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Community-based Water Quality Improvement in a Rehabilitated Slum Building

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Abstract

The Indian mega-city of Mumbai is undergoing a major makeover through large-scale shifting of slum dwellers from hutments to proper buildings with fixed size of dwelling units. This rehabilitated community of the urban poor is facing a high disease burden, apparently due to its poor sanitation and hygienic practices. This study conducted a baseline health survey, especially with regard to water borne diseases, along with water quality assessment, in a slum rehabilitated building of Mumbai. The health survey and water assessment indicated that while the rehabilitated slum dwellers had poor hygienic practices, the contamination of municipality-supplied water was causing significant health hazards for the residents. Some residents did use basic water disinfection processes like boiling, straining and chlorination, but with little positive impact on health quality. This study highlights the importance of sanitation and hygiene along with the significance of provision of better water quality. Quality of water supplied by the Brihanmumbai Municipal Corporation (BMC) being fairly good, the contamination of drinking water with sewer lines is indicated. For such problems, community-based treatment should augment household-level treatment of water.

Keywords: Household Survey; Drinking water; Contamination; Sanitation; Hygiene

Introduction

Water being an indispensable necessity of life, it is imperative that every human being has access to clean drinking water. However, for a large population of the globe, this remains either difficult to attain or actually impossible. According to a 2009 United Nations World Water Development Report, only 54% of the world's population had a piped connection to their dwelling, plot or yard, and 33% used other improved drinking water sources. The remaining 13% (884 million people) relied on unimproved sources. The rising populations are making matters worse. More than 60% of the world's population growth between 2008 and 2100 will be in sub-Saharan Africa (32%) and South Asia (30%) where the water stress is already severe. According to this report, an estimated 90% of the 3 billion people who are expected to be added to the population by 2050 will be in developing countries, many in regions that are already experiencing water stress and the current population does not have sustainable access to safe drinking water and adequate sanitation. The same report also mentions the fact that more than 5 billion people, i.e., 67% of the world population – may still not be connected to public sewerage systems in 2030 [1].

According to a WHO/UNICEF joint monitoring report of 2012, 11% of the global populations, i.e., 783 million people, are still without access to safe drinking water. The case of India is no different. India is the second most populated country in the world with over 1.2 billion people (Census of India, 2011). As the sources of freshwater are very limited, to provide water for all is an enormous challenge.

India has 97 million people without access to improved sources of drinking water, second only to China [2]. The 2001 Census reported that only 68.2% households in India have access to safe drinking water. Along with this, non-uniformity in the levels of awareness, socio-economic development, education, poverty, rituals, lack of accountability, and lack of a good civic culture also add to the problem of clean drinking water supply.

This speaks volumes about the need of a planned administration in providing clean drinking water at the government level. Article 47 of the Constitution of India speaks about "The duty of providing clean drinking water and improving public health standards to the State". The government has initiated various different types of programs since independence to provide safe drinking water to the masses. Till the tenth five year plan, 2002-2007, INR 1,105 billion has been spent on providing safe drinking water [3]. The global importance of water, sanitation and hygiene for development, poverty reduction and health has also been specifically mentioned in the eight Millennium Development Goals of the United Nations Millennium Declaration, in the reports of the United Nations Commission on Sustainable Development and at many international platforms.

The water distribution system in India is ridden with challenges. In the urban areas, especially in metro cities, the challenge is colossal due to the vast geographical area, high population density, and inaccessibility to many parts, like slums and *chawls*, resulting in poor water supply. Urban water delivery is also characterized by irregular delivery and pressure, lack of skilled manpower and solid infrastructure. The municipal boards are already over-subsidized and further expansion is beyond their capacity. The situation is especially complicated in a rapidly mushrooming city like Mumbai. Mumbai has often been called Slumbai or Slumbay as nearly 41.3% of its population resides in slums, according to the 2011 census [4].

Details of the present water supply system in Mumbai

According to the Chitale committee report (Table 1) [5], only 6222 MLD is available to Mumbai, while the demand is of 8316 MLD.

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This shows that the Mumbai Metropolitan Region (MMR) region has a deficit of 2094 MLD of water**.** Importantly, if we look at the water consumption pattern in slum and non-slum areas, as depicted in Table 2, it is evident that slums consume less water as compared to the non-slum area, despite a larger population density. The "Study of Mumbai MMR Sustainability: Housing and Transport" report also figures that though the slum population is much higher, their contribution towards wastewater generation is relatively less. The other major issue which emerges is that though the estimated water supply per capita is much higher, the actual per capita water available at the household level is lower. It indicates that this gap is due to leakage of water, pilferage or other reasons [6].

Water can be contaminated by organic materials such as animal carcasses, animal and human feces and sewage, food waste, plant matter, oil, petrol and grease or inorganic materials such as scrap metal, junk, sand and chemicals. The water supply also gets contaminated due to the entry of disease-causing germs or due to leakage in the sewer lines. USEPA report on 'Potential Contamination Due to Cross-Connections and Backflow and the Associated Health Risks' has mentioned the problems faced by the distribution system in typical cities. They are: microbial growth and biofilms, cross-connections, backflow, intrusion, corrosion, aging infrastructure, decay of water quality over distribution system residence time, contamination during infrastructure repair and replacement, nitrification, covered storage, permeation and leaching. Through cross-connections, backflow of non-potable water can mix with the potable one. Backflow can occur either due to reduced pressure in the distribution system (termed backsiphonage) or the presence of increased pressure from a non-potable source (termed backpressure). Backsiphonage may be caused by a variety of circumstances, such as main breaks, flushing, pump failure, or emergency firefighting water drawdown. Backpressure may occur due to heating/cooling or improper waste disposal. It may also occur when industrial manufacturing systems are connected to potable supplies and the pressure in the external system exceeds the pressure in the distribution system. During incidents of backflow, these chemical and biological contaminants have caused illness and deaths, with contamination affecting a number of service connections [7] (Table 3).

