Alternative to Urban water stress in informal settlement: A case of Hrishipara slum, Khulna

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Abstract:

The developing countries presents some of the lowest water and sanitation coverage figures globally, with some countries showing stagnating or even declining access to improved water and sanitation. Access to safe and adequate water has been a global developmental priority due to their intrinsic impacts on the achievement of the sustainable development goals. Despite the implementation of several measures to improve access to safe water, urban dwellers especially the marginalized, struggle to acquire water and access sanitation facilities. This paper intends to identify and examine the ins and outs of an alternative to this urban water stress in order to provide a complete sustainable water cycle for the slum dwellers of Hrishipara. Rainwater can act as a potential alternative source for scarce safe drinking water in informal settlements. Concomitantly, integrated long term planning and means of waste water reuse together can lead to a solution of the never-ending stress of urban water. Thus, this research proposes a framework for sustainable urban water management urban water stress in Khulna integrating the perception and experiences of the informal settlement of Hrishipara.

Key words: Informal Settlement, Water reuse, integrated water resource management, Water Cycle

1. Background:

Water has become a challenge of global dimensions. Many researchers and policy-makers have focused on this issue, the impact of future aspects on food security, and the quality of water, giving little thought to the ability of cities to handle the urban water cycle adequately. Urban water management (UWM) has recently gained more attention, in part due to the comprehensive Sustainable Development Goal on Water (SDG-6). The generally accepted approach to UWM builds on a well-established socio-technical system that, especially in the more vulnerable part of the world, the slum dwellers.

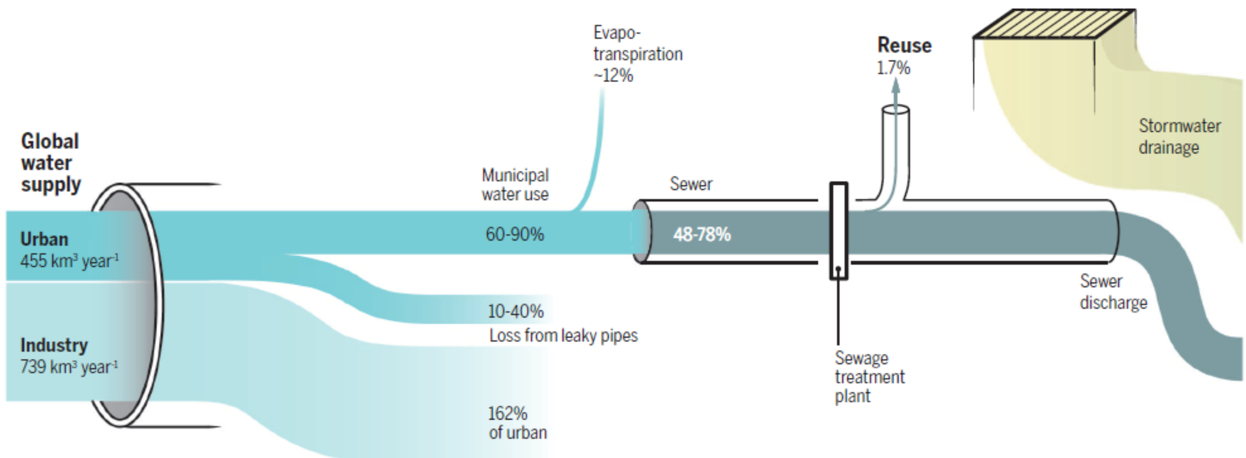

Figure 1: Water reuse condition globally(source: Ahmed 2009)

There is, in society in general, an increasing demand for sustainable solution for water reuse and constant supply of safe drinking water. This paper describes the framework of a dealing with the above issue. Which focus on urban water and wastewater systems. Drinking water is becoming a scarce resource in many areas and both use of water and wastewater outlet are of major ecological and economic importance in many countries. Consumption and discharge maybe considerably minimized by means of water reuse.

Urbanization has assumed momentum globally, but it is more pronounced in developing countries. Currently, about 54% of the world's population lives in urban areas and the UN estimated that by 2050 two thirds of the world's population would be living in cities. And to address this population, packaged "sachet" water has become the primary drinking water source for millions in the cities. The state of Khulna, Bangladesh is not an exception. Drinking water landscape shows the vulnerability of the 38 slums mushroomed throughout the city.

Water is an essential resource for health improvement, poverty reduction, food security, and empowerment in various spheres of life (Dapaah and Harris 2017; Hesselbarth 2005; Oluyemo 2012; UNDP 2017). Access to safe water and sanitation are critical to sustainable development (Hesselbarth 2005; UNICEF & WHO 2017; UNDP 2010). In spite of its importance, access to safe water and adequate sanitation remains a major challenge for the world's poorest citizens (Dapaah and Harris 2017; Hesselbarth 2005; UNICEF and WHO 2017). Several measures and strategies have been put in place by various governments to enhance access to water and sanitation facilities for most deprived communities (Songsore 2008). In spite of these interventions, 663 million people around the world still face water shortage and struggle daily to secure safe water.

