unquestionably established that an amount of Pak Rs 2, 99 706 (USD 4611.00) was being spent on medicine per year to deal with water related diseases as remedial measures. However, some distinct and significant factors that can absolutely increase the estimation are not considered at this moment due to certain limitations. These factors include Loss of working hours, hardship for depended family members, expenditure on infrastructure for medical facilities, expenses on transportation and nutritional needs, manpower looking after the patients, reduction in life expectancy rate, Immunity loss and anxiety.

Concluding the above estimates, an amount of Pak Rs. 181 054 (USD 2785.00) was needed to improve water and sanitation facilities against the expenditure of Rs. 299 706 (USD 4611.00) in the study area, assuming no cost needed for the improvement of personnel hygiene and environment. The improvement in personnel hygiene and environment can easily be achieved through education by means of print and electronic media. Mosques in the target areas can also play an effective role in this regard. It may be concluded from the ratio (1 : 1.66) of both costs that the preventive measures are better choice for water supply improvement like polio handling in the developing countries.

The benefit-cost analysis is often used to determine the acceptability of various projects in the public sector. Conceptually, it is an analysis considering the worthiness of allocating resources to a project and the extent to which the benefits exceed the costs for the various alternatives. The mechanisms of the benefit-to-cost

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



comparisons are straightforward and simple for calculating the highest Benefit-to-Cost ratio (B/C). In this case, comparison between the Benefit (B = saving of the expenditures occurred to purchase medicines i.e., Rs. 2, 99 706 \cong USD 4611.00) and the Cost (C = Expenditure to be needed to improve water and sanitation facilities i.e., Rs. 181 054 \cong USD 2785.00) is very reasonable. Therefore, the determined Benefit-to-Cost ratio (B/C) = 299 706/181 054 = 1.66 (B/C > 1). B/C greater than 1, indicates a good alternative, which can be adopted as a better option in future projects by the policy and decision makers.

3.1 Victim's Vs drinking water, sanitation and PHE

Hypothetically and truly three main factors are considered to reduce water related diseases that are ultimately responsible for excessive motility (M) and morbidity (MO) rates. These include main factors Drinking Water, Sanitation, Personal Hygiene and Environment. The rate of water related diseases are directly proportional to unsafe water quality or contaminated drinking water (C_{DW}), poor sanitation (P_S) and unhealthy personal hygiene and environment (UH_{PHE}). We may make this statement in an alternative way that the contaminated water quality, poor sanitation and lack of personal hygiene and unhealthy environment can increase the victims' rate (V_{WRD}). Mathematically, it can be written as:

$$V_{WRD} \text{ rate } \alpha(C_{DW} + P_S + UH_{PHE})/3 \text{ or} \\ [V_{WRD} \text{ rate} = k(C_{DW} + P_S + UH_{PHE})/3] \quad (1)$$

Where k is a constant.

Victims' rate due to water related diseases (in three categories) in the study area and ratio for each category are calculated with the help of data shown in Table 9.

Share and ratio in three categories is self explanatory and presented as under:

- a. Share of diseases over total population in C_{DW} Category = 16.04 %
- b. Share of diseases over total population in P_S Category = 10.08 %

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

- c. Share of diseases over total population in UH_{PHE} Category = 6.72 %
- d. C_{DW} % in study area = 87 % (based on water quality assessment)
- e. P_S % in study area = 82 % (based on sanitation facilities from household profile)
- f. UH_{PHE} % in study area = 51 % (based on illiteracy rate from household profile)
- 5 g. V_{WRD} rate in the study area = 32.84 % (391 from 1191 population)
- h. V_{WRD} rate if C_{DW} (100 %) = $16.04/87 \times 100 = 18.44$
- i. V_{WRD} rate if P_S (100 %) = $10.07/82 \times 100 = 12.28$
- j. V_{WRD} rate if UH_{PHE} (100 %) = $6.72/51 \times 100 = 13.18$
- k. V_{WRD} rate = 43.9 % (Based on study)
- 10 l. Ratio ($UH_{PHE} : P_S : C_{DW}$) = 1.073 : 1 : 1.5

By putting these values in Eq. (1), we can find

$$[V_{WRD} \text{ rate} = k \{(1.5C_{DW} + P_S + 1.073UH_{PHE})/3\}] \quad (2)$$

Where k is a constant and is equal to 0.3687, which is derived from Eq. (2) by putting actual values from data as shown below:

$$15 \quad 32.84 = K[(1.5 \times 87 + 82 \times 1.073 \times 51)/3]$$

$$[V_{WRD} \text{ rate} = 0.3687 \{(1.5C_{DW} + P_S + 1.073UH_{PHE})/3\}] \quad (3)$$

With the help of the Eq. (3), victim's rate can be predicted respecting water-related diseases by putting values for C_{DW} (%), P_S (%), UH_{PHE} (%).

