Risk Assessment for Urban water Supply in a developing Country: A case study of Dhaka City

A Thesis Submitted to the Department of Civil and Environmental Engineering Islamic University of Technology Organization of Islamic Cooperation in Partial Fulfilment for the Degree of Bachelor of Science in Civil Engineering

By

S.M. Anik Rahman (105431)

Md. Rabiul Hasan (095435)

NOVEMBER, 2014

Islamic University of Technology (IUT)

A Subsidiary Organ of OIC
Dhaka, Bangladesh

APPROVAL

This is to certify that the thesis submitted by S.M. Anik Rahman and Md. Rabiul Hasan entitled as "**Risk Assessment for Urban water Supply in a developing Country: A case study of Dhaka City**" has been approved by the supervisor for the partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering, Islamic University of Technology (IUT), Gazipur, Bangladesh in November,2014.

SUPERVISOR

____

Shakil Ahmed

Assistant Professor

Department of Civil and Environmental Engineering (CEE)

Islamic University of Technology (IUT)

Gazipur, Bangladesh

DECLARATION

We hereby declare that the undergraduate project work reported in this thesis has been performed by us and this work has not been submitted elsewhere for any purpose (except for publication).

November, 2014

S.M. Anik Rahman (105431)

Md. Rabiul Hasan (095435)

ACKNOWLEDGEMENT

All praises belong to the almighty Allah for giving us the strength and courage to successfully complete our B. Sc. Thesis.

We would like to express our sincere appreciation to our supervisor Shakil Ahmed Assistant Professor of the Department of Civil and Environmental Engineering, Islamic University of Technology (IUT), for his generous guidance, advice and encouragement in supervising us.

The authors also want to thank their course supervisor and DWASA for providing valuable data which were the nucleus of this comparative study.

ABSTRACT

Water supply access in most developing countries like Bangladesh is complex. 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 diarrhoea alone or one every 17 seconds. Upgrading water supply and sanitation services based on risk assessment can reduce vulnerability of people being affected by water borne diseases. 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. Risks can be identified at various stages, and prioritized in terms of likelihood and seriousness (ADB, 2010). A risk-ranking matrix should be 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 as shown : Risk = Likelihood * Severity. For the purpose of risk analysis of different zone of Dhaka city, we collect leakage value of different zones of previous 7years (2007,2008, 2009,2010,2011,2012,2013). Then we plot the data in graph for determine the monthly variation of leak for various zones of Dhaka city. Then we find out the average of leakage of each zone for different years. Then we create a risk analysis matrix from the weighting value of leakage and number of connection for risk ranking .We found that zone 4 is at higher risky position. From DWASA we know that zone 4 is included area Agargoan,West Agargoan, East Symoli,kallanpor, Paekpara,Pererbag,Taltola,West Sewreapara, West Kazipara. Some reasons behind this : Unplanned urbaniztion, Densly popullated, Narrow roads, Poor sewerage system, Lack of mintainance, Old pipe. Some risk reduction options for zone 4 are: Regular maintenance, Replacing old age pipe, Regular water quality test , Less joint in the pipe, Take proper safety when other construction works is done near to the pipe line ,Public awareness. We measured risk only for leakage. Further risk should be measured from pipe age, pipe diameter , pipe length and jointing , pipe material. We measured severity from the number of connection .Further if population data can be found then risk analysis can be more accurate.

Table of Contents

LIST OF TABLES AND FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background

Easy access to potable, safe and affordable water is one of the most important Millennium Development Goals and it 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 and 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 (UNWAP, 2006). Upgrading water supply and sanitation services based on risk assessment can reduce vulnerability of people being affected by water borne diseases.

Bangladesh is a developing country. Water supply access in most developing countries is complex (Gajanan, 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 2006). 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, UNFPA, 2007). Many households do not have piped water supply and have to rely on community based water sources. These include public taps, 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 hand pumps, protected springs and dug wells (Howard et al. 1999).

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.

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. The figure 1 below illustrates the intrinsic linkages between positive or negative testing of water quality, water collection and water-related health burdens.

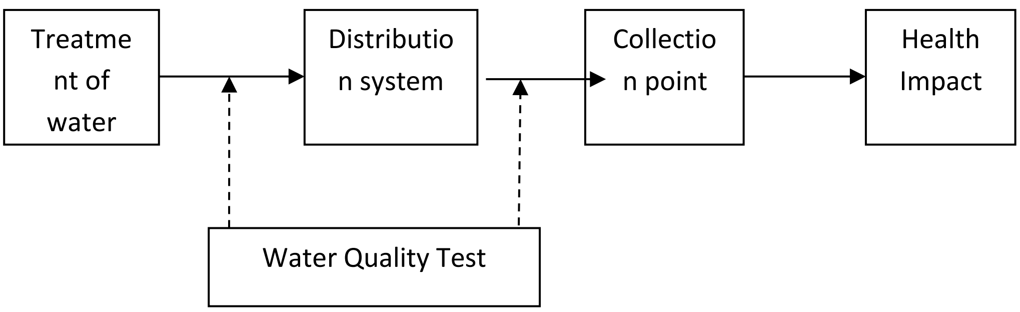

Figure 1.1: Traditional approach to water quality testing

The risk assessment approaches required for developing countries possess major challenges due to the following reasons:

1. The water supply distribution systems in developing countries expand in an unplanned way making it difficult to locate all supply mains as well as there are limited data available related to collection or storage of water.
2. There is a potential for cross contamination resulting from poor sanitation due to aging of pipes.
3. Poor maintenance system.

1.2 Objectives

The objective of risk assessment is 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. The specific objectives are:

1) Identify the major leaks of water distribution pipe in different water supply zones of DWASA and develop a map showing spatial variation of major leaks.
2) Collecting data on the number of connection served for each zone and use the data for later stage of risk ranking.
3) Propose measures for minimization of the risks based on identification of the hazards that the water supply is exposed to.

CHAPTER 2

LITERATURE REVIEW

2.1 Benefits of Risk Management Process

Like other management activities, risk management helps an organization meet its objectives through the allocation of resources to undertake planning, make decisions and carry out productive activities (Shortreed et al., 2003). Risk management focuses on uncertainties that an organization faces such as:

- Uncertainties in the probability of occurrence of events;
- Uncertainties in the value to the organization of consequences of events; and
- Other uncertainties that fall outside the normally expected range of variation.

In general, risks facing the water industry in catchments tend to have a low probability of occurrence, but have a high consequence that can cause major disruption or problems for the organization and the community as a whole. Risk management programs generally cover five main components:

- Context – What is at risk and why?
- Risk identification – What and where are the risks?
- Risk analysis – What is known about them?
- Risk evaluation – How important are they?
- Risk treatment – What should be done about them?

Risk assessment and management planning became an area of heightened interest for the Australian water sector following incidents within Australia and internationally. For instance, in late 1998, water quality incidents affected both Sydney and Adelaide. In Sydney, the incident arose due to suspected Cryptosporidium contamination and resulted in a boil water notice for millions of customers. The resultant costs of the incident were significant but fortunately there was no increased community illness. In

the same year, detections of Giardia and Cryptosporidium were found in Adelaide reservoirs. In this incident, the Giardia detection led to the closure of the Hope Valley Water Filtration Plant and Reservoir on two occasions. In addition to microbial contamination, pesticide detection in five Adelaide reservoirs led to the introduction of activated carbon dosing at the Barossa Water Filtration Plant at an annual cost of $1 m (Billington pers. comm., 2003), although there were not health impacts. Internationally, numerous microbial and chemical contamination incidents have occurred over the last few decades. Some of these are documented in Hrudey and Hrudey (2004), where one of the key findings was that a significant portion of the drinking water quality incidents had the origin of the contamination tracked to the source water. Risk assessment and management in water supply is linked with the demonstration of due diligence. Due diligence can mean the prevention of reasonably foreseeable harm. It may also have a practical definition of showing compliance with statutory obligations. Due diligence can be applied in both
Preventative and reactive operations:

• To mitigate water contamination; and
• To manage contamination to mitigate any further harms.