Although Bangladesh receives plenty of rainwater during its monsoon, both rural and urban areas suffer from shortages of safe drinking water during dry season. Arsenic contamination of ground water affects many rural areas, whilst some urban areas lack sufficient potable ground water to meet the demand. To cope with the problem, this research explores: the feasibility of harvesting rainwater as a source of quality safe drinking water in an informal settlement of Khulna city. The purpose of this research is to correctly priorities which the most important criteria are for a water cycle with regard to urban water management. The resultant looks forward to a complete sustainable water cycle for the slum dweller to adopt as the solution of this urban water stress.

2. Method:

To conduct this research, **JMP** (Joint Monitoring Programme) was the first tool applied to evaluate the water, sanitation and hygiene situation of the settlement. The JMP estimates for a total 26 indicators related to water, sanitation and hygiene (WHO, 2018). The JMP has developed a normative interpretation for each of the terms used in the targets, and the approach to global monitoring aims to reflect these as closely as possible. The JMP uses service ladders to benchmark and compare progress across countries, and these have been updated and expanded to facilitate enhanced monitoring (World Health Organization and UNICEF, 2017).

As a finding of vulnerable health and hygiene condition and also water logging, a **fishbone analysis** was done to find all cause and effect issues. The fishbone diagram or Ishikawa diagram is a cause-and-effect diagram that helps managers to track down the reasons for imperfections, variations, defects, or failures. The diagram looks just like a fish's skeleton with the problem at its head and the causes for the problem feeding into the spine. Fish bone diagram has proved to be simple, applicable, controllable, as well as adaptable. Primary data for the study is collected through FGD with two groups and committee members of sanitation and related projects, and concerned GO-NGO staffs. Books, project reports and implementation guidelines, journals, web pages, newspapers etc. are reviewed as secondary data sources.

Household interviews, focus group discussions and key informant interviews, observation etc. are the other methods which have been used. Although mapping, visual documentation etc. were used for the analysis of the data.

3. **Lit Review:**

1. **Water Treatment:**

Treating waste water and reusing it is the key to sustainable water cycle. The process is not necessarily always costly and cumbersome. The figure describes a short and efficient treatment flow.

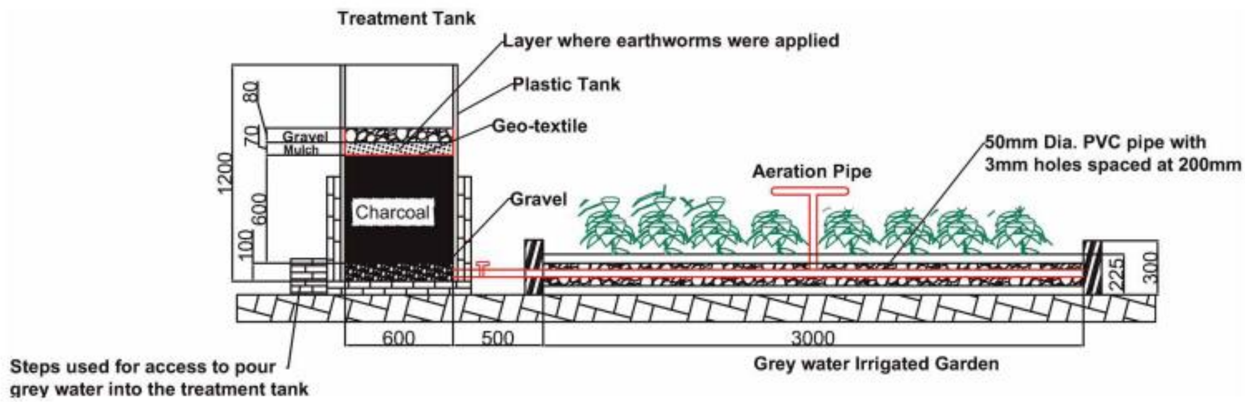

Figure 2:Water treatment Process (Source Erecsion et.al, 2009)

Grey water constitutes the largest fraction of domestic wastewater. It causes environmental sanitation and pollution problems if it is not managed well. If treated, grey water can be a resource for a variety of uses. A pilot system was constructed in February 2013 to treat grey water from a four-member household for sub-surface irrigation of local vegetables. Grey water refers to wastewater from laundry, bathtubs, showers, kitchen sinks and washing dishes (Eriksson et al. 2002). Grey water comprises 50–80% of the total residential wastewater generated (Al-Jayyousi 2003). Grey water usually receives the least attention compared to other environmental aspects like solid waste and black water, particularly in low- and medium-income counties where it is often discharged untreated into storm water drains and, if they exist, sewers (Morel & Diener

2006). Globally, the use of treated wastewater and grey water is emerging as an integral part of water demand management, promoting preservation of high-quality fresh water as well as reducing pollutants in the environment and overall supply costs (Lu & Leung 2003). In the wake of growing pressure on fresh water resources around the world, and increasingly scarce,

expensive and/or politically controversial new supply (Allen et al. 2010), efforts are underway to identify new ways of meeting water needs. The use of treated grey water is straightforward for non-potable uses, thereby replacing and thus reducing the demand for potable water. In Jordan, water resources are characterized by scarcity, variability and uncertainty, creating the need to reuse/recycle wastewater (Al-Jayyousi 2003). Grey water use is not limited to countries with a dry climate such as Jordan. In the Mediterranean region and European countries, the use of recycled water has also increased. Use of treated grey water is among the potential alternative sources of water, although previously considered unusable, an attractive addition to water-management options, for example, irrigation (Gross et al.; Allen et al. 2010).

