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Risk of bacteriological quality deterioration of potable water in the state initiated public housing schemes

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The occupants in public housing schemes in the City of Colombo receive treated potable water from the National Water Supplying Authority. The water is subjected to online contamination via several sources posing recipients at risk from waterborne diseases. The vulnerability of related health hazards are.high in urban communities living in housing schemes with high population densities, under poor sanitary conditions and depend on single water source. The research focused on determining the violations of WHO guidelines for potable water for bacteriological quality and associated risks in six housing schemes built mainly for underserved, low and middle income communities in Colombo. The study reveals violations of 30.85%, 16.31% and 2.48% free chlorine residual, total coliforms and fecal coliforms respectively at household end with high sanitation risk demanding strong in-scheme condominium property management with special environmental health and sanitation system via strong community mobilization and community –authority management partnership.

Introduction

In Sri Lanka, Colombo is the most densely populated City. As Land becomes the limitation for development due to increased urbanization trend, multi-storeyed apartments are becoming popular among urban residents. A common feature in these schemes is the high population density in a smaller space supported with basic infrastructure such as water, electricity, waste disposal facilities and roads etc.

These schemes receive treated potable water through the Greater Colombo piped water supply, provided by the National Water Supply & Drainage Board (NWS&DB). The ultimate quality of water received by households depends on the manner it is treated, stored and distributed within the scheme. The treated water could get re-contaminated by several means if the in-scheme water storage & supply system are not properly managed and safe guarded against on-line recontaminations. The potential risk of health hazards associated with potable water can be considered highly significant in urban public housing schemes with poor environmental sanitation especially in relation to in-scheme waste management. Number of factors mentioned bellow coherent to urban multistoried apartments can aggravate the potential risks even higher.

1. In each housing scheme, a large number of households (families with high household size) consume water from a single in-scheme source. In other words consumer density per source is high.
2. High pressure from urban pollution, poor off site and onsite waste management, design, construction and maintenance issues of in-scheme supply structures are causing risk of online contamination and are in an increasing trend. In the city of Colombo underground sewage lines are laid to take away the city sewage. The system is still relying largely on the originally placed structures of about 100 years old. This system is under degenerated conditions and hence has leaks, subjected to regular over flowing and clogging
3. Colombo is experienced with high intensity rainfall with long wet periods. Hence the water table is shallow and the area is subjected to frequent flooding during high intensity rain spells. This situation together with poor urban waste management could further increase the risk of online contamination because feacaly contaminated rain washouts, polluted surface & subsurface runoff would enter in-scheme distribution system especially via fractured underground sumps and leaking distribution lines.

4. The quality of Greater Colombo potable water distribution is regularly monitored by the NWS & DB to ensure its safety incompliance with national standards for potable water quality. However, the quality in the in-scheme supply of these housing schemes is never monitored. Therefore, the ultimate quality and the safety of potable water received by the consumer are unknown.
5. Poor in-scheme environmental health and waste management in public housing schemes could be considered as the principle cause responsible for contamination of potable water in the distribution system. Similar situation occurs in sewer lines of public housing schemes. The human excreta collected from toilets are disposed through closed sewer lines to the main sewers. However, these sewer lines can sometimes get blocked and over flowed. The groundwater and surface water can become contaminated from the excreta of stray animals too in the scheme and surrounding environment. Stray animals such as cats, dogs, cattle, rats & mice, pigeons, and craws are the commonest in many housing schemes. The excreta of these animals may contaminate the ambient water and thereby could find their way into water distribution lines. Many public housing schemes in the cities are overcrowded with occupation of families more than intended to be. Hence sanitary facilities are often inadequate. This may lead to disposal of human excreta via solid waste disposal stream.
6. During new installations, repair and maintenance of distribution system contaminated non potable water, soil & sediment and contaminated material could come in to contact with the potable water in the distribution line resulting deteriorated water quality.
7. Water within the distribution ages with time depending on the hydraulic residence time, determined by physical characteristics of the distribution system, chemical and biological properties. The most important indirect effect of water ageing is the reduction of disinfectant residual over time, resulting water to become re-contaminated making unsuitable for consumption.