Regions	Name of the Dams	Available Water (mld)
Greater Mumbai	Modak sagar, Tansa, Upper vaitarna, Bhatsa,	3392
	Vihar and Tulsi	
Rest of Corporations		
Western Mumbai	Usgaon, Tansa river, Pelhar, Ulhas river	119
North eastern region	Ulhas river, Barvi, Chikhloli	1550
Navi Mumbai	Patalganga, Ransai, Hetawane, Barvi	479
Municipal Council		
Panvel- Uran	Ulhas river, Morbe, Dehrang	474
Pen- Alibag	Hetawane, Amba (Nagothane)	208
Total Water Supply (MMR)		6222

Source: Compiled from Dr. Chitale Committee Report 2003 and Environment Status of Brihanmumbai 2008-2009 [5]

Table 1: Water Supply System in Mumbai

	Non-slum	Slum
Greater Mumbai	127	50
Rest of Corporations Region	139	44
Municipal Councils	170	39

Source: NEERI Survey 2009 [5].

Table 2: Water Consumed Per Capita / Day (lpcd) in Mumbai (from base line survey)

Problems related to water

Apart from water supply, sanitation and hygiene are other decisive parameters for good health, survival, overall progress and reduction in the burden of disease from sanitation and hygiene. Hygiene refers to acts that can lead to good health and cleanliness, such as frequent hand-washing and bathing with soap and clean water. Safe drinking water together with proper hygienic practices is vital for reducing the burden of disease from sanitation and hygiene-related diseases. According to a WHO Report [1], almost one-tenth of the global disease burden can be prevented by improving the water supply, sanitation, hygiene and management of water resources. Such improvements reduce child mortality and improve health and nutritional status in a sustainable way.

According to the Centers for Disease Control and Prevention (CDC), water also plays a critical role in the spread of insect-borne diseases because many insects such as mosquitoes breed around water. Worldwide, over one million people die each year due to mosquito-borne diseases, most of them being young children in sub-Saharan Africa [8].

Around 10% of the total burden of disease can be prevented by improvements related to drinking water, sanitation, hygiene and water resource management. These diseases are diarrhea, malnutrition, intestinal nematode infections, lymphatic filariasis, trachoma, schistosomiasis, malaria, and drowning. Other quantifiable diseases linked to water resource development and management are dengue, Japanese encephalitis and onchocerciasis [9]. Diarrhea is the most important public health problem directly related to water and sanitation. About 4 billion cases of diarrhea per year cause 1.8 million deaths, over 90 per cent of them (1.6 million) among children under five. Repeated episodes of diarrheal disease make children more vulnerable to other diseases and malnutrition [10]. In 2000, diarrhea accounted for 17% of the 10.6 million deaths in children younger than five, and malaria for 8%. Ordinary diarrhea remains the major killer among water, sanitation and hygiene-related diseases, contributing to 43% of deaths. Sub-Saharan Africa and South Asia are the most affected regions [10]. It is estimated that around 37.7 million Indians are affected by water borne diseases annually, 1.5 million children are estimated to die of diarrhea alone and 73 million working days are lost due to waterborne disease each year as discussed by Khurana and Sen [11]. The World Health Organization (WHO) estimates that about 1.1 billion people globally drink unsafe water [12] and the vast majority of diarrheal disease in the world (88%) is attributable to unsafe water, sanitation and hygiene [13]. Poor hygiene is third on the list of the 20 leading risks factors for health burden in developing regions after unsafe water and sanitation [14].

Globally, improving water, sanitation and hygiene has the potential to prevent at least 9.1% of the disease burden (in disability-adjusted life years or DALYs, a weighted measure of deaths and disability), or 6.3% of all deaths. Children, particularly those in developing countries, suffer a disproportionate share of this burden, as the fraction of total deaths or DALYs attributable to unsafe water, inadequate sanitation or insufficient hygiene is more than 20% in children up to 14 years of age [10].

Malaria is a serious disease caused by the *Plasmodium* parasite

	Non-slum	Slum
Greater Mumbai	516	304
Rest of Corporations Region	563	37
Municipal Councils	200	5

Source: NEERI Survey, 2009 [5].

Table 3: Waste water generated by total population (MLD) in regions of MMR

carried by the *Anopheles* mosquitoes. Humans are infected when bitten by the mosquitoes. Each year, there are 300 million to 500 million cases of malaria throughout the world and about 1 million child deaths. Reducing the mosquito population in households and communities by eliminating standing water (caused by poor drainage and uncovered water tanks) can be an important factor in reducing malaria cases [10].

Investment in water is a long-term benefit, not only in terms of better health and good life span, but also with respect to the amount of money returned. For every $1 (USD) invested in safe drinking water and sanitation, the World Health Organization estimates returns of $3-34 USD [15]. A recent World Water Development Report ranked India 133rd among 180 countries in terms of water availability and 120th among 122 countries in terms of water quality [16].

This paper highlights the health and water quality assessment in the Network Park Compound (NPC) of the Shivaji Nagar Area, MHADA Colony. Shivaji Nagar is a slum rehabilitated building (SRB) in the eastern suburbs of Mumbai, India. The residents here have not received due attention from the town planners considering that though they have been provided with decent living apartments, they face the challenging problem of safe drinking water.

The Government of Maharashtra has tackled the problem of slum rehabilitation only partially. The population living here has frequently complained about water sanitation problems. According to them, drinking water is reportedly mixed with discharge from the drainage pipeline, and clean water is not being supplied to them.