2. Uses of reclaimed water

Reclaimed water can be suitable for a large variety of applications. Among the most common reuse applications are irrigation; residential uses; urban and recreational uses; groundwater recharge, bathing water; aquaculture; industrial cooling water; and drinking water production. The next sections introduce the main water reuse applications and highlight the relevant specific issues of concern. Possible control parameter to assure a safe application are derived as well.

a. Irrigation

For agricultural use, the water quality should be sufficient to protect human health when consuming food produced from reclaimed wastewater irrigation. For other irrigation uses, the hazards are related to the possibilities of contact between the irrigated product and man or the environmental matrix. Furthermore, the soil, plant, groundwater and other aspects of the local environment should also be protected from contamination by reclaimed water irrigation in particular if compounds accumulate in certain phases. In most cases, salinity will be an important factor requiring close monitoring and control. In addition, bioaccumulation of organic and inorganic contaminants in soils and plants needs to be considered for public health protection, although in general, little data is available on such matters. Growth inhibition by several specific chemical species in reclaimed wastewater, such as boron, should also be taken into account. Other important species that can deleteriously affect plants include chlorides, sodium, potassium, and selenium. With agricultural reuse of wastewaters, the public health protection measures should be considered and recommended in the main strategic areas (e.g. management practices to interrupt the flow of pathogens), and selected to suit local circumstances (including crop selection; water application measures/control; and human exposure control). Components of reclaimed irrigation water can, in some cases, be degraded by microorganisms present in the soil. Also, soil salinity may be managed by practices such as leaching and runoff collection if good quality water is not available. In some Mediterranean countries, medium and sometimes high salinity water has been used for years without further damage where the management has been carefully optimized. An example can be given from the Dan Region Project where water reclaimed by the soil aquifer treatment (SAT) system has been successfully reused for 15 years for a large variety of crops although the salinity is relatively high (EC 1500–1700 and chlorides 250–300 mg/L). The tolerable limits from these experiences have been reported as chlorides: 250–300 mg/L; EC: 1500– 1700 µS/cm; boron: up to 0.4 mg/L; and sodium: up to 200 mg/L [1]. The risks associated with irrigation

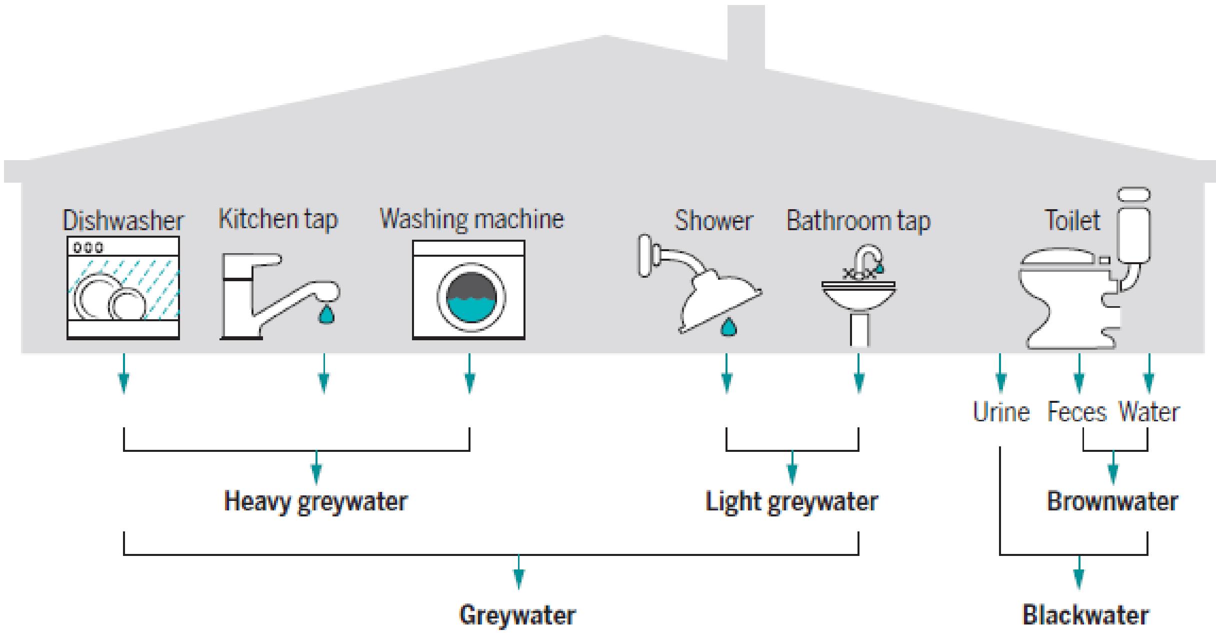

Figure 3: Seperation of Waste water

of raw consumed food crops and fruit trees are more serious when cleanliness and hygiene conditions are not carefully managed. The irrigation method affects crop contamination because humidity conditions influence pathogen survival: irrigation by periodic cycles of inundation/drying presents an advantage in front of sprinkling irrigation. Sprinkling is an irrigation method which needs to be performed frequently; the prolongation of the time existing between subsequent irrigations favors the action of environmental conditions (light and desiccation) on pathogens. When the cycle is shorter, the environmental inactivation is more difficult; desiccation is substituted by a wet environment that favors microbial survival. Drip irrigation allows the use of reclaimed water without contaminating crops, because water does not contact directly the vegetable growing in the soil surface. Bacteria survival in crops is somewhat influenced by the kind of crop. Several plant structures (e.g. such as those of lettuce leaves) give protection against ultraviolet rays of solar light. The survival is bigger in dense and leafy plants. Other factors which influence microbial survival include temperature, humidity and rain [2].