3.2 Simulation model for victim's rate

Victim's rate calculator was developed using Microsoft Visual Basic as a front-end program with Microsoft Access as a database. There are following three basic inputs in this program.

- 5 i. C_{DW} (Contaminated Drinking Water) in Percent.
- ii. P_S (Poor Sanitation) in Percent.
- iii. UH_{PHE} (Unhealthy Personal Hygiene and Environment) in Percent.

The final value for V_{WRD} can be calculated by putting values of these three inputs. The V_{WRD} Calculator verified against various statistics proved a useful programme for
10 estimating the number of Victims within a given population. The V_{WRD} is based on following formula:

$$V_{WRD} \text{ Rate} = K[(1.5C_{DW} + P_S + 1.073UH_{PHE})/3]$$
$$\{K = 0.3687\}$$

4 Conclusions

15 Despite the facts, that most of the diseases are waterborne and are responsible for higher number of morbidity and mortalities. Now it is a universally recognized that safe drinking water supplies, improved sanitation and better personal hygiene can improve the quality of life, human efficiency, effectiveness, mortality, morbidity and life expectancy rates. It is a bitter fact in developing and least developed countries that
20 neither the public nor the policy and decision maker are well aware of the gravity of the situation which may be prevailing due to less awareness, low literacy rate, political instability, socio-cultural problem, low priority to enhance their safe water supply coverage and lack of any model for economic feasibility between preventive and remedial

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



measures. Correlation between preventive and remedial measures proved the concept of taking preventive measures as the principal priority and is far better than treatment. B/C ratio (1.66, $B/C > 1$) also indicated a righteous alternative and is strongly recommended to implement this option in water and sanitation sector on the format of polio preventive treatment approach, which was adopted countrywide. This will uplift the standard of life of common and poor population. The computer simulation model for the prediction of victim's rate will also be helpful to create awareness and initiation of timely preventive actions. Gateways are open for further research studies in the similar sphere.

References

- APHA, AWWA and WEF: Standard Methods for the Examination of Water and Wastewater, American Public Health Association, American Water Works Association and Water Environment Federation, 21st Edn., Washington DC, 2–1 to 9–55, 2005.
- Chenoweth, J.: Minimum Water Requirement for Social and Economic Development, Desalination, 229, 245–256, 2007.
- Gleick, P. H.: Basic Water Requirements for Human Activities: Meeting Basic Needs, in: The Human Right to Water, Pacific Institute for Studies in Development, Environment and Security, USA, 84–88, 1999.
- Howard, G. and Bartram, J.: Domestic Water Quantity, Service Level and Health, World Health Organization Document Production Services, Geneva, Switzerland, WHO/SDE/WSH/03.02, 4–6, 2003.
- Lemay, L. and Leed, A. P.: Life Cycle Assessment of Concrete Buildings. Sustainable Development, NRMCA, Concrete Sustainability Report, National Ready Mixed Concrete Association CSR04-October, 2011.
- NRC: Recommended Dietary Allowances, 10th Edn., Subcommittee on the Tenth Edition of the RDAs, Food and Nutrition Board Commission on Life Sciences, National Research Council; National Academy Press, Washington, DC, USA, 247–250, 1999.

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Ray, B. D., Mazhari, H. K., Passah, P. M., and Pandey, M. C.: Population, Poverty and Environment in North East India, Noth East India Council for Social Science Research, Shillong, Concept Publishing Company, New Delhi, India, 318 pp., 2000.

Tahir, M. A.: Pollution Problems in the Water Supply Systems of Islamabad and Rawalpindi, Technical Report of the Pakistan Council of Research in Water Resources, Islamabad, Pakistan, 10–15, 1989.

UNESCO: World Water Assessment Programme, Water for People, Water for Life: The United Nations World Water Development Report, UNESCO Publishing, Berghahn Books, Paris, 7–23, 2003.

WHO: Guidelines for Drinking-Water Quality: incorporating first addendum, 3rd Edn., World Health Organization, Geneva, 210–459, 2006.

WHO and UNICEF: Joint Monitoring Programme for Water Supply and Sanitation, World Health Organization and United Nation's Children Education Funds, *Water for Life: Making It Happen*, 4–10, 2005, http://www.who.int/water_sanitation_health/waterforlife.pdf, last access: 21 December 2009.