To get an insight into the matter and for better understanding of the situation, these authors visited the site and conducted initial health assessment along with measurement of physico-chemical parameters of the drinking water samples from selected buildings of the location. To the best of the authors' knowledge, this is an exercise that has not been attempted before in the Mumbai rehabilitated buildings.

Objectives of the study

With this background, the study focuses on two primary objectives. First is to conduct a baseline survey and collect primary data about factors contributing towards the water problem. Currently, there is no updated information available on what people know, do and would like to do in relation to water, sanitation and hygiene. Secondly, the information collected through this baseline survey will aid in adopting the right approaches towards hygiene, education and environment, in particular for the access to adequate sanitation in the target area.

Methodology

The entire study has been divided into two broad parts - the health assessment study and water quality assessment. The main aim is to also assess the possible health burden reduction through community-based water treatment system.

Health assessment survey

4.1.1 Study area details: The Network Park compound has 60 buildings. Each of the 60 buildings has seven floors, and each floor has 12 apartments, making a total of 84 apartments per building. Out of these, 12 buildings where residents had complained of gastrointestinal ailments or waterborne diseases were randomly selected, along with two controls. Each household of the 12 selected buildings was assessed for health as per a standard questionnaire-based survey in accordance with WHO norms (Table 4).

Out of the total 12 buildings surveyed, 10 were taken as samples while two buildings represented the controls. The 10 buildings selected for target were named from B1 to B10. The criteria of selection of these buildings were their unhygienic conditions, maximum number of people affected and willingness of the residents. Here, the term people affected refers to the number of people that were affected by water borne diseases like diarrhea, typhoid, and jaundice or by unhygienic conditions like malaria and dengue. In buildings C1 and C2, it was observed that the walking space between the buildings was clean and hygienic with no fecal matter visible in the area. Hence, these two buildings were chosen as control. C1 and C2 buildings will henceforth be referred as control buildings while the others will be mentioned as target buildings in the rest of the paper (Figure 1).

Water quality assessment

To check the physicochemical properties of the water, water samples were collected from five buildings, based on availability of water in tanks, approachability of the tanks with safe staircases, willingness to participate of the residents, and complaints from the residents about quality of water. The samples were collected from B1, B3, B7, B9 and B10. From each building, the samples were collected from three points: two tanks at the ground level (L.H.S. and R.H.S.) and one overhead tank placed upon the roof of the building. These samples were tested for essential parameters as per Drinking Water Standards of BIS (IS: 10500: 1991). Sample collection, preservation and analysis were as per APHA guidelines (APHA 2005).

To ascertain the microbial contamination of the drinking water, samples were chosen randomly using a stratified random sampling process (stratified as per streets) and tested for the presence of Total Coliforms (TC) as well as Fecal Coliforms (FC) using the membrane filtration (MF) technique in 100 ml of sample. Water samples were collected in the pre – monsoon as well as in monsoon period. Water samples were collected aseptically in sterile PVC sampling bottles. The samples were transported within 1 hour of collection in an ice box to the laboratory for analysis. All samples were collected in triplicates.

Importantly, a few building tanks could not be approached because of poor infrastructure, i.e., safe staircases were not available for approaching the tanks or due to unavailability of samples. Water from such tanks could not be sampled, and these have been indicated by 'No Sample Collection' or NSC in the Tables.

Sr No.	Questions asked to Residents.
1	Number of family members in a family?
2	What is the main source of drinking water for members of your household?
3	What is the main source of water used by your household for other purposes such as cooking and hand washing?
4	Do you treat your water in any way to make it safer to drink?
5	What kind of toilet facility do members of your household usually use?
6	Has any of your family member been sick from waterborne diseases in the last 6months/ two weeks?
7	What and how many hand-washing facilities are available?
8	What water source is used for hand washing?
9	Is soap/ash/mud available?
10	What is condition of the house or nearby house?
11	Are feces visible in the area?
12	What is done with collected garbage?
13	What is the condition inside of water containers?
14	Are drinking water containers properly covered?

Table 4: Questions asked to the residents for baseline survey

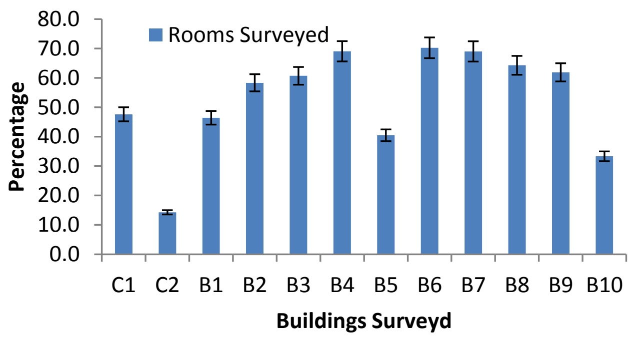

Figure 1: Percentage of total rooms surveyed in target buildings

Results and Discussions

As discussed, the Network Park compound area houses a total of 60 buildings. Of these, only 12 buildings along with 2 controls were selected as the study area.

The number of rooms surveyed in the target buildings ranged from 33% to 70%. All rooms could not be surveyed due to unavailability of the residents. In control buildings, it ranged from 14% to 47%. In these buildings, most of the rooms were vacant. These two buildings followed the strict regulation of not letting the rooms to ineligible candidates, i.e., only government-listed residents were allowed in. This is, in fact, a very good rule to follow as this in turn makes residents more responsible towards their society and makes them contribute more towards its welfare and growth.

However, in the target buildings, it was observed that there were many tenants. One common observation made during the visit was that the people living in the upper floors showed little concern about the ground floor residents. They were in the appalling habit of throwing garbage, kitchen waste and even fecal matter below, making the streets unfit for walking. Piled garbage could be easily noticed in this area.