For agricultural products that can be consumed after cooking, the cooking temperature and the rules of kitchen hygiene determine contamination risk. The risk of goods of animal origin as transmitters of pathogenic agents is often neglected or can be underestimated. Animals can accumulate in their bodies many pathogenic agents or toxic substances that they consume with fodder irrigated with raw or insufficiently treated wastewater and which are transmitted later in an indirect way [2,3]. Other potential means of infection or contamination include reclaimed water irrigation of public parks, gardens, sports fields and unwanted irrigation of paths. Polluted water can reach persons,

animals, plants or environment directly with the irrigation or indirectly through aerosols. The cross connection infection risk to work for who use reclaimed water for irrigation purposes without sufficient self-protection should be considered and carefully managed. Water quality in such systems should meet requirements that protect human health.

b. Residential uses

For private uses like garden irrigation, toilet flushing, home air conditioning and car washing, with reclaimed water delivered to households, a satisfactory water quality must be ensured. Furthermore, the presence of several pipelines with variable water qualities compounds the hazards associated with improper handling by the owners and plumbing professionals. Attention must be paid to avoid cross connections of potable and non-potable water as well as concerns with children playing in grounds with reclaimed water irrigation. The risk of infection by pollutant inhalation of reclaimed water aerosols, for example in home air conditioning, should also be considered

3.3. Urban and recreational uses

Urban uses include street cleaning, firefighting, ornamental impoundments and decorative fountains as well as water bodies and streams for recreational use. The most important issues for reclaimed water used for recreation of impoundments, water bodies and streams should be the protection of the aquatic environment as well as people in contact with this water (such as firefighters or children playing in water fountains). Hence for some ornamental impoundments bathing water regulations apply. The water quality should exert no adverse effects on the aquatic organisms and ecosystems. Therefore, compounds which are toxic to fish, such as endocrine disrupters, should be carefully controlled and monitored.

c. Bathing water

Reclaimed water used for bathing water purposes needs special requirements, concerning protection of human health, i.e. disinfection as well as consideration of dermatological effects. Quality requirements have been set by the European Bathing Water Quality Directive 76/160/EEC The physical, chemical and microbiological parameters applicable to bathing water are indicated in the Annex of the Directive which forms an integral part of it. Significantly, the European Commission presented a new proposal for a Directive concerning the bathing water quality in 2002. In this version, the monitored indicators were drastically reduced to only 2 parameters (*E. coli* and *Intestinal Enterococci*) compared to 19 parameters in the 1976 original directive.

d. Aquaculture

Reclaimed water used for aquaculture should not harm or affect the aquatic environment or the cultured species. In addition, consumers of the produced fish must be protected from adverse effects. Several substances are fish-toxic or accumulate in lipid tissue. Therefore the aquaculture water quality requires adequate limits considered in terms of potential bioaccumulation of toxic substances. The risk of goods of aquaculture origin as transmitters of pathogenic agents is often neglected or can be underestimated. Fish can accumulate in their bodies many pathogenic agents which are transmitted later.

e. Industrial water

Up to now, the main use of reclaimed water in industries is for cooling purposes; cooling could be performed in closed or open circuits. In the first case, does not have direct contact to humans or the environment, but in the second aerosols can be formed and generate risks related to *Legionella* presence. Correct management of the practice should prevent corrosion and calcareous crusts to protect pipelines and vessels. For example high amounts of dissolved organic carbon (DOC >5 mg/L) inhibit the corrosion protective coating of copper . The precipitation of mineral salts and silica during the heating process has also to be prevented. Other possible uses are relatively not extended in Europe, like dust control or raw materials pulling

f. Drinking water production

Reclaimed water is used for drinking water production in planned direct and indirect potable reuse schemes in numerous parts of the world. In California indirect potable reuse is achieved through aquifer recharge. The draft revision of California Title 22 reuse legislation remains very specific as to how objectives are to be achieved. It requires disinfection of reclaimed water before recharge, in addition to a minimum detention period below ground before recovery for drinking. This detention period is 6 months (with minimum travel distance of 150 m) for surface spreading and 12 months (and 600 m) for subsurface injection. Mandatory sampling and analysis procedures for total nitrogen in source water require reporting to California Department of Health Services if the concentration exceeds 5 mg/L and that action is required to ensure that mean concentration does not exceed this level.