DWESD

6, 1–26, 2013

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Measures for safe drinking water

M. A. Tahir and
H. Rasheed

[Title Page](#)

[Abstract](#)

[Introduction](#)

[Conclusions](#)

[References](#)

[Tables](#)

[Figures](#)

[⏪](#)

[⏩](#)

[◀](#)

[▶](#)

[Back](#)

[Close](#)

[Full Screen / Esc](#)

[Printer-friendly Version](#)

[Interactive Discussion](#)



Table 1. Water sources and topography.

Sr. #	Tehsil	Water Sources	Topography
1	Gujar Khan	Well, Tube well, Hand pump, Water supply and pond	Plain and semi-hilly area
2	Murree	Spring, well, water supply	Hilly area
3	Kahuta	Well, Hand pump, water supply, spring	Hilly area
4	Taxila	Well, Tube well, spring	Plain and semi-hilly area
5	Rawalpindi	Well, Tube well, Hand pump, water supply	Plain and semi-hilly area

Table 2. Important facts about study area.

1.	Total families interviewed	155 No.
2.	Total family members	1191 Nos.
3.	Literate	611 No.
4.	Literacy rate	51.30 %
5.	Average income per family per month	Rs. 1992
6.	Basic Health Unit:	
	i. Approachable	70.32 %
	ii. Non approachable	29.68 %
7.	Patients satisfied from BHU	15.48 %
8.	Patients not satisfied from BHU	84.52 %
9.	Drinking water sources;	
	i. Well	41.29 %
	ii. Spring	35.48 %
	ii. Hand Pump	20.65 %
	iii. Tap	4 %
10.	Families treating water with chemicals	12.26 %
11.	Families with proper sanitation and drainage	None
12.	Families using open field latrine	81.94 %
13.	Families using pit latrine	18.06 %
14.	Total numbers of water related cases	391
15.	Population suffering with water related diseases per year	32.84 %
14.	Annual medical expenditures on all families	Rs. 299 706 (USD* 4611.00)
15.	Annual medical expenditures per family	Rs. 1934 (USD* 30.00)

* 1 USD equivalent to Rs. 64.4 at the time of study.

DWESD

6, 1–26, 2013

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Table 3. Physico-chemical water quality of Gujar Khan and Murree Tehsils.

Sr. #	Parameters	Unit	Guideline Values	Gujar Khan			Murree		
				Mean	Max	Min	Mean	Max	Min
1	Alkalinity	m mol l ⁻¹	NGVS	7.67	15.6	2	5.55	8.2	3
2	Aluminum	mg l ⁻¹	0.2 (WHO)	0.08	0.3	0	–	–	–
3	Bicarbonates	mg l ⁻¹	NGVS	383	780	100	278	410	150
4	Carbonates	mg l ⁻¹	NGVS	0.69	10	0	0	0	0
5	Calcium	mg l ⁻¹	75 (KSA)	32	76	3	35	66	20
6	Chloride	mg l ⁻¹	250 (WHO)	129	1540	17.7	26	96	14
7	Copper	mg l ⁻¹	1 (WHO)	0.073	0.17	0	0.02	0.11	0
8	EC	μS cm ⁻¹	NGVS	983	5500	103	318	532	173
9	Free CO ₂	mg l ⁻¹	NGVS	0.67	1.1	0	0.99	1.9	0.27
10	Hardness	mg l ⁻¹	500 (WHO)	353	825	125	336	537	74
11	Iron	mg l ⁻¹	0.3 (WHO)	0.06	0.14	0	0.24	0.39	0.05
12	Magnesium	mg l ⁻¹	150 (Canadian)	26	89	3	47	29	5
13	Manganese	mg l ⁻¹	0.1 (WHO)	0.19	0.81	0	0.04	0.2	0
14	Nitrate (N)	mg l ⁻¹	10 (WHO)	11	72	0.3	–	–	–
15	pH	–	6.5–8.5	7.53	8.33	7.02	7.26	7.97	6.35
16	Phosphate	mg l ⁻¹	1–5	0.02	0.06	0	0.01	0.04	0
17	Potassium	mg l ⁻¹	NGVS	2.54	7.8	0.5	1.76	9.1	0.3
18	Sodium	mg l ⁻¹	200 (WHO)	185	1520	4	11	27	3
19	T.D.S.	mg l ⁻¹	1000	585	3280	61	189	317	102
20	Zinc	mg l ⁻¹	5 (WHO)	0.16	0.76	0	0.09	0.7	0.01

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Table 5. Economic facts due to unsafe water supplies (in Rupees).