For water supply, two tanks of 20,000 liter capacity each are placed at the two corners of the building at the ground level. For convenience, we have named them as Left hand side (L.H.S) tanks, and Right hand side (R.H.S) tanks. Water is pumped in the overhead tank with a 7.5HP pump. The water in each ground-level tank gets divided into four overhead tanks. From these four overhead tanks, water is supplied to the seven floors.

Health survey analysis

- **Source of drinking water:** The source of drinking water in all the buildings was piped water. The water is supplied from the Brihanmumbai Municipal Corporation (BMC) in the morning time for 3-4 hours. After that, the water is pumped into the four overhead tanks from where it gets distributed to all the households.
- **Main source of water used by the household for other purposes such as cooking and hand washing:** In this survey question, it was found that almost all the households use piped water. Only few homes bought packed drinking water, but its percentage was negligible. People generally stored the water in vessels and then used it for their daily activities.
- **Water collection time:** As the water was supplied directly through pipe, no one was involved in water collection from outside sources. Only when the water tasted foul or a clear contamination could be observed, few households preferred buying bottled water from the nearby shops. Else they opted for normal household disinfection treatment methods.
- **Kind of toilet facility and its sharing:** Each household had its own toilet with no sharing. The type of the toilet was pit latrine with slab.
- **Soap/ash/mud availability:** All the households used soap solution for hand wash as it is easily available. Also, being city residents, they were more exposed to media like T.V and radio and showed high awareness levels regarding the importance of hand washing and sanitation.
- **Condition of nearby Houses:** In the survey, we found that all the floors inside the apartments were very clean. However, the streets were piled up with garbage.
- **Collection of Garbage:** Daily door-to-door garbage collection is managed by the BMC, which also has the responsibility of cleaning the streets. Apart from the municipal people, most of the buildings have employed private staff for door-to-door garbage collection, considering the relative irregularity of the municipality staff. The collected garbage is then transferred to the nearby solid waste dumping ground. However, as people throw the garbage on the streets, it discourages many workers in their cleaning activity.
- **Conditions inside water containers:** The survey found that residents cleaned their water-collection vessels on a daily basis and also covered them properly.

Different disinfection methods employed at the household level

Treating water at the household level has been shown to be one of the most effective and economic measures for preventing waterborne diseases. Household water treatment and safe storage (HWTS) helps the populations to take charge of their own water in a better way. Because HWTS prevents recontamination of water at home, treating water at the household level is more effective than conventional improvement in water supply system for ensuring the microbiological quality of drinking water at the point of consumption, as discussed by Sobsey [17]. A more recent and comprehensive Cochrane review covering more than 38 randomized, controlled trials and 53,000 people in 19 countries found that household-based interventions were about twice as effective in preventing diarrheal disease (47%) than improved wells, boreholes and communal stand pipes (27%) [18,19].

In India, the common disinfection method to treat water ranges from boiling, adding bleach/chlorine, straining it through a cloth, use of water filter (ceramic, sand, composite, etc.) or allowing water to stand and settle.

Boiling of water: It was observed that many residents preferred the boiling of water. In target buildings, the percentage of people using this disinfection method ranged from 15.7% to 40.7%. In control buildings, this figure was from 25% to 42% approximately (Figure 2a). Overall, 28.6% test households boiled their water, which is comparable with that of control buildings (28.8%) (Figure 2b). As frequent boiling of water consumes electricity and gas, and many households are not financially sound enough, they prefer other modes of treating the water. Also, boiled water tastes slightly different, which is how some households explained their choice of other methods.

Straining of water through cloth: It is one of the commonest methods of treating water since it is cost free and convenient. In target buildings, 15% to 66% residents used this method while in control C1, more than half of the households opted for it (Figure 3a). In C2, no one reported using this method. As seen in Figure 3b, overall percentage in target and control buildings was similar –around 44.2% and 42.3%, respectively. In a few cases, straining was not through cloth but via a plastic filter fitting into the tap.

Use of water filter: Water filters are mostly popular in urban areas, but as they require frequent changing of the filter candles and are relatively more expensive, they are not common among the low income group residing in slum-rehabilitated buildings. Our observations supported this, with only 9%-32.9% of the target population opting for it. In the two controls, it ranged from 33%-62%, which is fairly good (Figure 4a). The overall percentage of households using the water filter was a mere 19.5% while in the two controls, it was approximately 56%, which is a very significant difference (Figure 4b). This shows that the residents of these buildings were more concerned and committed towards water issues apart from inculcating hygienic behavior.

Let the water stand and settle: Few people living in the rehabilitated buildings are not much inclined towards spending money for water-related issues. They use it directly, i.e., let it settle for 20-30 minutes and then use it for drinking and other purposes. This may be due to poor financial conditions or apathy. 19% to 47% (Figure 5a) people directly used the water. Most of the surveyed households cited economic constraints as an explanation for this attitude. In the control population, a mere 3.8% (Figure 5b) went for this option.

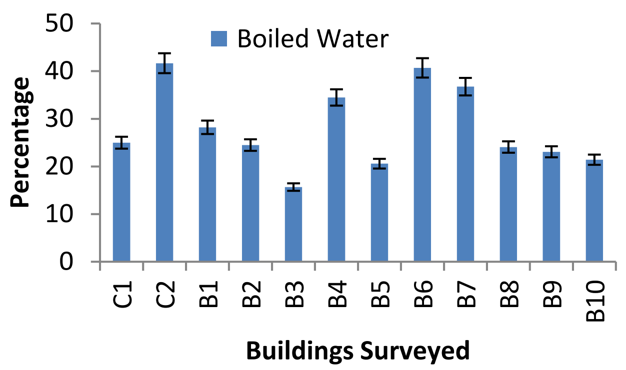

Figure 2a: Percentage of surveyed households using boiled water as disinfection method