These are in addition to requirements that nitrate and nitrite concentrations in groundwater remain within the limits for drinking water supplies, and that groundwater monitoring can track the evolution of the plume of recharged water to the point of recovery. Sampling locations should be located with 1-3 months travel time from the recharge site and at least one further monitoring well before the nearest downgradient domestic water supply well. Furthermore, the recharge water is required to comply with prescribed maximum concentrations of inorganics, organics, disinfection byproducts, lead and copper. Secondary limits for other constituents and characteristics also apply. Title 22 draft revision mentioned before has a reduced allowable total organic carbon in recharged water. Accounting for dilution at the recovery well by recharge from sources other than recycled water, and for attenuation in the unsaturated zone where recharge is occurring by surface spreading, the recycled water TOC contribution is not to exceed 0.5 mg/L. For any new well injection project, the entire stream is required to be treated by reverse osmosis in order to achieve this objective. Title 22 revision makes no provision for attenuation of TOC in the saturated zone, and appears to be based on application of best available technology, without reference to risk assessment. TOC is a gross measure of organic residual in water and is not necessarily an indicator of the abundance of chemicals of concern. This is significant since reverse osmosis has been reported to be less effective for the removal of some trihalomethanes compared to other organic chemicals

In Windhoek, Namibia, direct potable reuse has been used for domestic supply for more than 30 years, without any adverse effect detected. Treated wastewater is reclaimed applying the multiple barrier concept, i.e. several consecutive treatments each of them capable to generate tap quality water, and afterwards a maximum of 30% of reclaimed water is diluted with first hand water and then supplied.

Although wastewater reclamation and reuse has gained approval as a necessary tool to be included in sustainable integrated water resources management, there are still several key points to be developed for the safe use of the resource.

3.Fabrication of Automatic Initial Flushing Device

Rainwater receives impurities and contaminants during collection; therefore, it was necessary to have a first flush removal mechanism in the system. During the dry period, dirt and bird droppings may contaminate the quality of the collected rainwater.

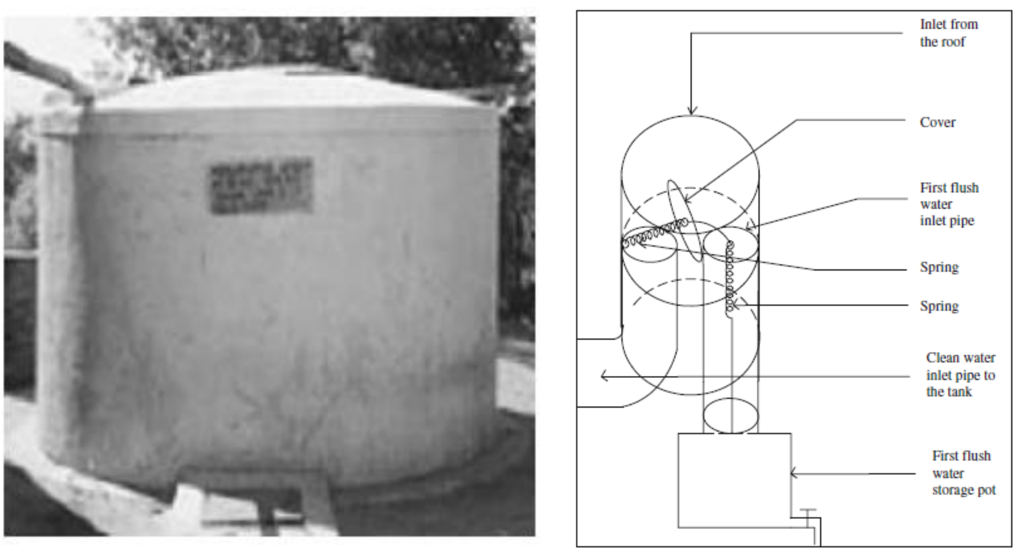

Figure 4: Details of automatic water flush ferrocement tank

A study conducted by the Development Technology Unit of the University of Warwick (Martinson and Thomas 2005) suggested that for each millimeter of first flush the contaminate load will halve.

The use of inlet filters provides another way to separate dirt from good quality rainwater. In order not to waste precious rainwater, inlet filters should have capacity to handle larger amounts of water and should therefore preferably be self-cleaning.

