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RISK ASSESSMENT FOR URBAN WATER SUPPLY IN A DEVELOPING COUNTRY: A CASE STUDY OF DHAKA CITY

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ABSTRACT

Traditional approach to water quality and safety management has mostly relied on the testing of drinking water either at the point of its treatment works or at selected points within the distribution system. But risk assessment approaches are required for developing countries like Bangladesh to upgrade water supply and sanitation services which can reduce vulnerability of people being affected by water borne diseases. The main purpose of the study is to show spatial variation of major leakages of distribution pipes in different water supply zones of DWASA and propose measures for minimization of the water pollution risks based on identification of the hazards that the water supply is exposed to. Growths of population, economy and industry are challenging factors for DWASA (Dhaka Water Supply and Sewage Authority). For this study, Dhaka city which is divided among ten zones by DWASA was selected. Leakage values of zones were collected for seven years (2007-2013). From the data, monthly variations of leakage across the zones and average of leakage of each zone for different years were determined. A risk analysis matrix was created using the weighting value of leakage and number of connection for risk ranking. Finally, hazard zone was identified in city map showing spatial variations of major leakages in different water supply zones. The findings of the study suggest that DWASA- Zone 4 is at higher risky position than other zones. Findings can be used to develop operational plans and identify causes with key priorities for action.

Keywords: *Risk Assessment, Leakage, DWASA, Water Supply, Weighting value*

1 INTRODUCTION

Availability of potable, safe and affordable water is one of the most important development goals which ensures social and economic growth, promotes health and overall welling being of human being. The World Health Organization (WHO) estimates returns of $3-$34, depending on the region and technology, for each $1 invested in safe drinking water and basic sanitation (Hutton & Haller, 2004). It is thus important for the water experts and specialists to convey this important message to the politicians and decision makers. Policy-makers can be motivated to use these data to justify their actions, identify areas of deficiency and better prioritize actions (Wallace et al., 2008). Expanding safe drinking water and sanitation services would drastically cut the loss of life from water-related illness and free up scarce health resources in developing countries. According to the UN-Water Report (2008) five thousand children die each day from diarrhea alone or one every 17 seconds. The overall economic loss in Africa alone due to lack of access to safe water and basic sanitation is estimated at $28.4 billion a year, or around 5% of GDP. Upgrading water supply and sanitation services based on risk assessment can reduce vulnerability of people being affected by water borne diseases.

Water supply is provided to secure sufficient amounts of treated water of good quality at any time and location downstream from the treatment facilities (Persson, 2009). But water supply access in most developing countries is quite complex (Khadse et al., 2011). The rapidly increasing demand for water particularly in developing countries is an obvious obstacle to sustainability. Conversely the urgent necessity for its provision is similarly an obstacle with short term solutions often leading to serious long term problems (Gray, 2005). Thus, the problems are very acute in densely populated informal or slum areas of developing countries. The main drivers for increasing water demands are growing populations, increasing urbanization and economic growth (Meinzen-Dick & Ringler, 2006). Urbanization is occurring throughout the developing world at alarming rate and by 2025 over 50% of the world's population will be urban dwellers (UNCHS, 2001; WHO, 2007). Many households do not have piped water supply and have to rely on community based water sources. These mostly include public taps and water purchased from vendors (Whittington et al., 1991; Cairncross & Kinnear, 1992; Howard, 2001; Tatietse & Rodriguez, 2001). They also include a variety of small point water supplies such as boreholes with handpumps, protected springs and dug wells (Howard et al., 1999).

The traditional approach to water quality and safety management has relied on the testing of drinking water either at the point of its treatment works or at selected points within the distribution system. This approach does not take into consideration the water quality at its final phase or consumers point making the water vulnerable to possible contamination at collection point. Risk assessment, as defined by BS 7799:1999 Part 1 is "assessment of threats to, impacts on and vulnerabilities of information and information processing facilities and the likelihood of their occurrence". This rather unwieldy definition translates into risk being some function of threat, asset and vulnerability. This concept has been around for at least two decades. Risk assessment examines the severity or magnitude of risk to human health posed by contaminants (Wen et al., 2006).

A risk assessment report can be either quantitative or qualitative. In quantitative risk assessment, an attempt is made to numerically determine the probabilities of various adverse events and the likely extent of the losses if a particular event takes place. This includes the selection of assessment and measurement endpoints and the comparison of endpoint water quality measurements or distributions to a guideline value. Qualitative risk assessment involves the use of expert groups assessing water quality issues, either as contaminants, pollution sources or hazard events, and prioritizing these issues from this assessment. Methods vary over different components such as driving compliance frameworks, input information, base categorization (hazard or hazardous event based) and if they are qualitative or quantitative in assessment.