Australian courts only recognize due diligence as a defense where it is expressly provided for by Statute (as it is in the Trade Practices Act and the proposed food safety legislation). Where due diligence is available as a statutory defense, the legislature has often left it to the courts to determine what is actually meant by the term 'due diligence'. Direction on the principal factors to be considered in environmental due diligence, has been given by a Canadian court. The establishment of a defense of due diligence on behalf of the company's directors was based on the following:

• Established or facilitated establishment of a pollution prevention system;
• Ensured that employees complied with relevant laws and industry practices and reported any non-compliance to the board;
• In being responsible for reviewing environmental compliance reports, placed unreasonable reliance on those reports;

• Were prompt in addressing environmental concerns which had been raised;

• Were aware of the standards of the industry (dealing with similar environmental pollutants or risks

• Personally reacted when they became aware of a system failure.

Intrinsic to demonstrating due diligence in the water industry, therefore, is:

• An assessment of the foreseeable risks to the consumer from source to delivery point;

• An appropriate system for managing those risks(in the appropriate regulatory and statutory context);

• Evidence of a culture of compliance (that the system is being adhered to);

• A rolling revision process to actively seek out and incorporate new knowledge; and

•Appropriate contingency planning.

Generally these key requirements can be addressed by an Environmental Management System (EMS) accommodating a key component of risk assessment. Adherence to an EMS can assist in establishing a defense of due diligence (Bates and Lipman, 1998). However currently only the ACT, South Australian and Tasmanian legislation explicitly recognizes the role for EMS in relation to due diligence .

As this manual has been designed to guide catchment risk assessments and actions to improve water quality in the catchment, storages and raw water delivery infrastructure, it is a preventative complement to incident response plans. The risk management approach outlined in this manual has been developed to allow compatibility with existing “downstream” treated water quality management processes, allowing outcomes of the catchment risk management to flow into the downstream water safety plan. This will result in mutual reinforcement of the actions of both mechanisms.

Within water utilities, the catchment risk management process is usually part of a larger program that encapsulates corporate risk and drinking water quality management. Some organizations use fully integrated management systems, linking all components of business risk (including catchment based) to a corporate risk plan. As such the guidance provided in this manual recommends how to ensure proper consideration of catchment risks in a water quality management plan.

2.2 Uncertainty of Information Used in Risk Assessments

In risk assessments it is imperative to recognize the level of certainty or confidence you have in the information you are using in the risk assessment (Sullivan, 1998). It is important to recognise that results of risk assessments are highly uncertain as a consequence of the significant gaps in our knowledge and understanding. Sullivan (1998) outlines that the most significant shortcomings are:

• Difficulties in estimating the likelihood of occurrence of low probability events;
• Limited understanding of the sources of pollution, in particular those sources which contain arrange of pollutant hazards;
• Limited understanding of the transport and fate mechanisms which determine the Concentrations and duration of pollutants in the environment;
• Difficulties in characterizing ecosystem responses to pollutants and other stressors;
• Limited data on the synergistic effects of chemicals.

There is also the potential for risk assessments to be biased or affected by external factors such as public concerns and health protection as well as economic and political interests (Sullivan and Hunt,1999). Guidance on the "level of certainty" that we have on a piece of information can be expressed in the form of Certainty Guidelines and thus allow this to be recognized in the risk assessment. These guidelines should be based on the drinking water supply or catchment manager's knowledge of the hazards or hazardous event and barrier or control measure effectiveness. It is suggested that four levels ranging from low, moderate, high, very high could be allocated. A low level of certainty is suggested as it reflects the reality of poor understanding of source characteristics, risks or water quality issues that can be common in catchment management. The use of certainty guidelines can then provide further emphasis to drive local and operational research and monitoring into areas of low or moderate certainty. Mitigation actions addressing a key hazard or hazardous event as a result of a risk assessment will be based on the recognition of this level. There is much value in including certainty or confidence guidelines, particularly for confidence in decision-making for financial allocations.

2.3 The Range of Risk Assessment Methods

There are a number of different risk assessment methods available. However, generically there are two distinct risk assessment approaches being used by water utilities and research organizations. One approach uses quantitative risk assessment (QRA) (whether human health or ecological) and is born out of the use exposure and reference dose data. This includes the selection of assessment and measurement endpoints and the comparison of endpoint water quality measurements or distributions to a guideline value. A second approach is qualitative and 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. Methodologies used include the AS/NZS 4360:2004 Risk Management and the HACCP system. Differing risk assessment methods based on these generic approaches and case examples are outlined in more detail below in this section. 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. Generically however, there are five main types of risk assessment methods as identified by Deere and Davison (2005):

2.3.1 Qualitative Risk Assessment Methods

1. Conceptual descriptions of the cause and effect relationships that lead to risks arising from a particular activity or scenario (e.g. Vigneswaran and Deere 2003).

These are not quantitative but provide a demonstration of the potential for cause and effect, to rule risks in or out and are particularly valuable as educative and illustrative tools. This approach was used in the original food HACCP risk assessments, pre 1996, and by Gold Coast Water in its catchment to tap HACCP risk assessment;

2. Qualitative, subjective risk ranking models (e.g. Deere et al., 2001). These models are used to rank scenarios, events or options in terms of risk or impact rather than to provide estimates of actuals. They include the Drinking Water Quality Management Framework approach, the AS/NZS 4360:1999 methodology and the more recent approaches to HACCP such as used by the Melbourne water utilities (Mullenger et al., 2002, Hellier, 2003);

3. Semi-quantitative objective risk ranking models (e.g. Deere et al., 2001). As for the above bullet point, such models are applied to ranking events, options or scenarios but these use objective data such as occurrence frequencies or receptor population sizes. This approach was used by Sydney Water in its 1999 catchment to tap risk assessment;

2.3.2Quantitative Risk Assessment Methods (QRA)

4. Point-estimate quantitative risk assessment models (e.g. Deere et al., 1998). These models do not represent uncertainty and variability well, although they are very useful in screening level assessments for single hazards and endpoints; and

5. Probabilistic quantitative models employing randomized frequency distributions to represent one or more elements. These models provide a useful representation of the uncertainty and variability in estimates and have been evaluated previously by the CRC for Water Quality and Treatment under project 1.1.1 (Deere 1998, Nadebaum et al., 2000a, b).

The two generic approaches are not necessarily un-related, but are not often used together. This may be due to the separate evolutions of the approaches, from toxicological/microbiological and from manufacturing and quality systems. The two however have intersected in the management of water resources. There is a need for the quantitative approach to be able to assess multiple contaminants, priorities these and link to the development of management (treatment) options. The qualitative approach suffers from a lack of use of actual water quality data and focus on an endpoint, unrecognized uncertainties and the potential for biased results from the “expert team” (Burgman,2001). Risk assessment methods can be informed by, and are perfectly consistent with the approach of pollutant budgeting. This has recently been expanded to cover pathogens and organic carbon (Ferguson et al., 2002).

2.4Case Study Area

The task of ensuring safe and sustainable drinking water for Dhaka city with a population of 14 million is getting difficult. The growth of population, economy and industry is a challenging factor for authorities like DWASA (Dhaka Water Supply and Sewage Authority). The water supply is largely dependent on ground water, 1700 mld (87%) which is now seriously depleting. The peripheral river is highly contaminated due to unplanned industrial growth and poor sewage facilities. It is becoming a difficult task for DWASA to find suitable location for intake of water.