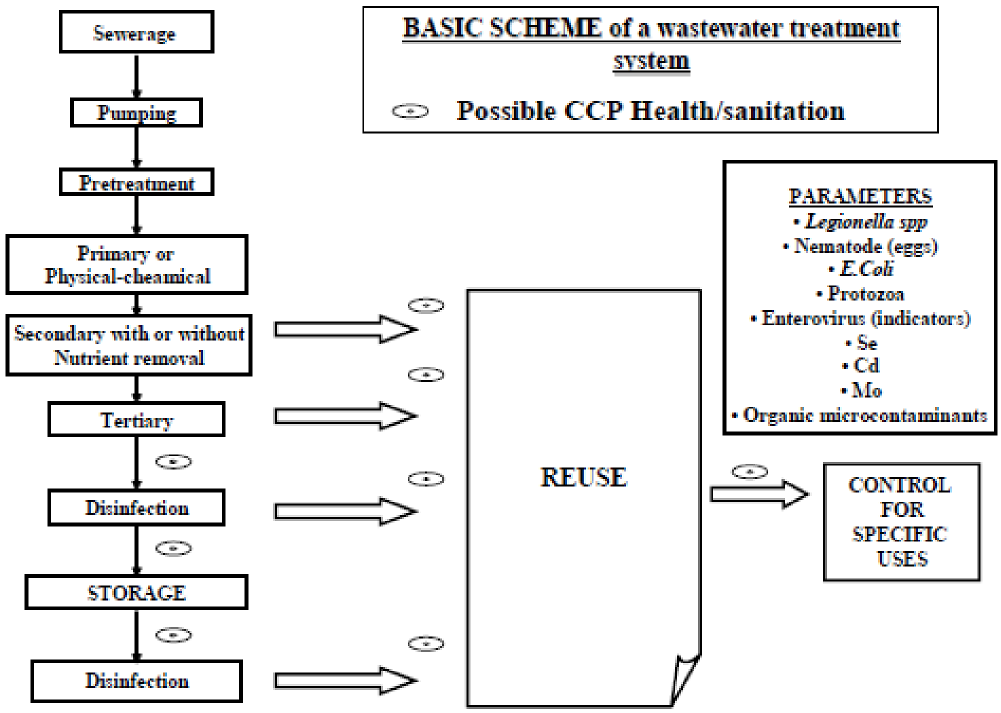

Figure 5: Basic waste water treatment system

Inlet filters are nowadays commercially available in industrialized countries that are promoting rainwater harvesting. During storage, and depending on the time after the last rainfall, bacterial die-off can be substantial, with a log-reduction achieved in one or two weeks. Bio-films developed at the tank-water interface were also considered to have a positive effect on the water quality (Coombes et al. 2005). The volume of first flush water that needed to be removed before water was safe to drink, found to vary in different studies. Yaziz et al. (1989) found that 0.5 mm of rain was sufficient to reduce the faecal coliforms count to zero on two roofs in a Malaysian campus. Villarreal and Dixon (2005) opined that collection processes should divert the dirty runoff from the first few millimeters of rainfalls away from the tanks to avoid contamination. Coombes et al.

(2000) have found that even after 2 mm was flushed, there were still significant faecal coliforms in the runoff from a building located close to a bus depot in Australia. Field studies in Uganda have shown unacceptable turbidity after 2 mm have removed although faecal coliform counts were in the WHO ‘low risk’ category. Despite this uncertainty, first flush systems are considered a very good method of improving the quality of roof runoff prior to storage (Faisst and Fujioka 1994).

An automatic initial flushing device was designed and fabricated during the study to flush the catchment. This device was developed to prevent the first rain from contaminating stored water with sediment and debris from the catchment. The device was fabricated using: a plastic pot (first flush water storage pot) having capacity of approximately 8 l (because it was determined that 6 to 8 l of water can clean the catchment), two PVC pipes (one to collect first flush and the other to collect clean water) of 30 cm length each, a cover (lid), two springs etc. The device could work automatically. There were two inlets at the top of the device of which one carried first flush water and the other carried the clean water to the storage tank. The inlets closed and opened, by one common cover on it with the help of two springs. Spring 1 closed the clean water inlet and it had less tension than spring 2. The first flush water collection inlet closed with the help of spring 2. If the cover opened the first flush water collection inlet, the clean water inlet would be closed by the cover simultaneously. When the water holding capacity exerted the tension on spring 2, it pulled the cover and closed the first flush inlet. Whe the rain stopped, the first flush water holding pot emptied manually to make it ready to use before started the next rain. The system was evaluated considering three different volumes of water: 8, 12 and 18 l, which were considered to be needed to clean different sizes and different conditions of the catchments.

4. Context:

Despite the prominence of communal practices as a last resort for any decent way of sanitation in slum areas, its application and use are flagrantly ignored. This paper provides insight in the appropriateness of community-based water cycling for slum conditions.Rapid urbanization in developing countries creates massive demand for basic infrastructure in cities. The urbanization is attributed to natural increase and rural–urban migration. The rate of urbanization often exceeds the rate of economic growth. As a result, infrastructure development lags behind the population growth particularly in the low-income areas (Konteh, 2009). Population increase in most cities is projected to be highest in slums (Paterson et al., 2007). Because many slum dwellers are recent migrants from rural areas, many of them live without the social networks and kinship ties that can provide emotional, physical, and financial support in times of crisis (Majale, 2008). Root causes of slum formation include long-term failure of governments to implement structural plans, to enforce development control and to provide effective municipal services. A third of the

Figure 6:Drinking water condition in Hrishipara

urban population in the developing countries is estimated to be living in slums (UN-HABITAT, 2008, 2009).

Unhygienic water resources expose the slum dwellers to high risk. Bangladesh is located between latitude 20◦34 to 26◦38 N and longitude 88◦01 to 92◦41 E and is subjected to tropical monsoons with high rainfall (1,250 to 3,500 mm) from April to September. Yet urban and rural communities in Bangladesh have historically depended almost exclusively on groundwater, which is free from pathogens and available in adequate quantity in shallow aquifers. The development of a dependable water supply system is limited because of high salinity in surface and ground water in the coastal region and due to unavailability of shallow aquifers and difficulties in sinking tube-well through rocky layers in the hilly areas. Water table depletion due to heavy extraction of groundwater for irrigation during summer is the main constraint for the development of dependable water supply system in the north and north-western regions of Bangladesh.