The objectives of risk assessment are to ensure the delivery of safe drinking water through identification of the hazards that the water supply is exposed to and the level of risk associated with each, minimization or reduction of each hazard, hazard monitoring and verification of the proposed measures for minimization of risks. Following this, the main purpose of the study is to show spatial variations of major leakages of distribution pipes in different water supply zones of Dhaka Water Supply and Sewerage Authority (DWASA) and propose measures for minimization of the water pollution risks—based on identification of the hazards that the water supply is exposed to.

2. STUDY AREA AND METHODOLOGY

Overall Study Area and Methodology involves selection of Study area and Data collection (Section 2.1), Hazard identification (Section 2.2) and Risk analysis (Section 2.3).

2.1 Study Area and Data Collection

Dhaka, the capital of Bangladesh, is the most densely populated cities which is situated in central Bangladesh at $23^0 42'0''$N $90^0 22'30''$E, on the eastern banks of the Buriganga River. It covers a total area of 360 square kilometers (BBS, 1991, 2001 & 2011). Water Supply and Sewerage Authority (WASA) is a service oriented self-explanatory commercial organization in Bangladesh for providing water to the urban dwellers. It covers more than 360 sq. km service area with a production of nearly 2110 million liters per day (DWASA, 2011). Dhaka WASA (DWASA) is divided into 11 geographic zones where Dhaka city organized with 10 zones and 1 in Narayanganj city for improving their operation, maintenance, and customer care. DWASA distribution system has pipeline of nearly 3040 km. The total number of consumers for DWASA is residential 2,88,401 (92.71%), commercial 19,872 (6.39%). Piped water supplies are generally distributed according to three levels of services: house connections, yard connections and public standpipes. Assessing the distribution system possesses a more significant challenge than water treatment works due to unplanned expansion of pipe networks, an understanding of the hydraulics of the system, the materials, age and size of the pipes and the location of the water supply pipes in relation to areas where hazards exist. The system loss for Dhaka city is 28.8% (DWASA, 2012).

For this study, Leakage values of seven zones were collected for four years (2007-2010) and ten zones data were collected for three years (2011-13) from DWASA official website. From the data, monthly variations of leakage across the zones and average of leakage of each zone for different years were determined.

2.2 Hazard Identification

The cross contamination of groundwater leakaging into pipes is a major concern in the pipe network system of Dhaka city and causing various water borne diseases. This risk can be assessed by analyzing the condition of the pipe. Key indicators of pipe condition that could be considered are:

- ✓ Pipe age – the effects of pipe degradation becomes more apparent over time.
- ✓ Pipe diameter – small diameter pipes are more susceptible to beam failure.
- ✓ Pipe length and jointing - long water pipes are more susceptible to longitude breaks.
- ✓ Pipe material – assess vulnerability of pipe to failure based on combination of hydraulic pressure exerted on the pipe and corrosivity of soil in which pipe is laid.

Apart from the above causes, ingress of contaminated water during periods of low or no flow and prolonged storage in pipes are the main causes for deterioration of water quality.

2.3 Risk Analysis

In order to identify a hazard event in distribution systems, it is important to consider the source-pathway-receptor model of contamination (Fig. 1).

Figure 1: pathway-receptor model of contamination

In this model the source is the source of the hazards, the receptor is the water supply (in this case the pipes that form the distribution system) and pathways are the means by which the hazards can leave the ‘source’ and reach the ‘receptor’. The source-pathway-receptor model recognizes that the presence of a hazard in the environment is insufficient on its own to represent a risk; a feasible pathway must exist that allow hazards to travel from the source to the water supply. When this occurs, it is a ‘hazard event’.