Water Consumption:

Sources:

The demand for water supply has increased from 150 mld to 2240 mld from 1963 to 2012 with number of deep tube well increased from 30 to 622 over the same period. DWASA can supply only 2180 mld against a demand of around 2240 mld (DWASA, 2012). 87% of Dhaka’s water supply is coming from groundwater. Production capacity of surface water treatment plant is 535 mld out of which 450 mld is from Saidabad Water Treatment Plant, 39 mld of Chadnighat Water. Treatment Plant and 46 mld of Narayanganj Water Treatment Plant. Apart from the rapid decline in groundwater table in Dhaka city the flow of river in Old Bhamaputra and Dhaleswari have reduced from 10% to 4% of flow from river Jamuna. Most importantly, these perennial distributaries have become seasonal distributaries causing acute shortage of water during the dry season.

Distribution System:

DWASA distribution system has pipeline of nearly 3040 km. The total number of consumers for DAWASA is residential 2,88,401 (92.71%), commercial 19,872 (6.39%). In developing countries, 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). 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). Therefore, the departments undertaking monitoring and those responsible for water operation must share their knowledge of existing trends in water quality and hydraulic patterns within the network that might result in intermittence, discontinuity or pressure waves in supply. It is possible to indentify the 'problem spots' susceptible to contamination within the network by analyzing the information related to pipe network system.

CHAPTER3

METHODOLOGY

3.1Methodology

It is important in developing the description of the distribution system to understand the environment around it and to consider what hazards or hazard sources it may contain that could affect the supply. The data to collect includes: sanitation coverage data (on-site and off-site), location of sewers, drains and major roads, population data, population served by the supply by area, areas of industrial development, areas that are low lying and vulnerable to flooding. Many of these data are collected as surrogates for hazard information. For instance, population density can be used as a surrogate for fecal loading (Howard, 2003). Others are more directly related to potential hazard events, for instance sewers that are very close to water supply mains could lead to contamination events. This data will be used to identify priority areas for inspection during the field assessment stage and later incorporated into maps of hazardous events and risk. Collecting data on the population served is very important for the later stage of risk ranking. To do this, information on the number of people that may be affected by a contamination event must be estimated, and this requires knowledge of how many people use the water downstream of the point of entry of a hazard.

3.2 Hazard Identification

Contaminated groundwater leaking into pipes / pipe leakage: The cross contamination of groundwater leaking 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 corrosively 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.

Poor storage of water: This risk involves water stored in over head reservoir tank of a distribution system, underground reservoir and roof top tank of individual houses including percentage level of sanitary risk associated with each facility. These are often the cause of deteriorating water quality due to prolonged storage and poor cleaning.

Ineffective mixing of chlorine leading to poor disinfection: Sometimes lack of proper mixing of chlorines lead to poor disinfection and possess a serious threat to spread of water borne diseases.

Pump failure: In the contest of developing countries frequent load shedding results into pump failure which results into pressure drops in the pipes with no flows. Under this condition the ground water or water from leaking sewerage pipes penetrates through the leaks of the distribution pipes making the supply water contaminated.

Declining water table resulting water scarcity leading to poor hygiene.

3.3Risk analysis

In order to identify a hazard event in distribution systems, it is important to consider the source-pathway-receptor model of contamination, which is shown Fig. 2 below

Figure 3.1 Source-pathway-receptor model

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.

Severity is usually gauged in relation to both the number of people affected and the likely impact on those affected (for instance separated into morbidity and mortality). The nature of the hazards will determine the likely health outcome (for instance pathogens and massive pollution by chemicals may lead to mortality, whereas lower levels of chemicals may only lead to morbidity). When estimating severity and defining severity profiles, it is important to consider the impact of short-term and long-term exposures. This may result in some long-term chemical exposures (e.g. to arsenic from source water) being giving a higher severity rating than short-term exposures alone. 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. This approach can be further refined by considering the vulnerability or susceptibility of the users affected and whether this will influence the outcome. For instance, poorer communities will be more susceptible to many waterborne pathogens and therefore hazard events that affect these groups may have a greater severity than those that affect higher income groups.

Risks can be identified at various stages, and prioritized in terms of likelihood and seriousness (ADB, 2010). A risk-ranking matrix should be 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 as shown below.

Risk = Likelihood * Severity

The selection of the categories and the weighting allocated to different categories with guidelines to definitions are provided in Table 1 below as there is no uniform ‘industry standard’. It should be noted that semi-quantitative estimates are sufficient at this level.

Table 3.1 Risk and severity; some guidance to definitions (Modified after Deere et al, 2001).e*al*

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

The weightings used in Table 1 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.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

For the purpose of risk analysis of different zone of Dhaka city, we collect leakage value of different zones of previous 7years(2007, 2008,2009,2010,2011,2012,2013 Then we plot the data in graph for determine the monthly variation of leak for various zones of Dhaka city. Then we out find out the average of leakage of each zone for different years. These graph are given bellow :

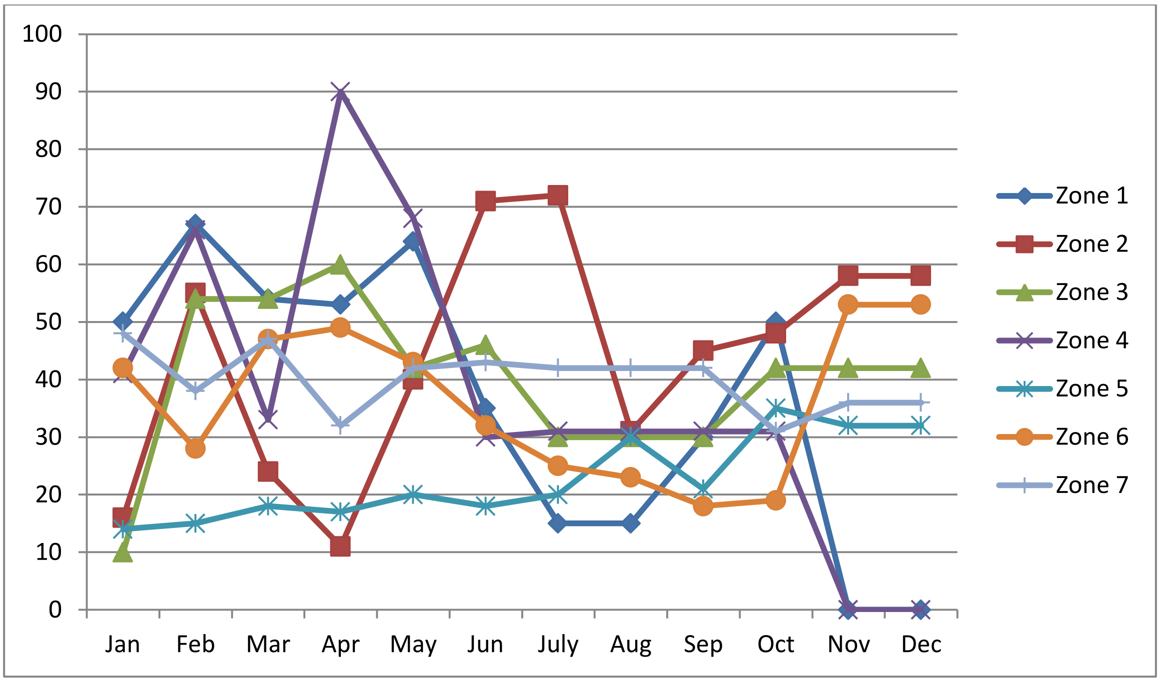

Fig 4.1: Monthly variation of leak for various zones of Dhaka city 2007.