The research

The research focused on estimation and characterization of actual risk and risk factors responsible for bacteriological quality deterioration of potable water supplied to selected public housing schemes in City of Colombo.

Methodology

The research was carried out in 6 typical state initiated public housing schemes (HS) built mainly for underserved, low and middle income communities in Colombo They were Samagipura flats Demel flats, Serpentine flats, Zoysa flats, Sanchiarachchigewatta flats and Kamlurupura flats. Typical pattern of water distribution in urban public housing is given below.

Typical pattern of water distribution in an urban public housing schemes

The housing schemes receive their potable water from the Greater Colombo Piped Water Supply (NWS & DB) as a bulk supply from the distribution mains. Water is supplied within the scheme via in-house distribution lines. In all cases the water is stored in underground storage sumps and pumped to one or two overhead tanks and then to a series of sub tanks. A sub tank usually serves an average of 4-10 households and number of houses served by each tank may vary depending on the individual housing units.

The field surveys, quality testing of water samples were done for a period of 18 months from (January 2008 to June 2009) Water Sample collection for quality testing, transportation and analysis were carried out as per APHA, 1998.

Studies

The assessment study focuses on:

1. Determination of bacteriological quality deterioration along the distribution from the supply mains to consumer end. For these, feacal coliform indicator bacteria (FC) and total coliforms (TC) were tested two times per month from the main supply, underground sumps, and water taps of households at the consumer receiving end.
2. Analysis and characterization of risk factors responsible for bacteriological quality deterioration.

Risk factor 1: Loss of Free chlorine residual (disinfectant) level of the potable water in the distribution
Free residual chlorine level of the potable water in the main supply, underground sumps, and water at the consumer end tested along with testing bacteriological parameters.
Risk factor 2: Location, design of in-scheme storage systems and supply
Risk factor 3: In scheme waste management systems.
Risk factor 4: Operation and maintenance of in-scheme potable distribution system structures.
Assessment of risk factors 2-4 were based on based on the visual observations and the prevailing existing situations in the area.
A sanitary risk assessment (SRA) was conducted and sanitary risk scoring (SRS) was derived by assessing factors responsible for bacteriological quality deterioration of potable water (Risk factors 2 ,3 and 4) in in-scheme storage and supply.

Assessments

Determination of bacteriological quality deterioration along the distribution from the supply mains to consumer end
The bacteriological quality deterioration of the potable water along the distribution systems was analyzed against that of the main distribution using WHO guidelines value for piped water supplies: treated water in the distribution system as quoted bellow.

Guideline value for bacteriological quality

A. Piped water supplies
A.1 Water in the distribution system

Organism	Unit	Guideline value
faecal coliforms	number/100ml	0
total coliforms	number/100ml	0

(based on WHO Vol.1, Recommendations, 1984)

Analysis and characterization of risk factors responsible for bacteriological quality deterioration
Loss of Free chlorine residual (FCR) level of the potable water in the distribution
FCR level of the potable water in the main supply, underground sumps, and water at the consumer end were tested along with testing bacteriological parameters and the WHO guideline value lower limit (0.2mg/l)was used to assess the violations.

Information on Location and design of in-scheme storage system and supply, in-scheme waste management systems, Operation and maintenance of in-scheme distribution system structures were used for determining the SRA. Accordingly, 21 issues related to risk were considered for the analysis and each issue was considered having equal influence on the environmental health and sanitation risk. Depending on the level of risk imposed by each issue, values were assigned in the range 0 (no risk) to 10 (maximum risk). Overall sanitary risk score (SRS) was derived by summing up individual scores for each housing scheme.

Results and discussion

The research assessed the bacteriological safety and potential risks of consumption of potable water by the households in the housing schemes.

Risk of bacteriological quality deterioration along the distribution from the supply mains to consumer end

In the main distribution, the violation of WHO guideline value for FC is less than 1%. The same for sumps is higher for both FC and TC and it is somewhat less for households. The violation levels were 4.23% and 2.48% for FC and 16.9% and 16.31% for TC for sumps and at household end respectively (Fig 1. and 2.). The maximum FC count were in the range of 40-50 for water in sumps and households, and the average for same is in the range of 12 for sumps and 8 for households. The maximum value for TC counts was 260 and

300 respectively for water in sumps and households. The average TC counts were 40 and 30 for sumps and households res respectively.