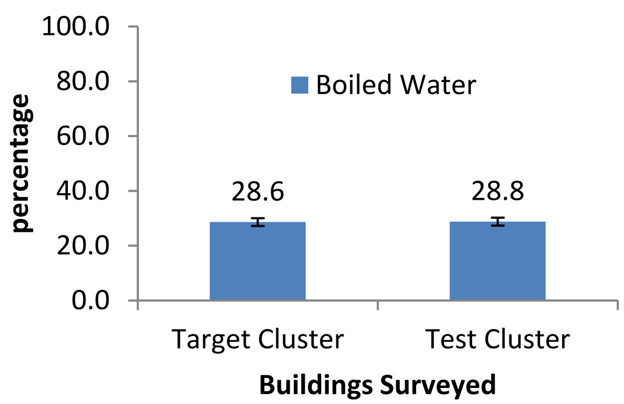

Figure 2b: Comparison between target and control households using boiled water as disinfection method

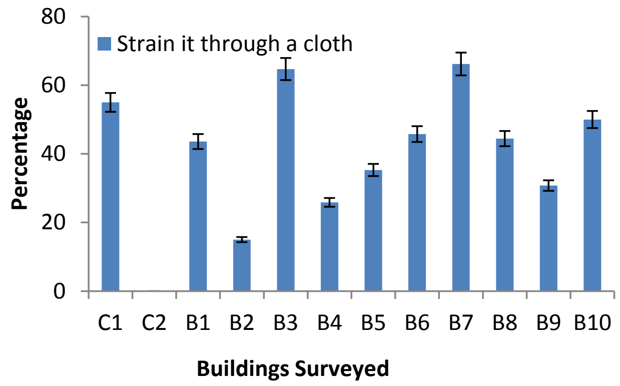

Figure 3a: Percentage of target and control cluster opting for water treatment by straining through cloth

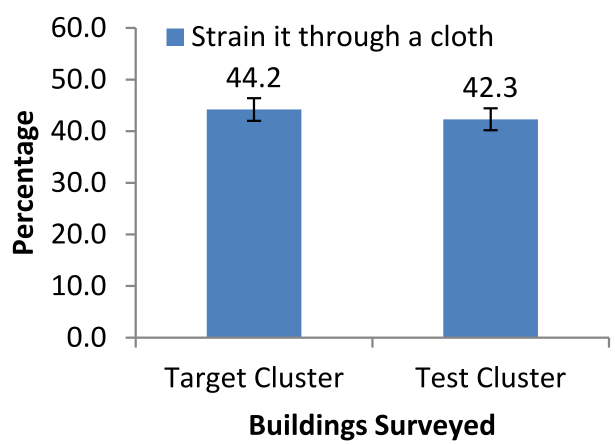

Figure 3b: Comparison between target and control households using cloth strained water as disinfection method

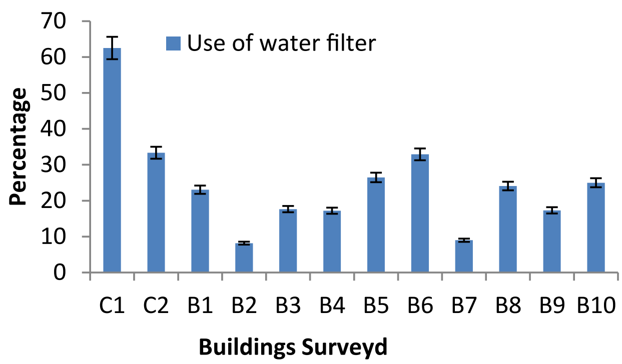

Figure 4a: Percentage of target and control cluster using water filter

Addition of bleach/chlorine: For more than 100 years, chlorine has been used around the world to disinfect drinking water supplies [20]. Chlorine is simple, effective and relatively inexpensive. It also provides protection against contamination by micro-biological organisms. This makes it a very popular disinfectant worldwide. A recent WHO-sponsored analysis also concluded that household-based chlorination

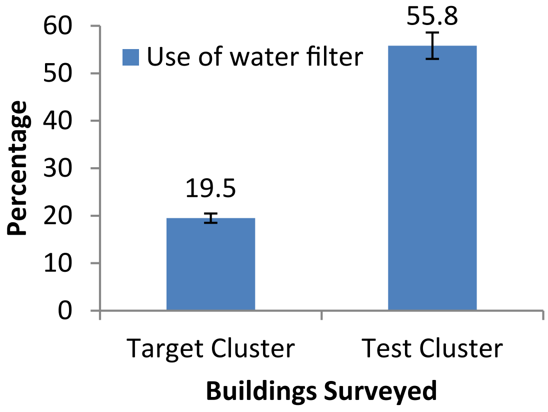

Figure 4b: Comparison between target and control households using water filter

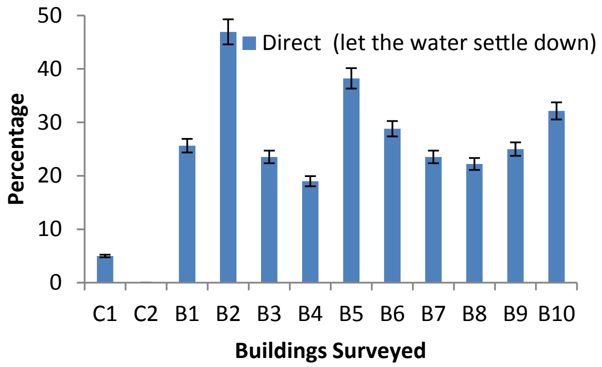

Figure 5a: Percentage of target and control cluster going for direct use of water