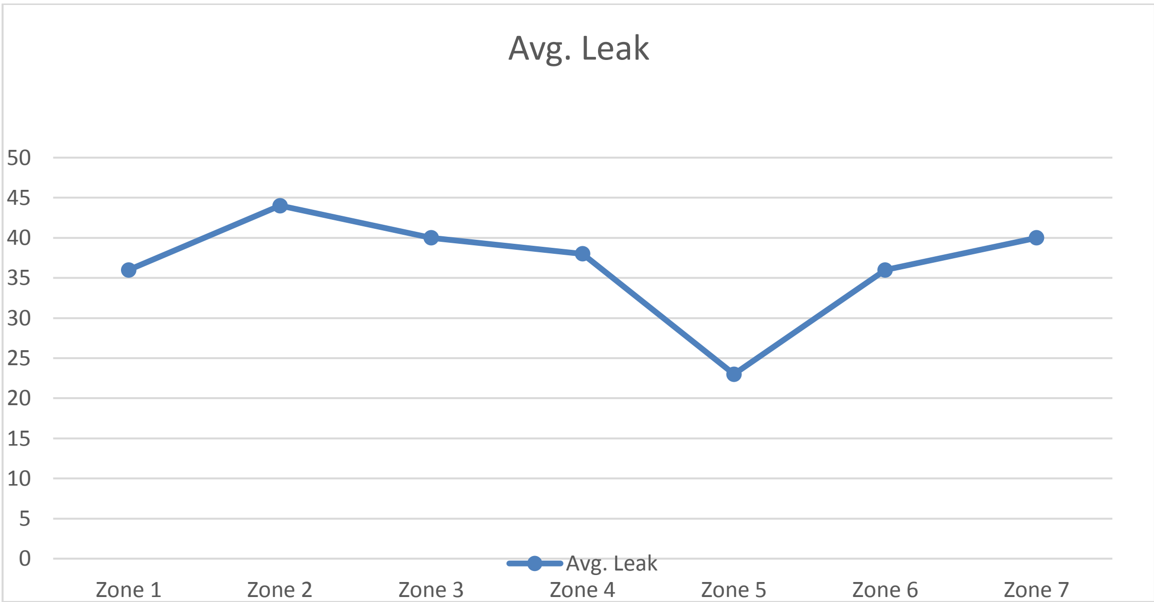

Fig 4.2 : Average leak for various zones of Dhaka city 2007.

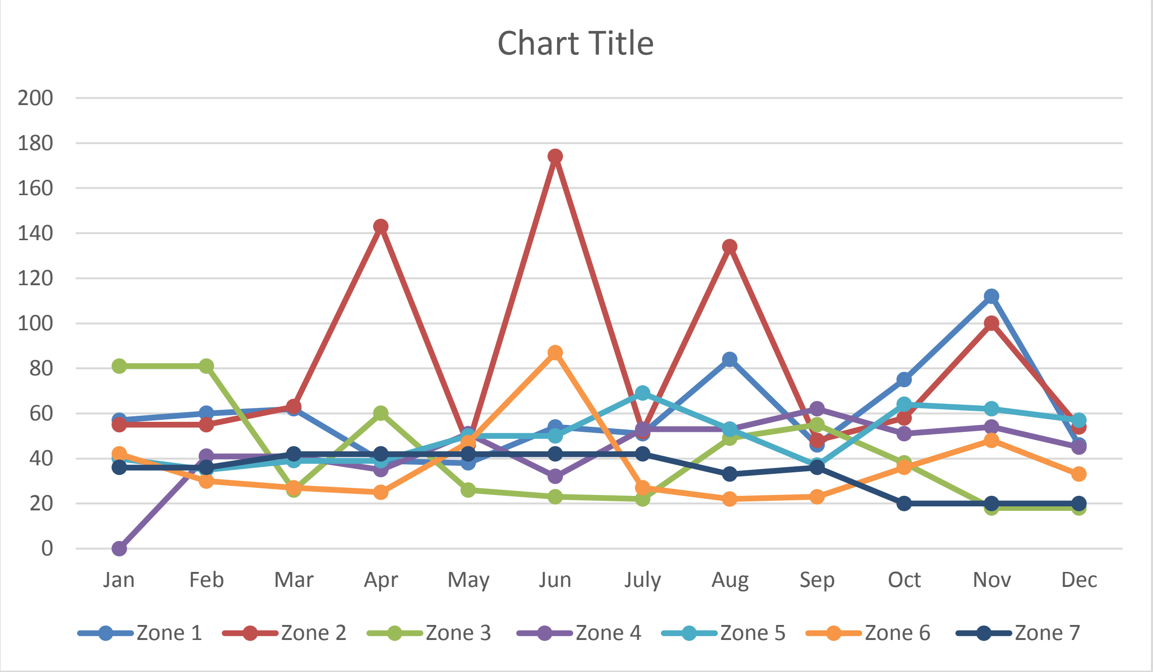

Fig4.3 : Monthly variation of leak for various zones of Dhaka city 2008.

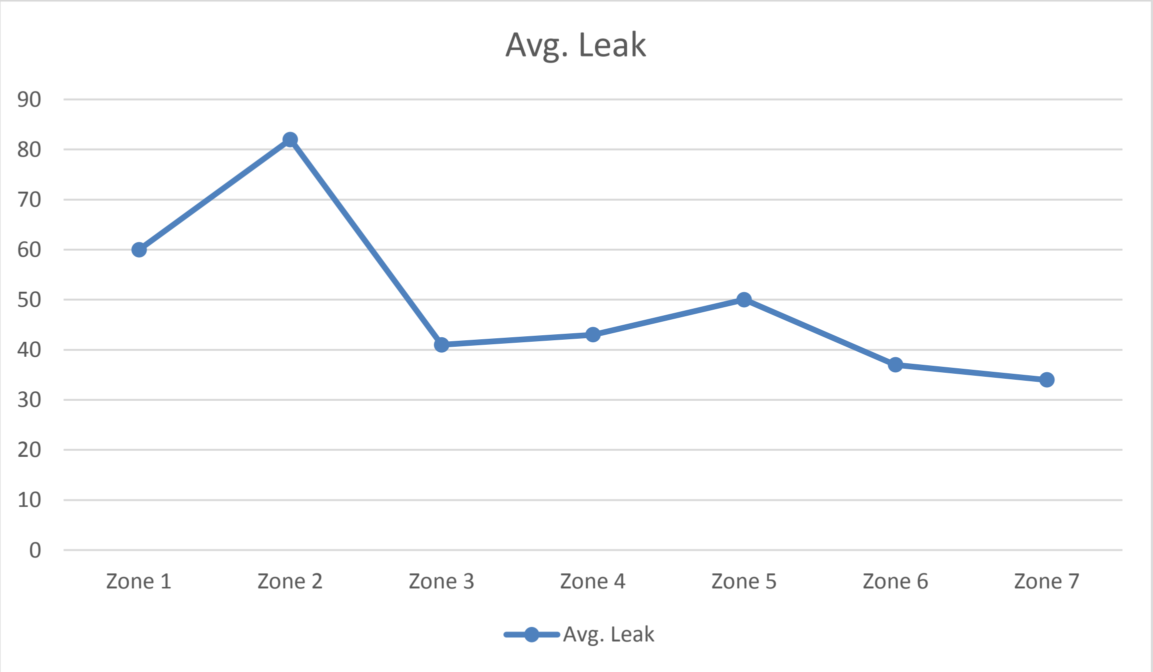

Fig 4.4: Average leak for various zones of Dhaka city 2008.