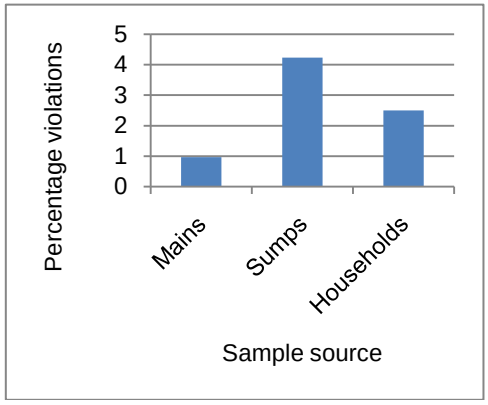

Figure 1. Percentage of samples violating the WHO guideline value for FC along the potable water distribution

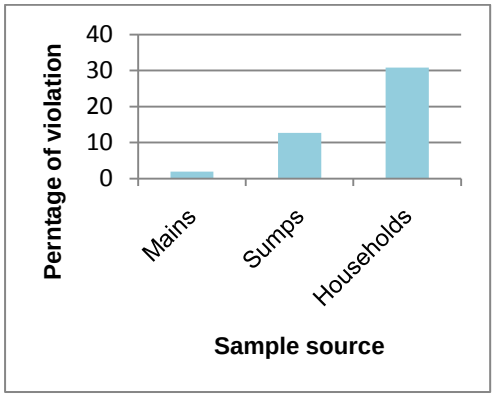

Figure 2. Percentage of samples violating the WHO guideline value for TC along the potable water distribution

Analysis and characterization of risk factors responsible for bacteriological quality deterioration

Risk factor 1: Analysis of risk due to violation of WHO guideline value the lower limit, for free chlorine residual of potable water in the distribution and the decay (loss) of free chlorine residual) along the distribution system due to water aging.

As per the fig 3, percent violation of WHO guideline lower limit for is high in sumps and household end compared to main supply, by 12.68% and 30.85% respectively. This is further confirmed by the information in fig 4 which shows decay of free residual chlorine along the in-scheme distribution. The computed average rate of decay is 0.12mg/l. This has resulted about 30.85% of samples at the household end at risk by violating WHO guideline value for FCR lower limit. Although required FCR level is effectively maintained in the main distribution (the average FCR is 0.55mg/l), it has failed to remain in the required levels at the household end in many schemes. The FCR levels have degraded along the in-scheme distribution and this signals possible in-scheme online contamination. This indicates the potable water at the consumer end is at potentially high risk of feacal contamination.

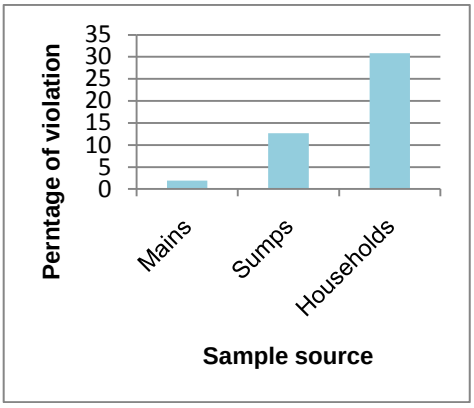

Figure 3. Percentage of samples violating the WHO guideline value for free residual chlorine level <0.2 mg/l

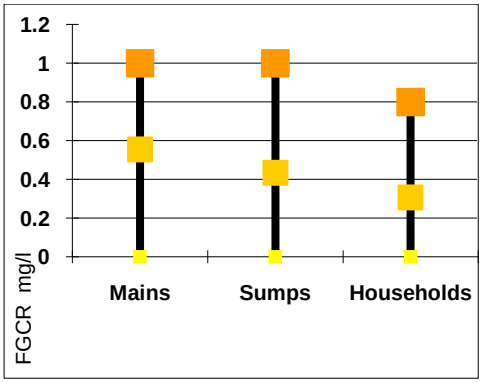

Figure 4. Distribution of free residual chlorine (max. average, min. (WHO guideline value for free chlorine residual 0.2 mg/l)

Risk factor 2: Location/design of in-scheme storage systems and supply

The underground sumps in some housing schemes are located in places with potential risk of contamination by external contaminant sources. As Colombo is experienced with high intense year-spread rainfall storm water stagnation was a usual occurrence in Samagipura and Kamkarupura housing schemes**.** Contaminated runoff may enter the sumps through unprotected walls, weaken seals etc. However, all sumps in housing schemes except Samagipura HS have been raised adequately above the ground to prevent potential entry of storm water runoff.