Sr. No	Socio-Economic Facts	Share	
		Pak Rupees	USD*
1.	Annual Income of all families	3 705 600	57 009.00
2.	Monthly Income of all families	308 800	4751.00
3.	Annual Income of Single family	23 907	3678.00
4.	Average family income per month	1992	31.00
5.	Average income per person per year	3111	48.00
6.	Average income per person per month	259	4.00
7.	Average expenditure on medicines (Water Related Diseases) per family per year	1934	30.00
8.	Average expenditure on medicines per family per month	161	2.5
9.	Average expenditure on medicines per person per year	252	3.9
10.	Average expenditure on medicines per person per month	21	0.32
11.	Total expenditure on medicine (Water Related Diseases) per year	299 706	4611
12.	Expenditure percentage on medicine of total income	8.09 %	8.09 %

*1 USD equivalent to Rs. 64.4 at the time of study.

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

[Title Page](#)

[Abstract](#)

[Introduction](#)

[Conclusions](#)

[References](#)

[Tables](#)

[Figures](#)



[Back](#)

[Close](#)

[Full Screen / Esc](#)

[Printer-friendly Version](#)

[Interactive Discussion](#)



Table 6. Recommended basic requirements for human needs.

Usage	Recommended Lit./person/day	Range Lit./person/day
Drinking water	5	2 to 5
Sanitation services	20 to 75	–
Bathing	15	5 to 70
Cooking and kitchen	10	10 to 50
Total recommended basic water requirements	50	–

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

[Title Page](#)

[Abstract](#)

[Introduction](#)

[Conclusions](#)

[References](#)

[Tables](#)

[Figures](#)

[⏪](#)

[⏩](#)

[◀](#)

[▶](#)

[Back](#)

[Close](#)

[Full Screen / Esc](#)

[Printer-friendly Version](#)

[Interactive Discussion](#)



Table 7. Total cost for disinfection of drinking water in study area.

Sr. No.	Item	Per unit Cost (Rs)	Requirement	Total Cost	
				Pak-Rupees (Rs.)	USD
1	Tri-Chloro-Iso-Cyanuric Acid (TCICA)	277/–	300 Kg	83 205/–	12 800.00
2	Cost of Chlorinator	50 000/–	based on 10 yr life span	5000/–	77.00
3	Man power (Operator)	4000/–	12 months	48 000/–	738.00
4	Total Expenditures for safe water supplies per year	–	1191 family members (155 families @ >7 members/family)	136 205/–	13 615.00

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Table 8. Total cost for improvement of water and sanitation condition.

Sr. No	Cost	Total Cost	
		Pak-Rupees (Rs.)	USD
1	Safe water supplies per year	Rs. 136 205/–	2095.00
2	Improvement of sanitation facilities per year	Rs. 44 849/–	690.00
3	Total cost to improve water and sanitation facilities	Rs. 181 054/–	2785.00

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Table 9. Share in different categories.

Sr. No.	Water Related Diseases	Total Patients (No.)	Overall Share (%) of Each Disease from Total Population
<i>C_{DW}</i> Category (16.04 %)			
1	Dysentery	93	7.81
2	Enteric Diarrheas	21	1.76
3	Cholera	27	2.27
4	Typhoid	7	0.59
5	Goiter	26	2.18
6	Ascaries	2	0.17
7	Others	15	1.26
<i>P_S</i> Category (10.08 %)			
8	Scabies	84	7.05
9	Hook Worm	36	3.03
<i>U_{H_{PHE}}</i> Category (6.72 %)			
10.	Malaria	80	6.72

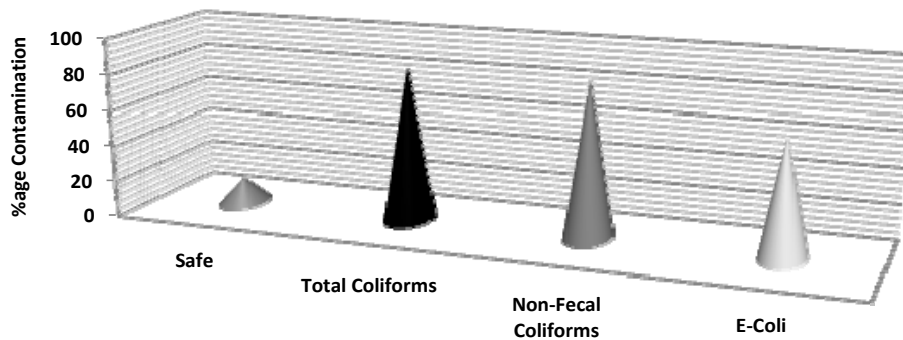


Fig. 1. Bacterial contamination in Gujar Khan.