Figure 7: Provision of Rain Water Harvesting

The case of Hrishipara is not an exception. A bustling population pressure on a little source of safe water is what making the lives of the slum dwellers miserable. For ages there were no safe drinking water source for the dwellers while it is the recent years that they are provided with four safe water supply. Besides the KWASA supply to households are being generated. The people in the settlement also seemed to adopt rain water harvesting as an alternative means. Thus, the scenario seems promising for the instalment of a pilot water cycle framework.

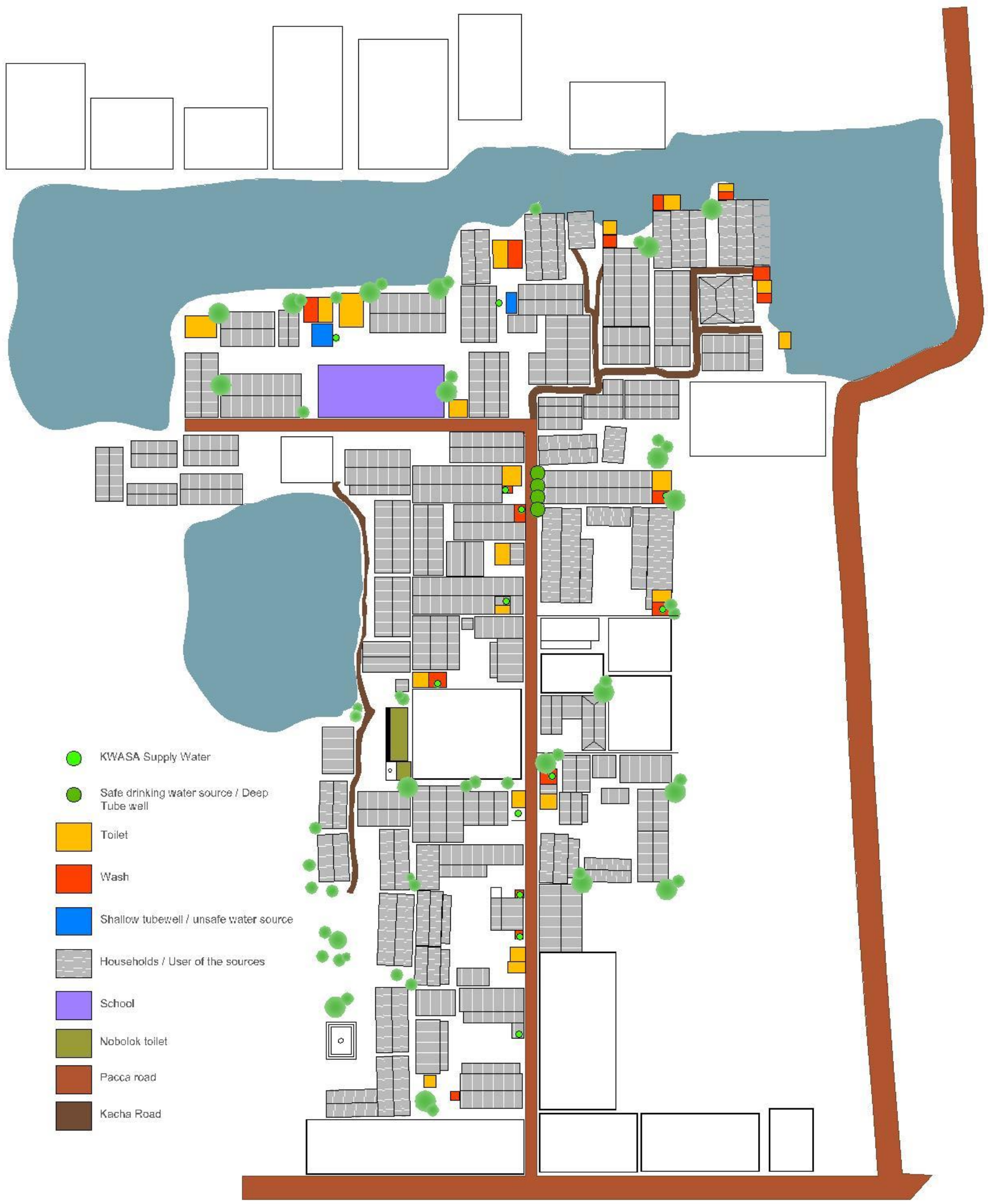

Figure 8: Problem Mapping of Hrishipara

5. Data Analysis:

The reasons behind stress of urban water has been shown in the fishbone below;