Risk factor 3: Onsite/in-scheme waste management systems

The waste systems include sewerage, wastewater and solid waste. Management organization (MO) is the responsibility of operation and maintenance of on- site/in-scheme waste management infrastructure and local authority is responsible in removal of waste from the system. I.e., main wastewater lines, sewer lines and in the case of solid waste the Local authority is responsible for house to house collection and removal.

Sewage

In all housing schemes, sewage is taken through closed pipelines. They run within the walls or externally, sometimes close to water and or wastewater lines. Hence there is a high risk of possible on line contamination via weak joints. Some schemes experience permanent /temporary sewer blockage. Hence by pass systems have done as a temporary remedy to channel sewage to open wastewater drains which are meant to carry storm water runoff and wastewater.

Solid waste

Solid waste collections in some housing schemes were quite unsatisfactory. As a result onsite accumulation of solid waste could be seen in almost all HSs. Main collection points were always onsite open dumps with unlined bottoms. Some schemes have extremely poorly operated chute systems for solid waste disposal. Many schemes were used to dispose mixed waste which was highly unhygienic. As many housing schemes are over populated their sanitary facilities are often inadequate to cater the total occupant population. Therefore, there is a risk of fecal matter being disposed with the solid waste. Chutes have been blocked or encroached at some places preventing convenient collection and have lead attraction of stray animals. Waste is generally removed on daily basis; however, in some situation this is failing leading to accumulation of waste in-scheme. As Colombo is a high rainfall experienced area wet dumps are a critical sanitary risk factor especially in relation to fecal contamination. Also, faecal matter of stray domestic animals (such as stray cat and dogs) can pose a possible risk of contamination in the situations where water supply infrastructure has been maintained unsafe evidencing leaks in unprotected openings of storage infrastructure; sumps and overhead tanks etc.

Risk factor 4: Operation and maintenance of in-scheme distribution system structures

Water Supply Authority is responsible only for the bulk supply up to the entry point of the scheme. However, in some large housing schemes the Water Supply Authority involved in the maintenance and major repairs also. For the in-scheme distribution, the MOs should carry out their own repair and maintenance. At the household level individual house owners were responsible for their own repairs & maintenance. Some schemes had MO established to carry out regular maintenance at their own cost (Demel flats). This system was effective and more systematic. Whereas several other schemes did not have properly established MOs over past several years and dilapidated systems were an obvious result (e.g. Kamkarupura, Samagipura and Sancharachchigewatte).

In general, some schemes faced critical situations due to old corroded pipelines which need replacement. It is questionable how MOs can accommodate such large rehabilitation costs. There were reported cases of leaking lines trapped within the walls (Demel flats). Inability to convenient access to lines laid within the walls is also a critical O&M issue. In many cases sumps were not properly protected and surfaces are not maintained cleanly (Samagi pura and Kamkarupura flats). Sump openings were not safely closed so that stray animals or contaminated rainwater can enter in to the system. The sump in Kamkarupura and Samagipura housing schemes had visible cracks in the sump wall and leaking water was observed. This signals a potential risk situation of ingression of contaminated groundwater in to sumps because these cracks could be extended.

Sanitary Risk Scoring (SRS)

The table 1 below interprets the scores assigned for each risk factor and the overall sanitary risk score for the HSs studied**.**

The highest sanitary risk score has been gained by Smagipura flats (86%) and the scorers were above 60% for Kamkarupura and Sanchiarachchigewatte flats. One clear observation of those three housing schemes is that management organizations were either not established or malfunctioned. SRS of other three HSs, SRCs were relatively very much lower (less than 50%) than the former. Compared to former three they have established management organizations effectively attending to management of common amenities.