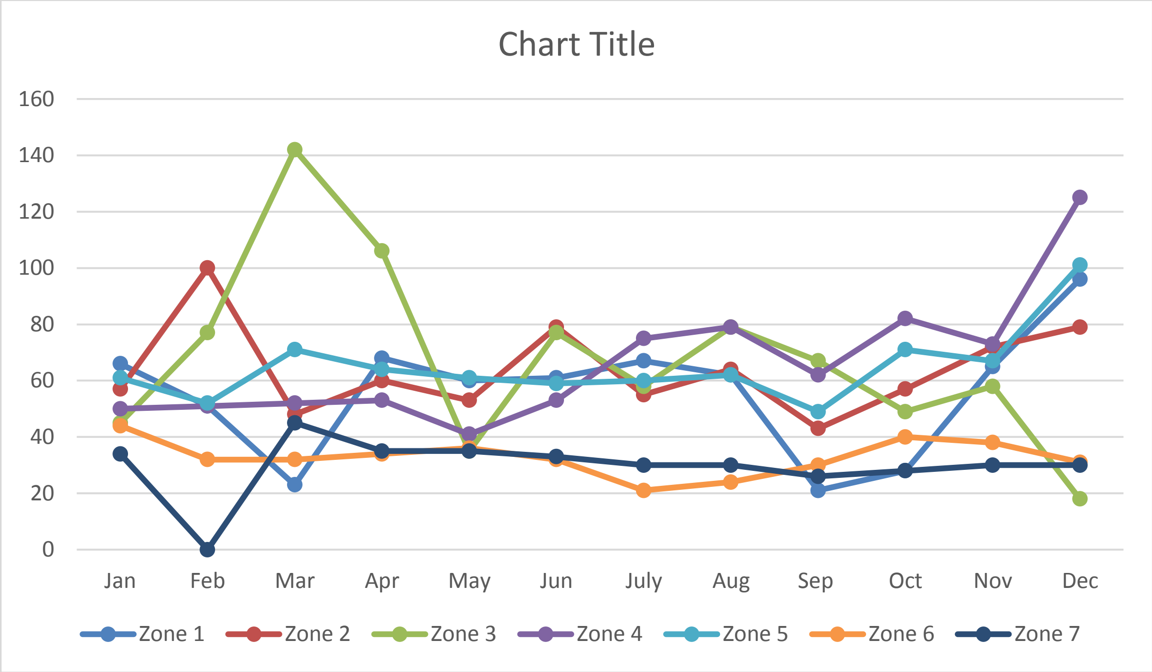

Fig4.5 : Monthly variation of leak for various zones of Dhaka city 2009.

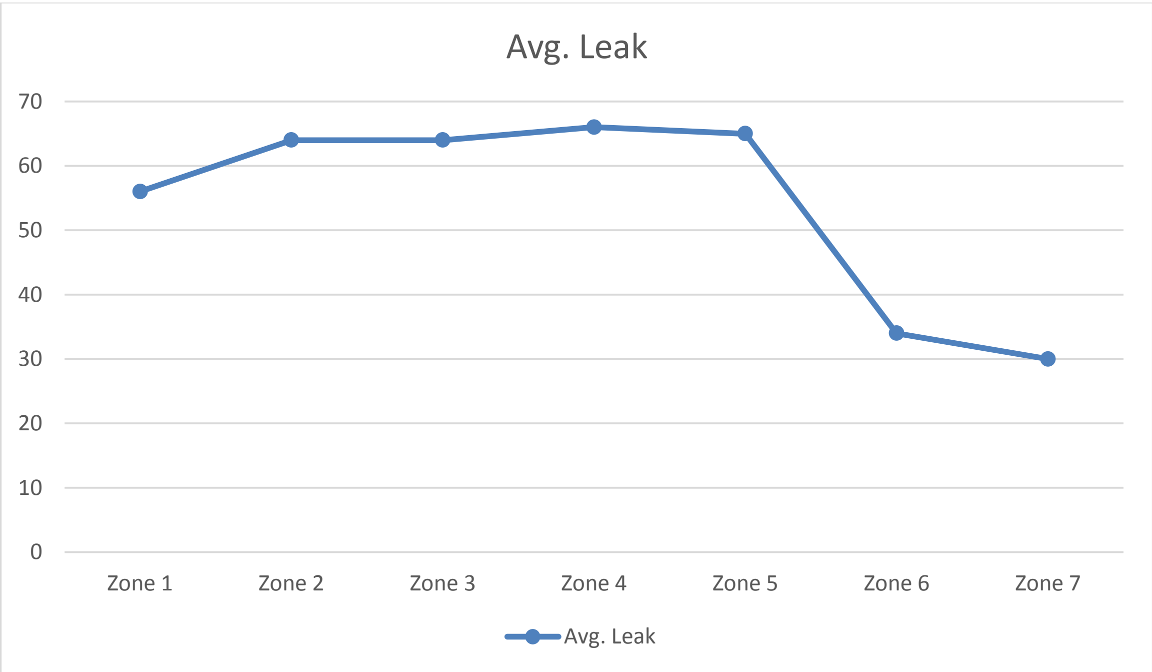

Fig 4.6: Average leak for various zones of Dhaka city 2009.

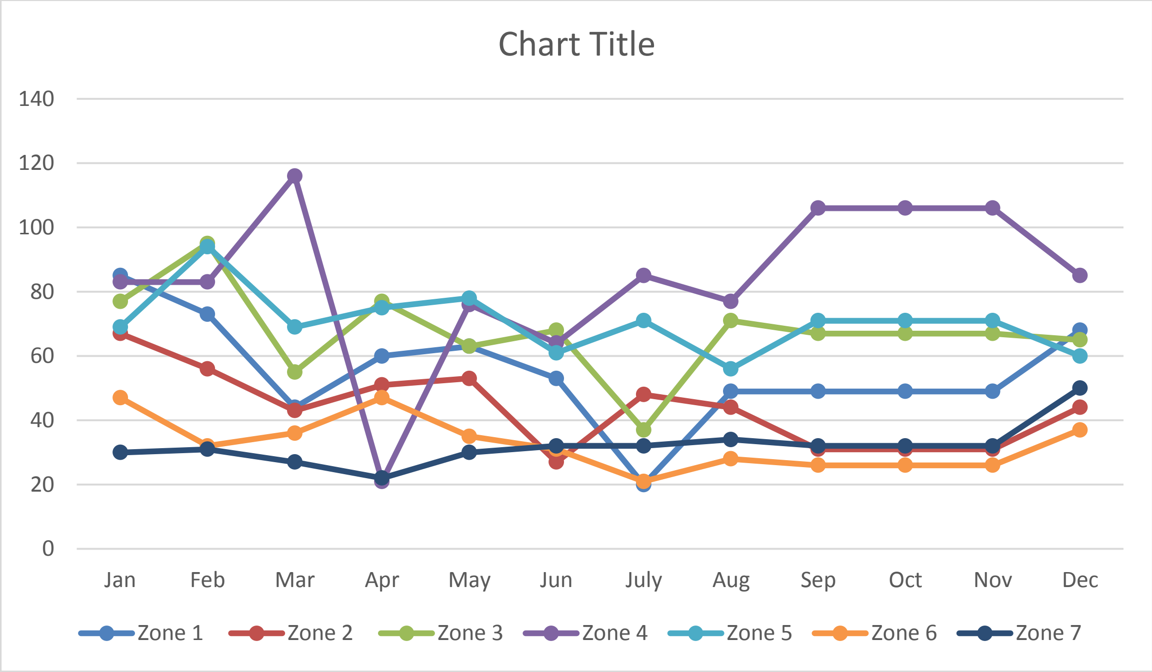

Fig 4.7: Monthly variation of leak for various zones of Dhaka city 2010.