The nature of the hazards will determine the likely health outcome. Pathogens and massive pollution by chemicals may lead to mortality, whereas lower levels of chemicals may only lead to morbidity. The location of the hazard event will influence the number of people affected for instance hazard events on major transmission mains or in service reservoirs will be likely to have an impact on many people, whereas a hazard event in a small tertiary pipe may only affect a very small number of people. Risks can be identified at various stages, and prioritized in terms of likelihood and seriousness (ADB, 2010). A risk-ranking matrix is developed to address both likelihood and severity. Most approaches use some form of semi-quantitative ranking system by allocating numbers to different levels of likelihood and different levels of severity. A risk score is then calculated by multiplying these two numbers together.

$$\text{Risk} = \text{Likelihood} * \text{Severity} \tag{1}$$

The selection of the categories and the weighting allocated to different categories with guidelines to definitions are provided in Table 1 as there is no uniform 'industry standard'. The weightings were applied in South-East Water, Australia (Deere et al., 2001) and in Uganda (Godfrey et al., 2002). These are applied to each of the inspection points in order to define the severity of risk associated with individual hazard events in piped supply.

Table 1: Risk and severity; some guidance to definitions

Likelihood	**Definition**	**Weight**
Almost certain	Once a day	1
Likely	Once per week	0.8
Moderate	Once per month	0.6
Unlikely	Once per year	0.4
Rare	Once every 5 years	0.2
Impact	**Definition**	**Weight**
Catastrophic	Potentially lethal to large population	1
Major	Potentially lethal to small population	0.8
Moderate	Potentially harmful to large population	0.6
Minor	Potentially harmful to small population	0.4
Insignificant	No impact	0.2

3. ANALYSIS AND RESULTS

The results obtained following the outlined methodology are organized into five sub-sections. Section 3.1& 3.2 are for leakage data analysis, Section 3.3 is for overall data analysis comparison. Then city map has been shown in section 3.4 to identify hazard zone and finally risk reduction options are discussed to minimize hazard of zones (Section 3.5).

3.1 Leakage Data Analysis for 2007 to 2010

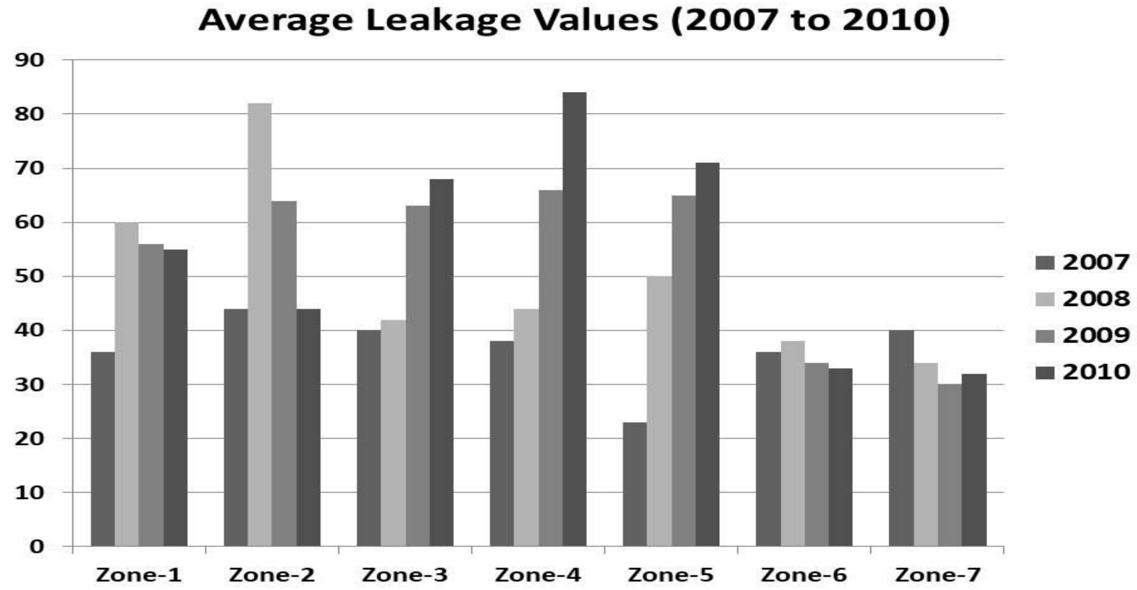


Figure 2: Average Leakage Values for Year 2007-2010

In the study, average leakage value of each year was estimated taking the monthly leakage values of the certain year. Subsequently, average leakage value of seven zones for year 2007 to 2010 has been showed in figure 2. From 2007 to 2008, Zone-2 has the peak average leakage values (44, 82). Zone-2 covers area involving B.D.R-3, Kalunagar Hazaribagh, Hazaribag Park. In 2009, average leakage values in zones waere very close to each other (56, 64, 63, 66, 65, 34, and 30) and thus no significant variation has been found. In year 2010, reduction in average value has been noticed in Zone-2. Besides, Zone-4 (Mirpur 6 /Ta, Rupnagar-1, Uttar Bissil) gained the highest average value (84). Furthermore, almost in each zone expect from Zone-2, average leakage values represent an increment in 2010.