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

[Title Page](#)

[Abstract](#)

[Introduction](#)

[Conclusions](#)

[References](#)

[Tables](#)

[Figures](#)

⏪

⏩

◀

▶

[Back](#)

[Close](#)

[Full Screen / Esc](#)

[Printer-friendly Version](#)

[Interactive Discussion](#)



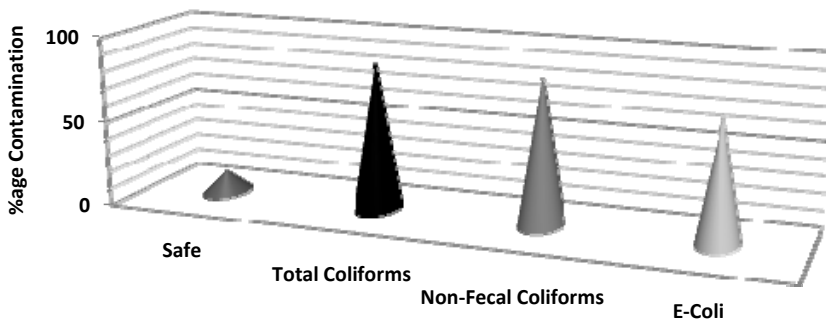


Fig. 2. Bacterial contamination in Murree.

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

[Title Page](#)

[Abstract](#)

[Introduction](#)

[Conclusions](#)

[References](#)

[Tables](#)

[Figures](#)

⏪

⏩

◀

▶

[Back](#)

[Close](#)

[Full Screen / Esc](#)

[Printer-friendly Version](#)

[Interactive Discussion](#)



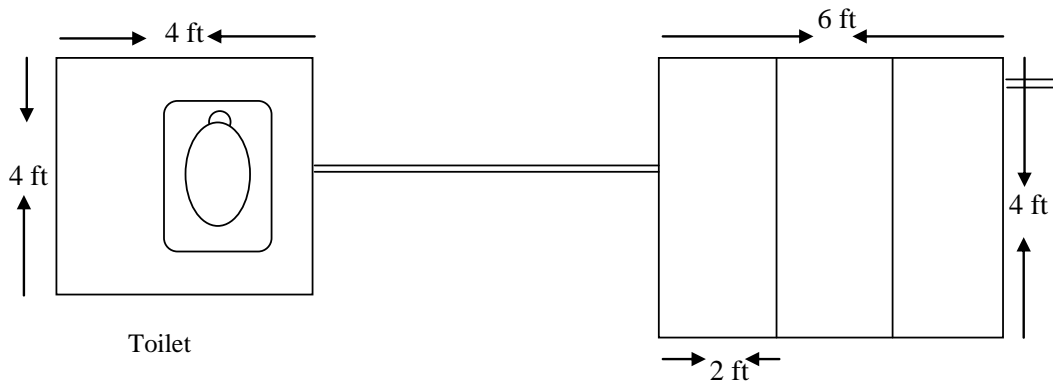


Fig. 3. Horizontal X-section of the Toilet.

Measures for safe drinking water

M. A. Tahir and
H. Rasheed

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

⏪

⏩

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Measures for safe drinking water

M. A. Tahir and
H. Rasheed

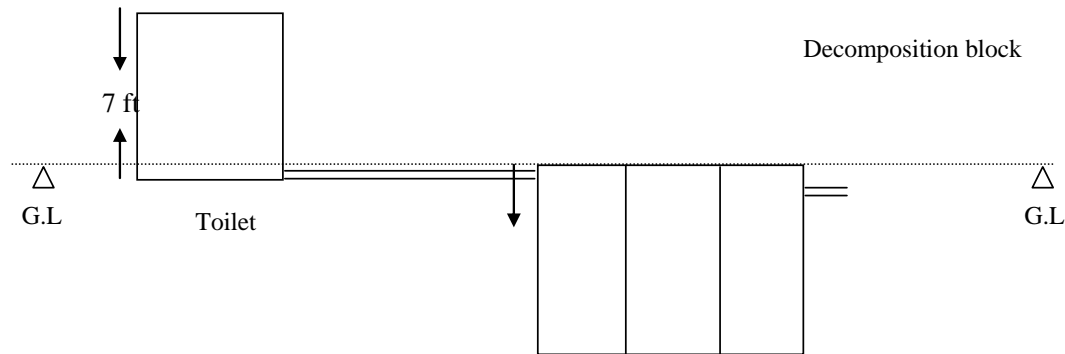


Fig. 4. Vertical X-section of the Toilet.

Title Page	
Abstract	Introduction
Conclusions	References
Tables	Figures
⏪	⏩
◀	▶
Back	Close
Full Screen / Esc	
Printer-friendly Version	
Interactive Discussion	