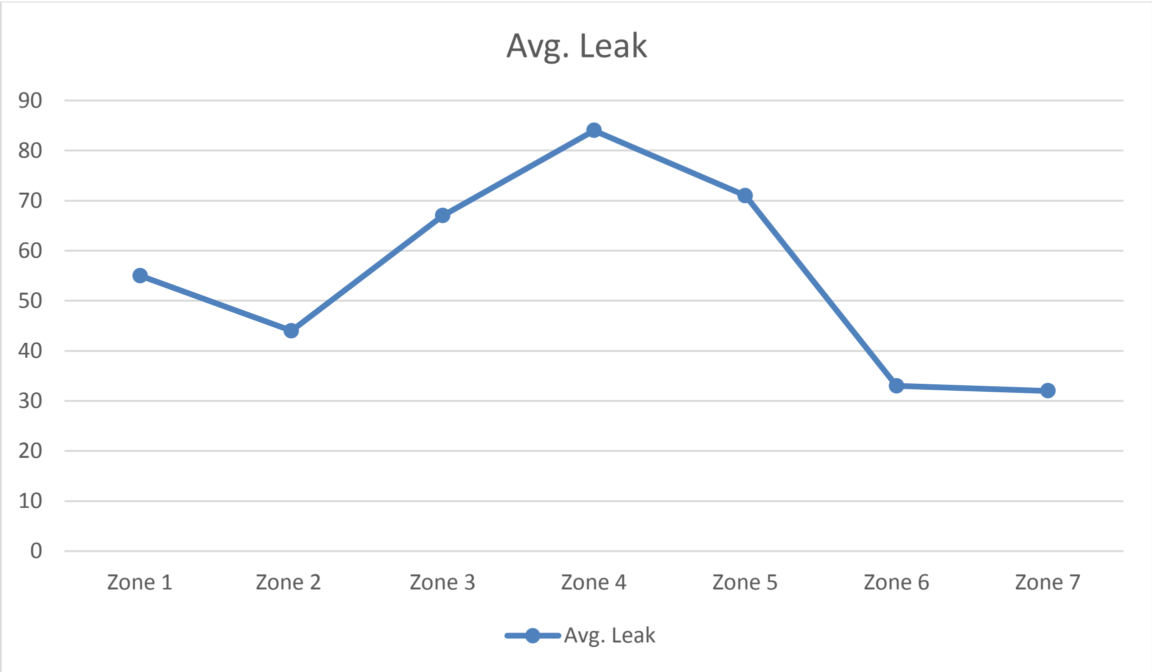

Fig 4.8: Average leak for various zones of Dhaka city 2010.

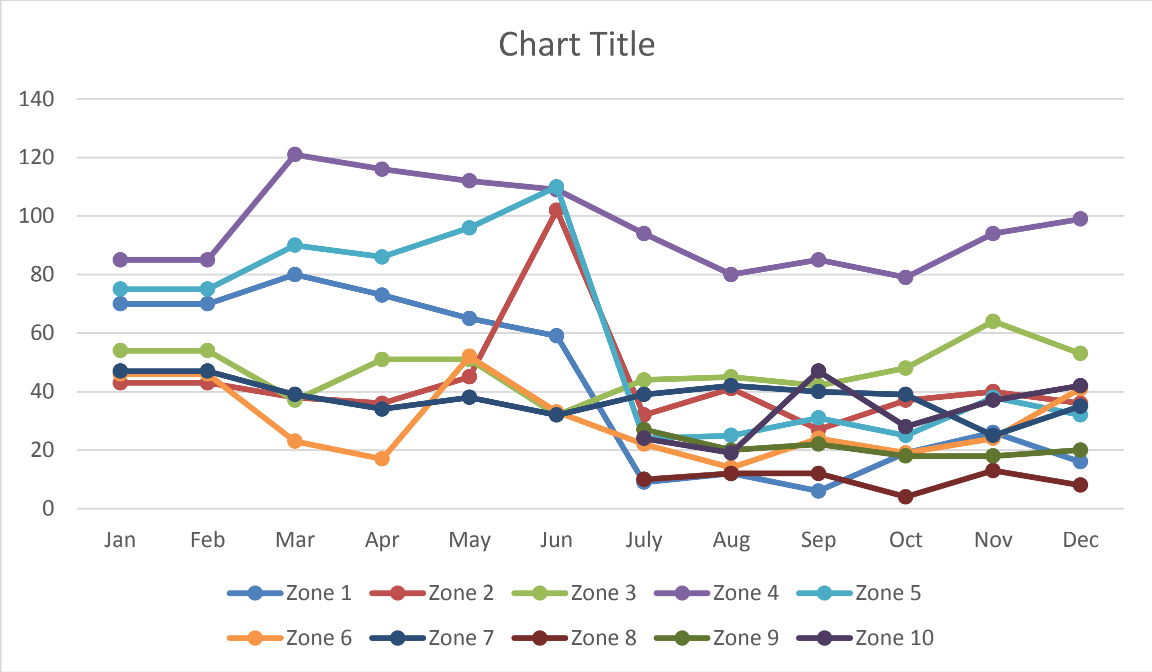

Fig 4.9: Monthly variation of leak for various zones of Dhaka city 2011.

Upto June 2011 there were seven zones in DWASA . After June they make it into ten zones ,so for 2011 we cannot find the yearly average data of leakage for each zone .

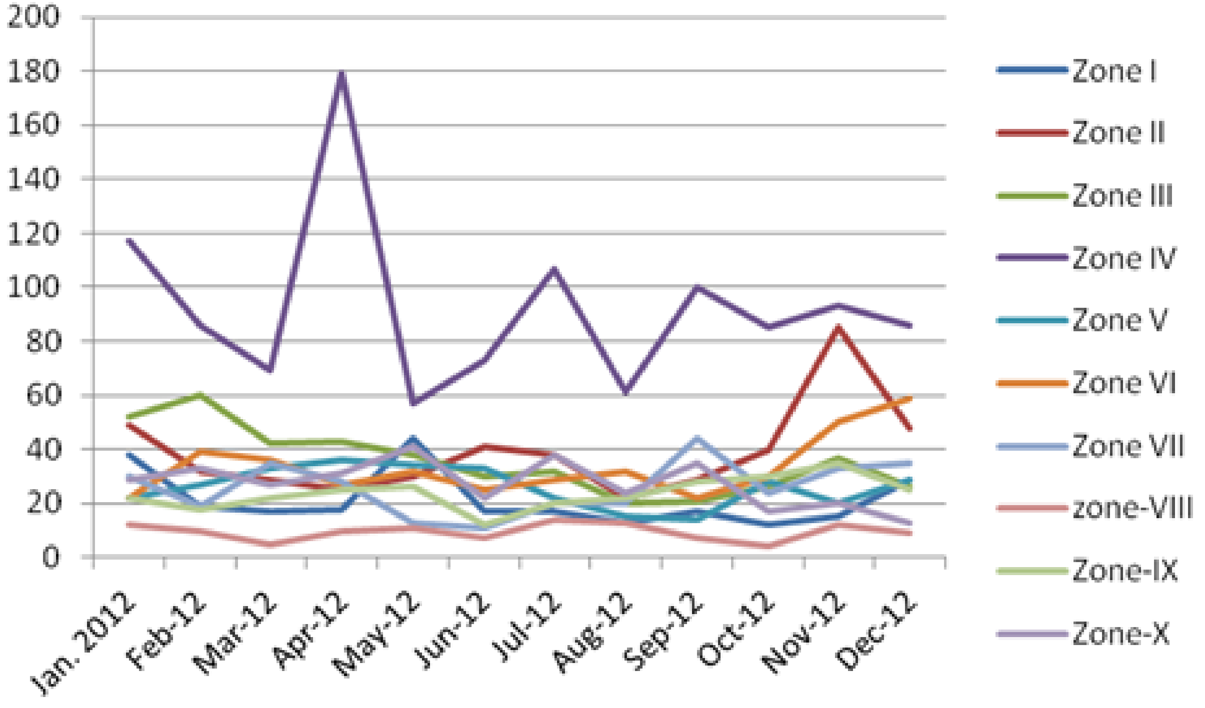

Fig 4.10: Monthly variation of leak for various zones of Dhaka city 2012.