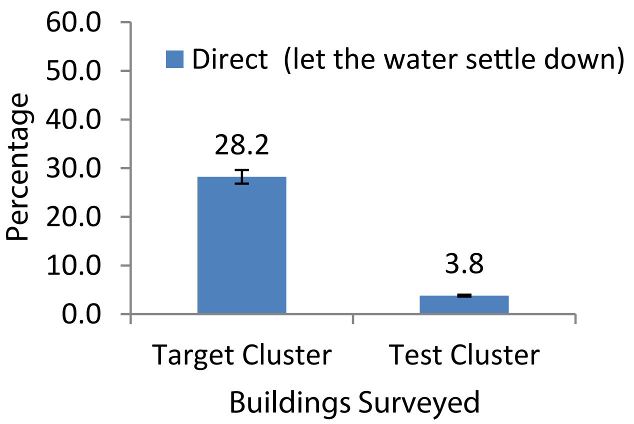

Figure 5b: Comparison between target and control households going for direct use of water

was among the most cost-beneficial of the various options for pursuing the Millennium Development Goals (MDG) water and sanitation targets, yielding high returns on every dollar invested, mainly from lower health care costs and also increased productivity and value of school attendance [21].

However, it was observed that only 1%-15% (Figure 6a) of the target population went for this option. In the control buildings, a mere 7.5% of the population was using this disinfection method. This may be due to a lack of awareness, or unwillingness to pay (Figure 6b).

Water quality analysis

All the samples were colorless, odorless and tasteless. The pH, conductivity, turbidity and total hardness of the water were within the permissible limits of drinking water. In the summer season, residual chlorine could not be traced in any of the water samples, leading to the presence of microbial contamination, as indicated by the presence of Total Coliform (TC) and Fecal Coliform (FC). However, in the monsoon water sample collection, few buildings showed the presence of residual free chlorine, which can be correlated with the absence of TC and FC in those buildings, as shown in the above results (Table 5).

In the study area, there is only a single line of separation between the collection tank (L.H.S and R.H.S) and the nearby sewerage line. Due to reduced or increased pressure in the sewerage line, backflow or backsiphonage occurs, as discussed above in the introduction section. This may result in cross-contamination of the collection tank with the sewerage line, leading to the presence of total and fecal coliforms in the sample. There is also a probability of household contamination from dirty vessels, and unhygienic water handling practices. At the household level, contamination of stored water is even more common. In one of the pilot countries, only 43.6% of samples from stored water were in compliance with the WHO guideline value and national standards, and more than half of the household samples showed post-

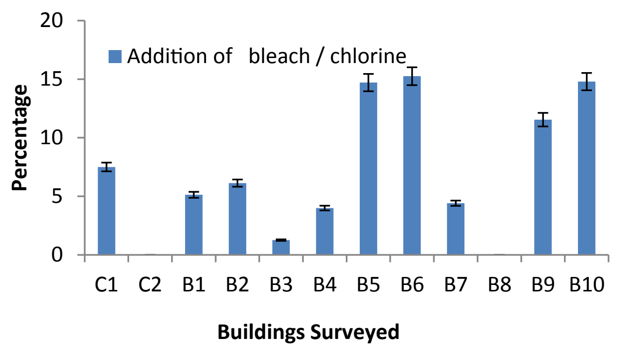

Figure 6a: Percentage of target and control cluster using Chlorine/ Bleaching powder

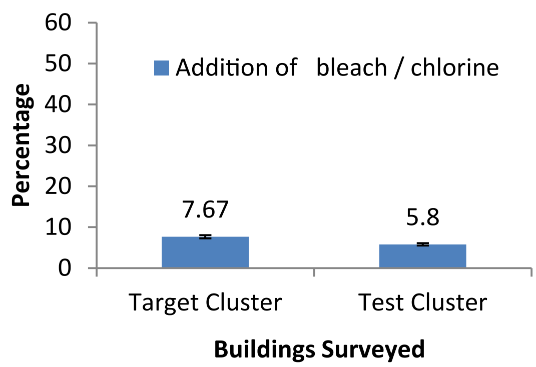

Figure 6b: Comparison between target and control households using Chlorine/bleaching powder

Building No	Place of Collection	pH	Conductivity	Turbidity (mg/l)	Chloride (mg/l)	TC/ 100ml	FC/ 100ml
Pre-Monsoon Season							
B1	L.H.S	6.5 ± 0.06	143 ± 1.00	1.32 ± 0.01	8.9 ± 0.15	12 ± 1.00	4 ± 1.00
	R.H.S	6.5 ± 0.10	281 ± 1.00	1.14 ± 0.02	7.9 ± 0.10	10 ± 0.58	5 ± 0.5
	Overhead Tank	6.5 ± 0.21	149 ± 1.53	1.22 ± 0.01	7.9 ± 0.21	16 ± 1.53	6 ± 1.15
B3	L.H.S	6.6 ± 0.10	96 ± 0.5	2 ± 0.15	8.9 ± 0.10	30 ± 1.5	6 ± 1.53
	R.H.S	6.5 ± 0.00	101 ± 1.73	2.03 ± 0.02	8.9 ± 0.25	32 ± 2.52	4 ± 1.00
	Overhead Tank	6.7 ± 0.17	104 ± 1.00	9.67 ± 0.05	8.9 ± 0.17	40 ± 2.08	8 ± 1.53
B7	L.H.S	6.7 ± 0.10	83 ± 2.00	0.94 ± 0.02	8.9 ± 0.10	42 ± 2.5	16 ± 2.52
	R.H.S	6.8 ± 0.26	93 ± 3.21	1.44 ± 0.02	7.9 ± 0.10	Nil	Nil
	Overhead Tank	NSC	NSC	NSC	NSC	NSC	NSC
B9	L.H.S	NSC	NSC	NSC	NSC	NSC	NSC
	R.H.S	NSC	NSC	NSC	NSC	NSC	NSC
	Overhead Tank	6.5 ± 0.3	93 ± 2.00	1.22 ± 0.00	7.9 ± 0.20	4 ± 0.10	1 ± 0.00
B10	L.H.S	NSC	NSC	NSC	NSC	NSC	NSC
	R.H.S	6.5 ± 0.10	91 ± 1.50	0.72 ± 0.00	10.9 ± 0.20	50 ± 2.10	16 ± 1.50
	Overhead Tank	6.5 ± 0.15	201 ± 1.00	2.3 ± 0.21	8.9 ± 0.21	38 ± 1.53	12 ± 0.58