Table 1. Sanitary risk assessment (SRA) and sanitary risk scoring (SRS)

	Risk related issue	**Risk score**					
		HS1	**HS2**	**HS3**	**HS4**	**HS5**	**HS6**
1	**Location, design of in-scheme storage systems and supply.**						
1.1	Age of the distribution system (tank/pipelines /overhead structures) over 25 years	10	5	5	6	8	8
1.2	Possible entry of runoff water in to sumps	8	2	1	0	0	0
1.3	Possibility of surface water stagnation in the proximity of the sump and within the scheme	8	2	2	2	7	8
1.4	Possible entering of obnoxious (stray animals) animals/substances in to the sumps and overhead tanks through unprotected openings	10	2	5	4	6	8
1.5	Leaks detected in the sumps, overhead tanks, distribution lines	9	6	3	3	3	8
1.6	Entry of contaminants through unprotected sump/overhead tank (improperly closed) lids	9	2	6	6	4	8
1.7	High rainfall intensity	7	7	7	7	7	7
1.8	Shallow ground water table	7	7	7	7	7	7
2	**In scheme waste management systems**						
2.1	Unlined /poorly managed storm water drains carrying polluted water	10	3	6	4	9	10
2.2	Over crowding	10	0	0	3	8	9
2.3	poorly managed/functioning of sewer lines and septic systems	9	0	7	2	7	8
2.4	Canals /stream in the proximity, carrying polluted water	7	3	6	6	7	7
2.5	Feacally polluted subsurface groundwater	2	2	2	2	2	2
2.6	Poorly designed onsite storage systems for solid waste	10	4	6	2	9	9
2.7	Poorly managed on site solid waste disposal	10	2	6	2	9	10
2.8	Obnoxious animals (rats, stray cats and dogs)	9	3	3	3	9	9
2.9	Trees or structures over overhead tanks or sumps	9	3	5	0	1	6
3	**Repair and maintenance**						
3.1	No regular tank cleaning and distribution system R & M	8	4	4	4	8	8

3.2	No regular leak detection	9	5	4	4	7	7
3.3	Low pressure transients	9	4	4	4	7	7
3.4	No regular monitoring on potable water safety	10	10	10	10	10	10
Total sanitary risk score		**180**	**76**	**99**	**81**	**135**	**156**
Sanitary Risk Score (SRS) %		**86**	**36**	**47**	**39**	**64**	**74**

HS 1 - Samagipura HS 2 - Demel HS 3 - Serpentine flats
HS 4 - Zoysa flats HS 5 - Sanchiarachchigewatta flats HS 6 - Kamlurupura flats

Conclusions

Although required FCR level was effectively maintained at the main distribution and it had failed to sustain in the same manner to ensure water safety at the household end (30.85% violation of WHO guideline value) indicating that the drinking water at the consumer end is at potentially high risk of in-scheme online feacal contamination. The potential risks are considered even high as quality of potable water of none of housing schemes at the consumer end is monitored and known. This has resulted 4.23% and 2.48% violation of WHO guideline value for feacal coliform for sumps and households respectively.

The scheme level analysis reveals that among the six housing schemes monitored:

- Potable water of all schemes have violated the WHO guideline value for TC and FC
- All schemes have failed to maintain the required FCR value lower limit in the water in sumps and at the consumer end
- The potential risk of in-scheme-online contaminations of potable water in these concentrated public housing schemes are higher as they are located in lands, which are marshy and with shallow water table, subjecting to wet weather conditions with less distinct dry periods, under extremely poor waste management in urban cities in relation to sewage, wastewater and solid waste management, and certain housing schemes (especially, those built for underserved communities)
- Strongly lack capacity to establish Management Organizations. The transition stage resulted after formation of Condominium Authority and the weaknesses in establishment of management organizations have worsened the situation resulting high sanitary risk score for many schemes

The study reveals strong emphasis need to compensate the in-scheme condominium property management with special emphasis on management systems of waste (in-scheme solid waste, toilets and sewer lines, wastewater lines, runoff) and the Condominium Authority may require developing special management plans for addressing different management issues of these housing schemes

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Note/s

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