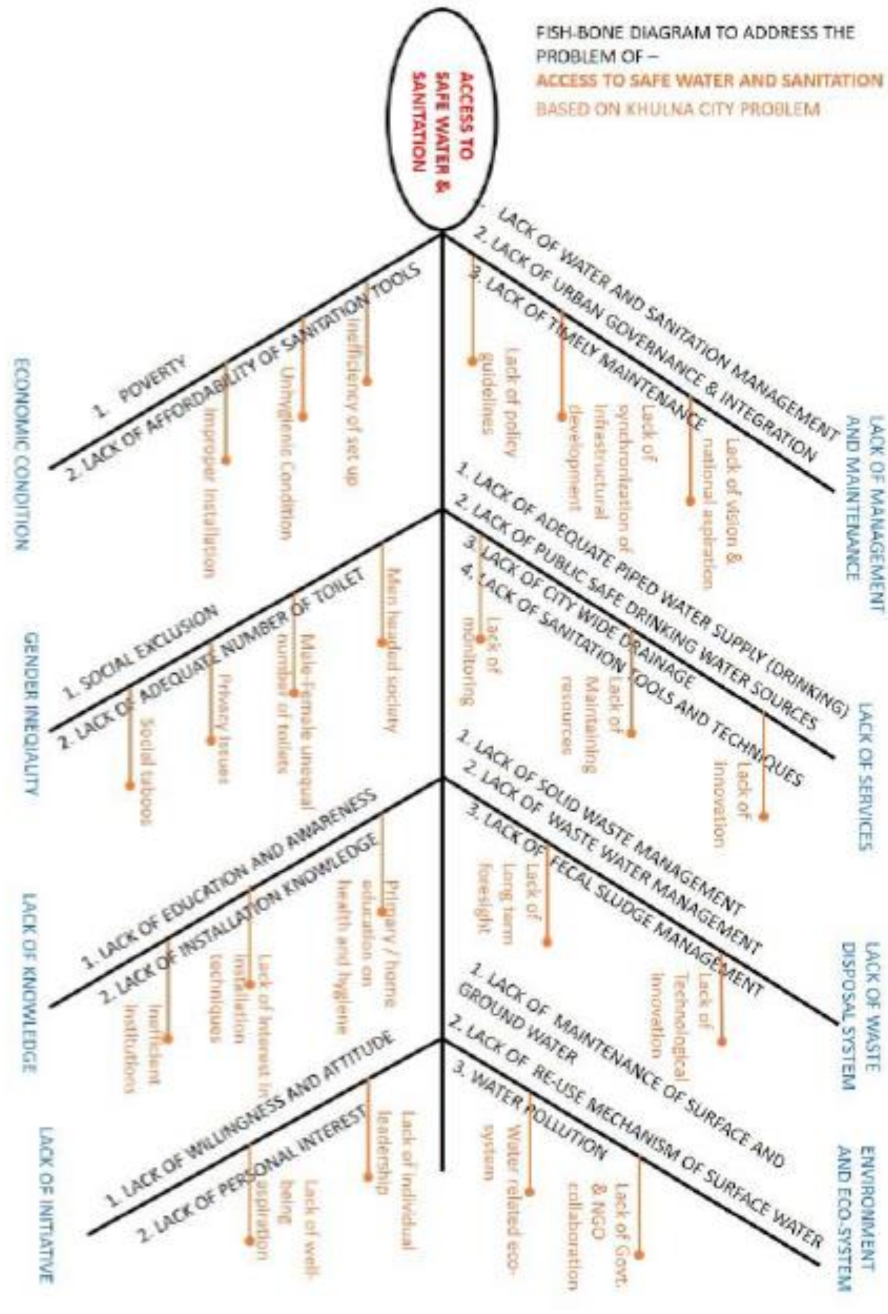

Figure 9:Fishbone Analysis forsafe water access in Hrishipara Slum

Emerging Solutions to the Water Challenges of an Urbanizing World is the current necessity.Safe Drinking Water Trials in Developing Countries are more in need. Its just the community participation, decentralization of system and a slight technological intervention with awareness what can make the water cycle a sustainable one.

We present an informal settlement case study of drinking water knowledge, attitudes, and practices in Hrishipara slum, with persistent socio-economic deprivation despite having substantially better water access than most of the Khulna slums. The drinking water decisions of many slum residents thus depends on proper long-term planning and attitude which leads to the tackling of urban water stress for the marginals.

6. Conclusion:

Few would contest that slum formation is one of the greatest challenges for this generation and the generations to come. Slums are mushrooming and policy makers seem not to be willing and able to serve their inhabitants. Scientists working closely on issues of water reuse are far from having solved all concerns related to the practice. From the very beginning of a water reuse project, scenarios must be prepared from the 'zero scenario' (no reuse) through to more complex and expensive ones (e.g. reverse osmosis for potable water treatment) to help stakeholders to select the best option for increasing available water resources, the ultimate purpose of reuse. In any case, the use of adequate tools to build scenarios is paramount. From Decision Support Systems to the simplest analytical tools, all knowledge is valuable. Detailed studies must be undertaken to identify necessary technologies, schemes and control tools.

Facing the numerous challenges to implementation of water reuse practices in informal settlement is unavoidable due to increasing demands on declining freshwater supplies, environmental and economic incentives resulting from reuse, and the great potential for water reuse at the context. Mobile demonstration units maybe helpful when evaluating the economic and technical feasibility of water treatment methods for particular settlements for improving systematic water cycle system. For this, key Objectives for Water Reuse Concepts are to be advocated well with the users. implementation of Water Treatment and Reuse Based System in the Slums are to be made affordable enough and contextual as well as a cooperative approach with enablement of the community is the key to this issue.

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