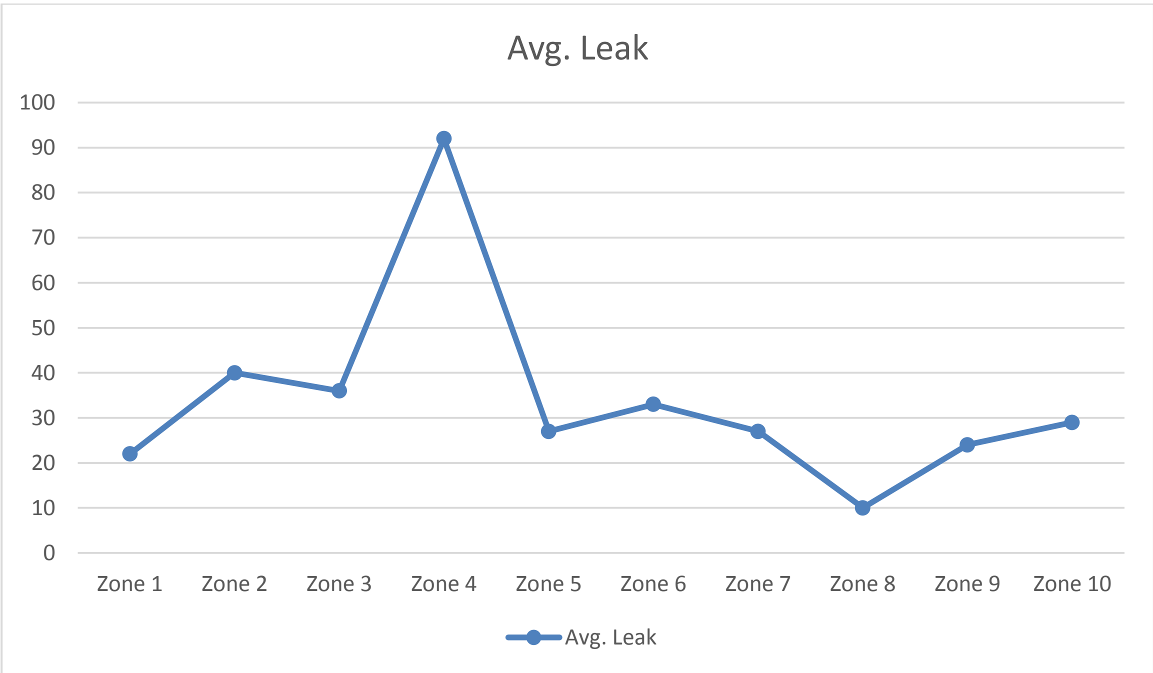

Fig 4.11: Average leak for various zones of Dhaka city 2012.

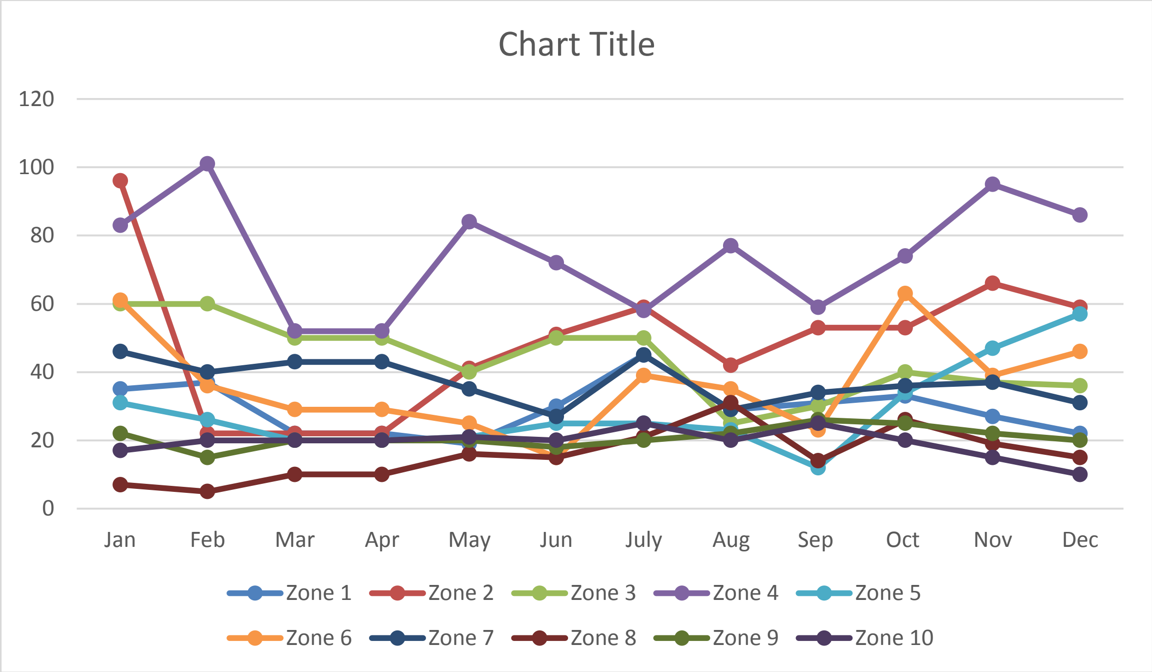

Fig 4.12: Monthly variation of leak for various zones of Dhaka city 2013.