Table 2: Average Leakage Values for Year 2007-2010

Zone	Weighting Value of Avg. Leakage Value (2007-08)	Weighting Value of Avg. Leakage Value (2008-09)	Weighting Value of Avg. Leakage Value (2009-10)
1	0.76	0.79	0.74
2	1.00	1.00	0.72
3	0.65	0.72	0.87
4	0.65	0.75	1.00
5	0.58	0.79	0.91
6	0.59	0.49	0.45
7	0.59	0.44	0.41

Using average leakage values of 2007 to 2010 (Figure 2), Table 2 has been generated exhibiting weighting value of average leakage for time period 2007-2008, 2008-2009, and 2009-2010. As average leakage values are larger in Zone-2 for 2007 and 2008, weighting values of the zone obtain the highest (2007-08, 2008-09). Following this concept and estimation, Zone-4 exhibited maximum weighting value for 2009-10. On that certain time period, Zone-2 achieved a weighing value between 0.7 and 0.8. In each time period, Zone-6 (Modhubag Madrasha, Moghbazar Wireless, Santibag) and Zone-7 (Sonakanda, Kadam Rasul, Paikpara) showed less weighing value than other zones.

3.2 Leakage Data Analysis for 2011 to 2013

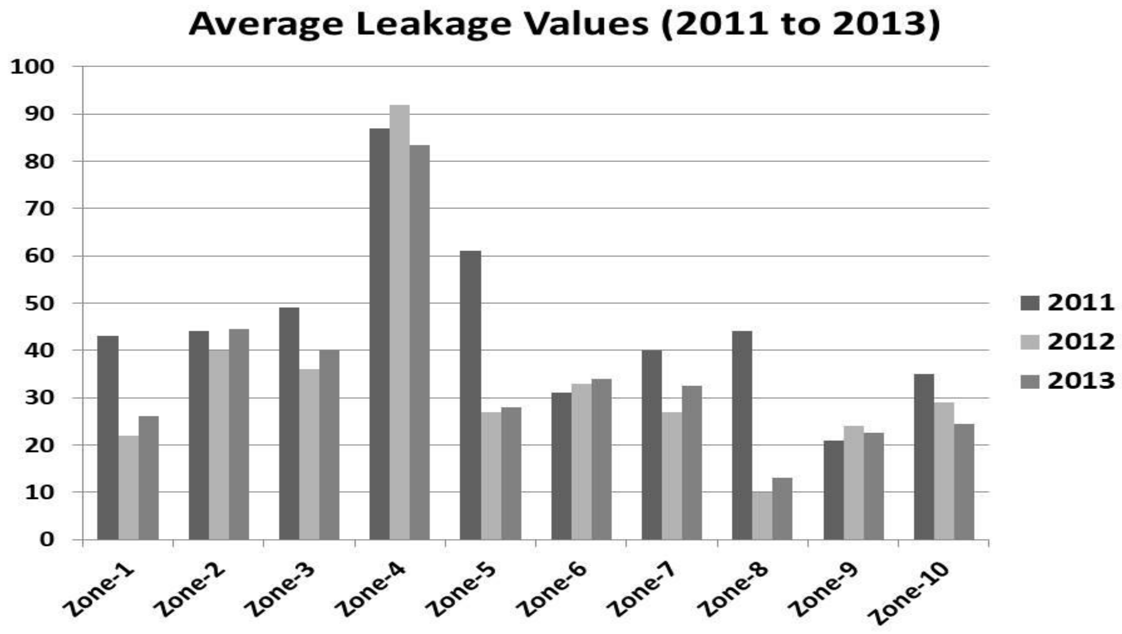


Figure 3: Average Leakage Values for 2011 to 2013

Ten zones average leakage values for 2011 to 2013 has been illustrated in figure 3. Average leakage values of Zone-4 were the highest in each year (87, 92 and 83.5) which is subsequent to 2010. Considerable changes has been noticed in Zone-5 (Banani-5, Shahin Bag) as 2012 and 2013 average values (27 and 28) were much lower than 2011 (61). Zone-6 to Zone-10 continued with their low average value compared to other zones.