					Monsoon Season				
Bldg.No	**Place of Collection**	**pH**	**Cond.**	**Turbidity (mg/l)**	**Chloride (mg/l)**	**ResidualChlorine (mg/l)**	**Total-Hardness (mg/l)**	**TC/ 100 ml**	**FC/100 ml**
B1	L.H.S	6.5 ± 0.06	281 ± 1.00	2.51 ± 0.10	9.9 ± 0.15	Absent	0.8 ± 0.01	16 ± 1.08	4 ± .0.10
	R.H.S	6.7 ± 0.00	142 ± 2.00	1.32 ± 0.02	8.9 ± 0.30	Absent	0.7 ± 0.10	20 ± 2.00	5 ± 0.60
	Overhead Tank	6.6 ± 0.10	147 ± 3.1	1.38 ± 0.05	10.9 ± 0.1	Absent	0.6 ± 0.2	2 ± 0.60	Nil
	Room	6.5 ± 0.10	146 ± 3.00	2.86 ± 0.04	8.9 ± 0.40	Absent	0.7 ± 0.1	6 ± 1.00	1 ± 0.60
B3	L.H.S	6.7 ± 0.10	102 ± 1.50	1.49 ± 0.02	9.9 ± 0.2	Absent	1.1 ± 0.1	35 ± 1.5	8 ± 1.0
	R.H.S	6.7 ± 0.2	98 ± 2.00	0.85 ± 0.02	8.9 ± 0.2	Absent	1.3 ± 0.2	30 ± 1.0	8 ± 1.2
	Overhead Tank	7.0 ± 0.1	102 ± 3.50	1.21 ± 0.02	9.9 ± 0.1	Absent	1.0 ± 0.0	25 ± 3.5	5 ± 1.5
	Room	7.0 ± 0.2	99 ± 1.5	0.91 ± 0.02	8.9 ± 0.2	Absent	1 ± 0.2	13 ± 2.1	3 ± 1.00
B7	L.H.S	7.0 ± 0.00	93 ± 2.1	1.24 ± 0.02	8.9 ± 0.3	0.25 ± 0.02	0.9 ± 0.2	Nil	Nil
	R.H.S	6.9 ± 0.1	84 ± 2.00	0.71 ± 0.02	10.9 ± 0.2	0.25 ± 0.05	0.8 ± 0.1	Nil	Nil
	Overhead Tank	7.0 ± 0.1	82 ± 0.6	0.86 ± 0.03	11.9 ± 0.2	0.25 ± 0.01	1.0 ± 0.0	Nil	Nil
	Room	7.0 ± 0.0	93 ± 0.60	1.1 ± 0.02	11.5 ± 0.30	0.25 ± 0.01	0.5 ± 0.10	Nil	Nil
B9	L.H.S	6.4 ± 0.30	88 ± 2.6	0.4 ± 0.04	10.9 ± 0.20	0.25 ± 0.0	0.5 ± 0.1	Nil	Nil
	R.H.S	6.3 ± 0.20	81 ± 1.0	3.13 ± 0.03	8.9 ± 0.20	0.25 ± 0.02	0.4 ± 0.1	Nil	Nil
	Overhead Tank	6.0 ± 0.0	93 ± 1.5	2.39 ± 0.03	9.9 ± 0.10	0.25 ± 0.0	1.2 ± 0.1	Nil	Nil
	Room	6.0 ± 0.10	98 ± 2.60	3.36 ± 0.03	10.9 ± 0.20	0.25 ± 0.01	1.2 ± 0.2	Nil	Nil
B10	L.H.S	6.5 ± 0.1	91 ± 2.60	1.09 ± 0.1	9.9 ± 1.20	0.25 ± 0.0	2 ± 0.1	Nil	Nil
	R.H.S	6.6 ± 0.1	144 ± 1.5	0.67 ± 0.02	9.9 ± 0.1	0.25 ± 0.02	1.9 ± 0.0	Nil	Nil
	Overhead Tank	7.0 ± 0.1	201 ± 1.00	4.08 ± 0.03	9.9 ± 0.1	0.25 ± 0.03	1.1 ± 0.1	Nil	Nil
	Room	6.2 ± 0.1	104 ± 1.5	0.48 ± 0.04	8.9 ± 0.1	0.25 ± 0.01	0.9 ± 0.1	Nil	Nil

All samples collected were colorless, odorless and tasteless.
Symbols used: NSC means No Sample collection
L.H.S: left hand side tank
R.H.S: Right Hand side tank
Overhead Tank: tank at the overhead, collected form one overhead tank only, out of four

Table 5: Physico-Chemical Analysis of water samples carried at Network Park Compound for the pre-monsoon and monsoon Season

source contamination. This is consistent with a large body of research worldwide that has shown that even drinking water which is safe at the source is subject to frequent and extensive fecal contamination during collection, storage and use at home [22].

People affected due to water borne diseases and unhygienic conditions

Interestingly, the percentage of affected people varied from 19% to 47% in the target buildings while in the two controls it was in the vicinity of 40% (Figure 7a). In other words, both test and control populations were almost equal as far as overall effect was concerned (Figure 7b). Though the control population followed very good hygiene practices and maintained their society fairly well, a significant percentage of people were affected by gastrointestinal infections. This might be due to the contamination of water by the nearby sewer lines.