Table 3: Weighting Value of Average Leakage Value 2011 to 2013

Zone	Weighting Value of Avg. Leakage Value (2011-12)	Weighting Value of Avg. Leakage Value (2012-13)
1	0.36	0.31
2	0.47	0.53
3	0.47	0.48
4	1.00	1.00
5	0.49	0.34
6	0.36	0.41
7	0.37	0.39
8	0.30	0.16
9	0.25	0.27
10	0.36	0.29

Weighing values of average leakage of two specific time period, 2011-12 and 2012-13, has been illustrated (Table 3) considering average leakage values for 2011 to 2013 (Figure 3). In both time periods, Zone-4 held the position of peak weighting value. Zone-2 had weighting values between 0.45 and 0.55. Low weighting values represent less average leakage values especially in Zone-6 to Zone-10.

Table 4: Monthly Leakage Values of 2012

Zone	Jan	Feb	Mar	April	July	August	Sep	Oct	Nov	Dec
1	38	19	17	18	17	13	17	12	15	29
2	49	32	29	25	38	22	29	40	85	48
3	52	60	42	43	32	20	21	26	37	26
4	117	86	69	179	107	61	100	85	93	86
5	22	27	33	36	22	15	14	28	20	29
6	22	39	36	27	29	32	22	30	50	59
7	30	19	35	28	20	20	44	24	33	35
8	12	10	5	10	14	13	7	4	12	9
9	22	18	22	25	20	22	28	30	35	25
10	29	33	27	31	38	24	35	17	20	13

Table 5: Monthly Leakage Values of 2013

Zone	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1	35	37	22	22	19	30	45	29	31	33	27	22
2	96	22	22	22	41	51	59	42	53	53	66	59
3	60	60	50	50	40	50	50	25	30	40	37	36
4	83	101	52	52	84	72	58	77	59	74	95	86
5	31	26	20	20	21	25	25	23	12	34	47	57
6	61	36	29	29	25	15	39	35	23	63	39	46
7	46	40	43	43	35	27	45	29	34	36	37	31
8	7	5	10	10	16	15	21	31	14	26	19	15
9	22	15	20	20	20	18	20	22	26	25	22	20
10	17	20	20	20	21	20	25	20	25	20	15	10

Table 4 & 5 represent seasonal variations in leakage data for years 2012 and 2013. In 2012, the highest leakage was detected in the month of April (179). Total precipitation was 196.192 mm in April 2012 (Source: World Bank). Poor infrastructures like old aged pipes, lack of maintenance or illegal connections and high rainfall are responsible for high leakage. February month recorded the peak leakage in 2013 (Table 5). According to World Bank, average precipitation in February 2013 was 11.4669 mm. Consequently too dry period where cracks occur increases leakage value.

Table 6: Risk Analysis (2012-2013)

Zone	Weighting Value of Avg. Leakage Value	Number of Connections	Weighting Value from the Number of Connections	Risk
1	0.31	38458	1.00	0.31
2	0.53	30086	0.78	0.41
3	0.48	30266	0.79	0.38
4	1.00	35811	0.93	**0.93**
5	0.34	13659	0.36	0.12
6	0.41	33211	0.86	0.35
7	0.39	35688	0.93	0.36
8	0.16	26291	0.68	0.11
9	0.27	34935	0.91	0.25
10	0.29	29401	0.76	0.22

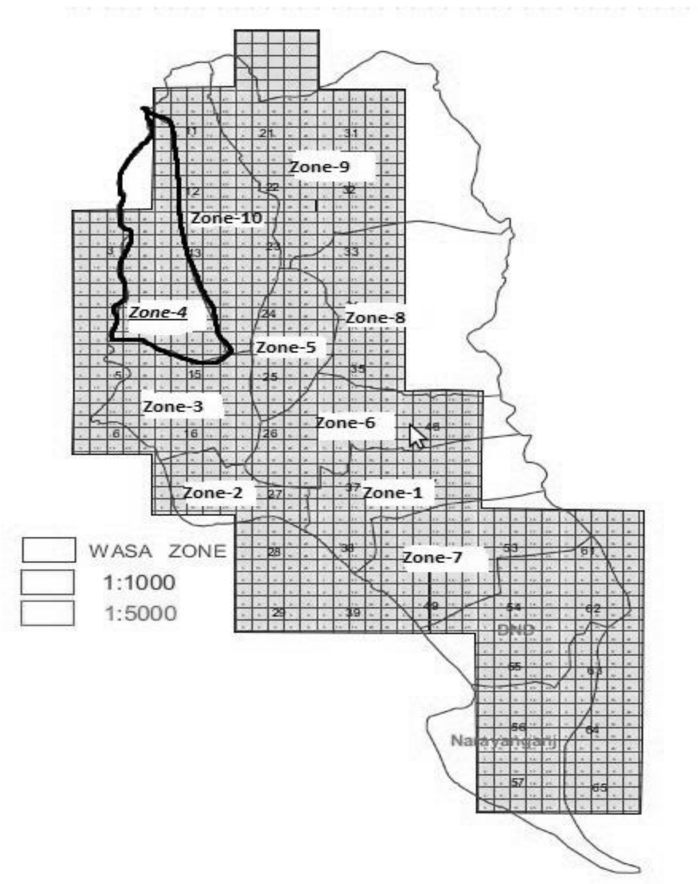
Risk analysis is the multiplication of weighting value of average leakage and weighting value from number of connections (Equation 1). As development of any society increases, number of connections also changes with time period. Table 6 illustrates estimation of risk analysis for ten zones in the time period 2012-13. As discussed earlier, Zone-4 presented the peak weighting value for average leakage (2012-13). Weighting value from number of connection obtained the highest in Zone-1 (Bashaboo-3 (Middle), Boishakhi Housing, Forashgonj). Finally, Zone-4 is found to be the most risky zone (0.93) among the ten zones. Observing weighting values of Zone-2, the zone can also be considered as hazard zone having risk value 0.41.

3.3 Comparison of Overall Analysis (2007 to 2013)

In the Study, observation of average leakage value for different years (2007-2013) is essential to identify hazard zones of Dhaka City. Zone-1 average value is decreased from 2008 to 2013 (Figure 2 and Figure 3). Development in water supply management system, population change and zonal purpose contribute to the changes. Besides, Zone-1 possesses maximum number of connections in Dhaka City which indicates raising development and population of the zone. Zone-2 can be risky in some perspective (Risk-0.41). In 2007 and 2008, Zone-2 had the peak average leakage values. With time interval, average value variations have been noticed in the zone but any significant change is not found. Zone-3 had a consistency in peak average leakage in five years (2009-13). Consequently, this zone holds position of the most risky zone. Other zones stay in mostly uniform leakage values with changing time periods. Considerable reduction in leakage value has been exhibited throughout time period 2012-13.

3.4 Hazard Identification in City Map

One of the purposes of the paper is to identify most risky zone in Dhaka City map. According to the map (Figure 4), Zone-4 is included area Agargoan, West Agargoan, East Symoli, kallanpor, Paekpara, Pererbag, Taltola, West Sewreapara and West Kazipara.



Map Source: www.dwasa.org.bd

Figure 4: Water Supply Zone in Dhaka City Highlighting Risky Zone

3.5 Risk Reduction Options

A number of different risk reduction measures can be taken to decrease the risks. For example, storage of water in open buckets, pitchers or dirty bottles or containers falls in red zone of risk matrix and this could be minimized through awareness program to store water in a hygienic way either by covering the pitchers, buckets or containers and getting water supply through network of pipes consisting of running water from the water supply authority. Ineffective mixing of chlorine leading to poor disinfection can be reduced by regular monitoring and water quality parameter tests with addition of optimum chlorine required. A stand by pump may be used to supplement the pump failure because of failure in continuous supply of electricity. The cross contamination of groundwater leaking into pipes can be reduced by replacing the aging pipe with new pipes but this involves a lot of cost.

4. CONCLUSION

Risk assessment with risk matrices and risk weighting and scoring method is a useful method and the data can be easily understood. However, the risk can be identified as the health and number of affected people who fall victims to a particular hazard. The major risks were found in the leakage and storage of water followed by the scarcity of water to ensure personal hygiene. Risk reduction options were found to reduce the risks significantly. By developing risk assessment, the system managers and operators will gain a thorough understanding of their system and the risks that must be managed. This knowledge can then be used to develop operational plans and identify key priorities for action. Effective policy and legal frameworks are necessary to develop, carry out and enforce the rules and regulations that govern water use and protect the resource. Water policy operates within a context of local, national, regional and global policy and legal frameworks that must all support sound water management goals. Corruption remains a poorly addressed governance issue in the water domain. This domain is a high-risk sector for corruption because water service provision is a near natural monopoly. The resource is becoming increasingly scarce in many countries, and the water domain involves large and often complex construction contracts. Furthermore, water has multifunctional characteristics and is used and managed by a mix of private and public stakeholders.

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