Intervention

Studies have shown that household water handling, clean utensils, type of utensils, together with good sanitation practices play a significant role in the risk associated with outbreak of water borne illnesses. An intervention study in Zimbabwe found that homes where traditional drinking water containers are replaced with covered, narrow mouthed urns with a tap outlet have significantly less contamination than the control group [23]. A combination of special storage vessels with point of use treatment has given very promising results [24]. The study also found that fecal contamination in households using a specially designed safe water storage container alone, but not in households using both the container and a 5% calcium hypochlorite solution [24]. In Calcutta, India, the introduction of a narrow-mouthed and covered container from which water was poured significantly reduced cholera

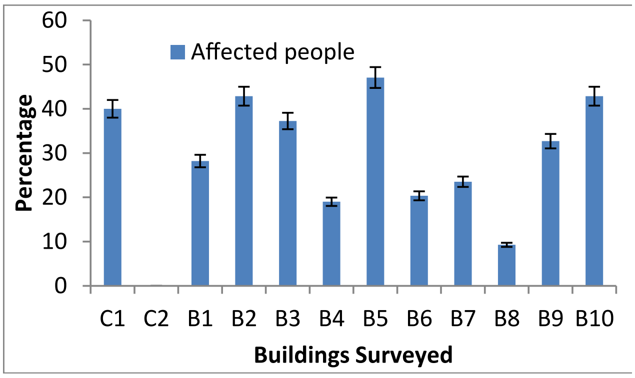

Figure 7a: Percentage of affected people in target and control cluster Bleaching

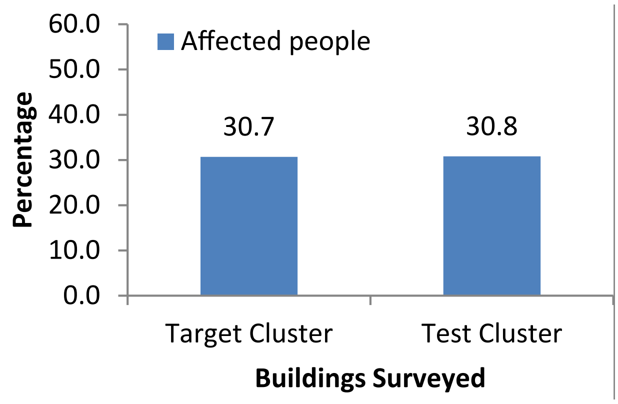

Figure 7b: Comparison between Percentage of affected people in target and control cluster

contamination [25]. In a study of randomized control trials in Pakistan, it was observed that hand washing initiatives and the introduction of point-of-use disinfection can reduce diarrheal incidence [26]. A Cochrane review of the efficacy of hand washing interventions concluded that diarrheal incidences may be reduced by about 30% [27]. Other factors such as number of residents in a household and presence of sewage in streets have been associated with feco-orally transmitted parasitic diseases [28].

Nevertheless, in this case, it is a clear case of high level microbial contamination. Hence, to provide clean drinking water on a long-term basis, community level water disinfection treatment would be very economical and effective, to augment household level water treatment process. To provide clean drinking water to the residents, on a pilot scale, water purifying devices like Ozonator, NaDCC (Sodium Dichloroisocyanaurate)-based water filters; sand and activated carbon-based filter, and UV irradiation and chlorinators were installed. Based on the economic feasibility and efficiency in water treatment process, these filters will be compared and the best one will be implemented in the entire study area (Table 6) [29].

Sr. no	Water treatment Method	Cost/person/ year
	Solar Disinfection	US$0.63
	Chlorination	US$0.66
	Ceramic Filters	US$3.03
	Combined	US$4.95
	Flocculation/Disinfection	US$4.95
	Installing & Maintaining Wells, borehole and Communal Tap Stands in Africa	US$1.88

* The combination of lower cost and higher effectiveness renders household-based chlorination the most cost effective of water quality interventions to prevent diarrhoea, with a cost effectiveness ratio in Africa of US$53 per disability-adjusted life year (DALY) averted, compared to US$123 for conventional source-based interventions [29].

Table 6: The cost of implementing water quality interventions varies as per table*

Conclusion and Policy Recommendations

It is evident from the health survey assessment that it is the habit of inculcating cleanliness and hygienic condition that is responsible for a clean neighborhood and better health quality. . Control buildings were observed to be much cleaner as compared to the target buildings due to better hygienic practices. This may only be attributed to the practice of clean habits and a will power to keep the society clean. During monsoon season, drainage pipeline should be cleaned on a regular basis and any scope of mixing with the drinking water supply should be completely avoided.

Besides, basic treatment of the water at the community or household level by chemical disinfection using chlorine, filtration using simple household filters, and boiling should also be promoted. These interventions may have a great impact on the health of the residents.

The findings from this study act as an eye-opener regarding the quality of water in the rehabilitated buildings of Mumbai. However, more sampling of different water sources in other such buildings is highly recommended. Proper measures should be drafted for periodic monitoring and stricter implementation of sanitation and hygienic activities. Moreover, at definite time intervals, the old and rusted pipelines should be replaced by the new ones. At the administrative level, there should be proper planning during the construction of SRA buildings. Sewerage lines should not be placed near the drinking water collection tank. Apart from this, concrete steps should be taken for significantly improving the situation. The need of the hour is to change the mindset and overall inculcation of civic behavior. All this will certainly help in improving the current situation. Qualitative and quantitative measures along with better reformed, time-suited administrative reforms, and the introduction of advanced technology is required to provide better quality of drinking water to the inhabitants.

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