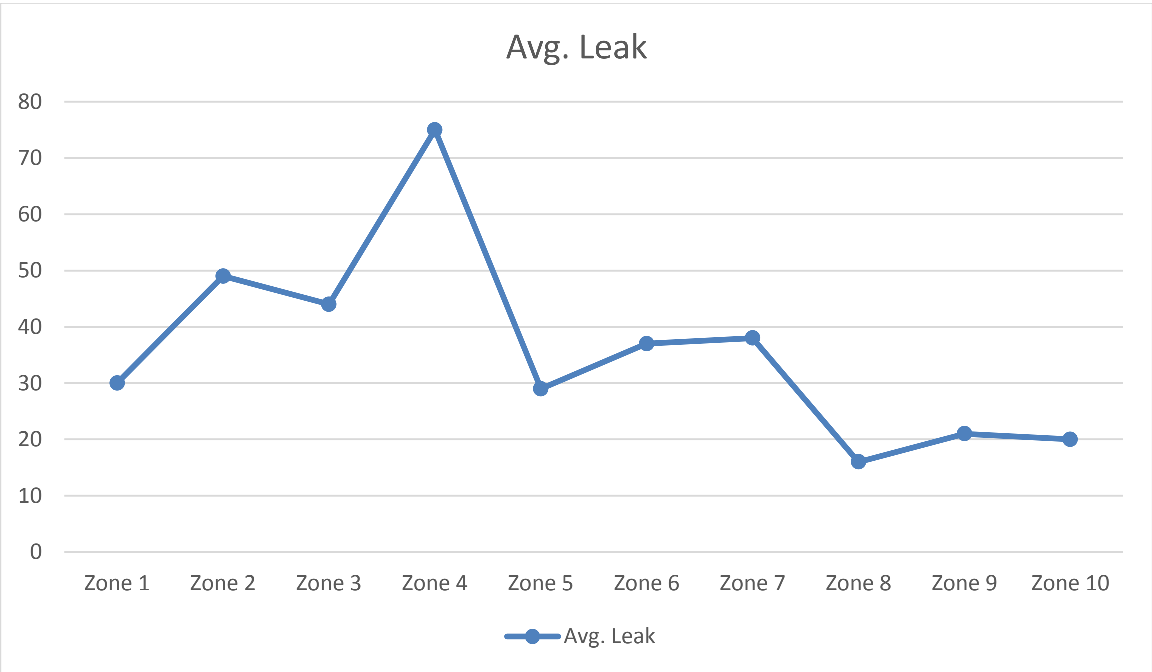

Fig 4.13 : Average leak for various zones of Dhaka city 2013.

Now we take the average value of 2012 and 2013 for find out the weighting value for leakage .

Table 4.1 : Avg. Leakage Value of 2012 & 2013

Zone	**Leakage Value (2012)**	**Leakage Value (2013)**	**Avg. Leakage Value of 2012 & 2013**
1	22	30	26
2	40	49	44.5
3	36	44	40
4	92	75	83.5
5	27	29	28
6	33	37	34
7	27	38	32.5
8	10	16	13
9	24	21	22.5
10	29	20	24.5

Here we can see that zone 4 have the maximum average leakage , we divide the each zone value with the maximum leakage value ,then we get the weighting value for leakage , it indicate the likelihood ,

Table 4.2 : Weighting value of avg. leakage value of 2012 & 2013

Avg. Leakage Value of 2012 & 2013	**Weighting value of avg. leakage value of 2012 & 2013**
26	0.31
44.5	0.53
40	0.48
83.5	1
28	0.34
34	0.41
32.5	0.39
13	0.16
22.5	0.27
24.5	0.29

we take number of connetion for each zones from DWASA, from here we can find the weighting value for number of connection s ,it indicate the severity

Table 4.3: Weighting value from the number of connection

zone	Number of connections	Weighting value from the number of connection
1	38458	1
2	30086	.78
3	30266	.79
4	35811	.93
5	13659	.36
6	33211	.86
7	35688	.93
8	26291	.68
9	34935	.91
10	29401	.76

We know that,

Risk = Likelihood * Severity

From the weighting value of leakage and number of connection and by multiplying them we can get a risk rank .find out which zone is more risky

Table 4.4 : calculate risk

Zone	**Likelihood from weighting value of leakage**	**Severity from weighting value of number of connection**	**RISK**
1	.31	1	.31
2	.53	.78	.41
3	.48	.79	.38
4	1	.93	**.93**
5	.34	.36	.12
6	.41	.86	.35
7	.39	.93	.36
8	.16	.68	.11
9	.27	.91	.25
10	.29	.76	.22

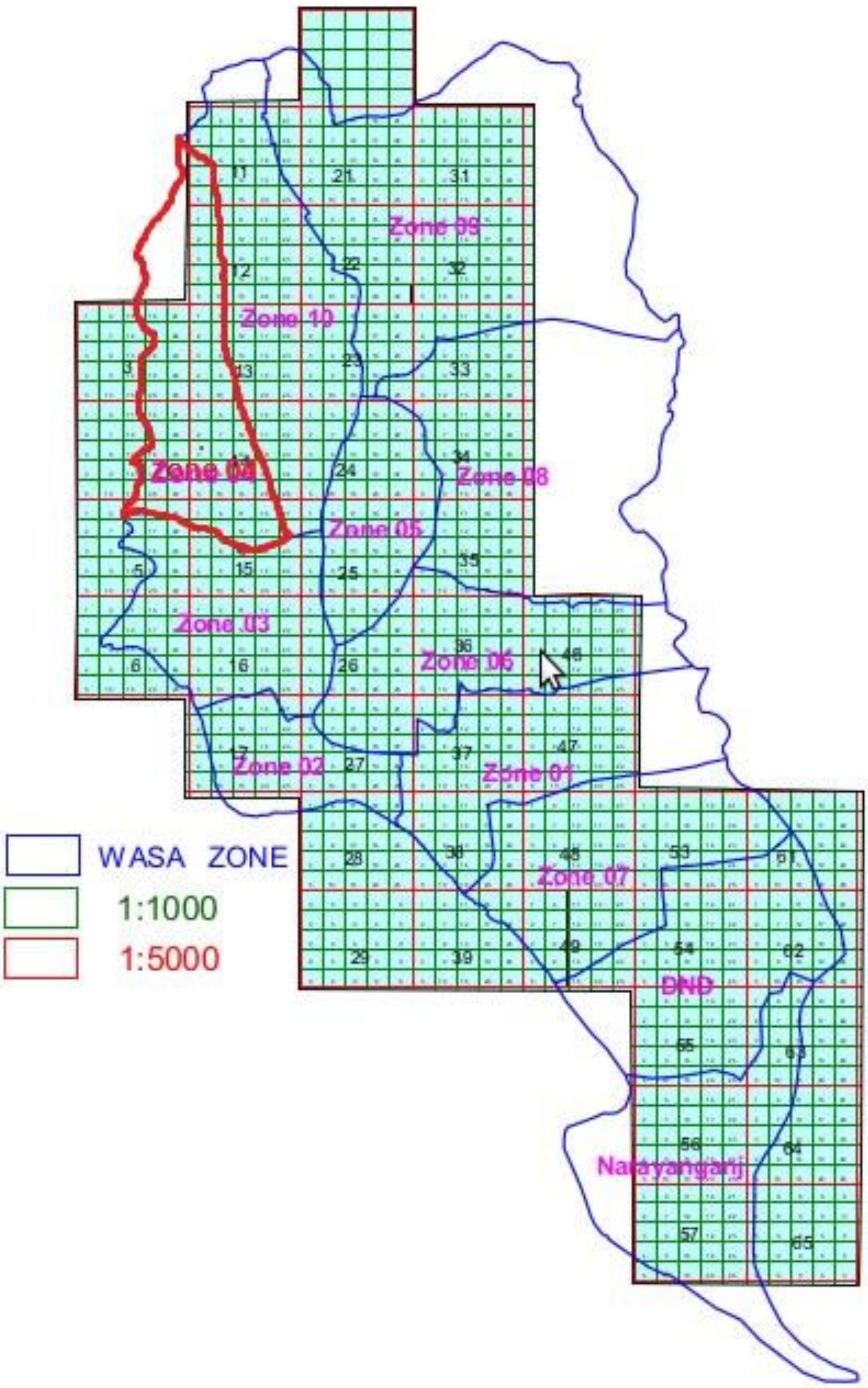

Figure 4.14 : indicating zone 4 in Dhaka city map

4.2 Discussion

Here we can see that zone 4 is most risky zone. From DWASA we know that zone 4 is included area Agargoan,West Agargoan, East Symoli,kallanpor, Paekpara,Pererbag,Taltola,West Sewreapara, West Kazipara. Some reasons behind this :

- Unplanned urbaniztion
- Densly popullated
- Narrow roads
- Poor sewerage system
- Lack of mintainance
- Old pipe

4.3 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 programmer 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.

CHAPTER 5

CONCLUSION

5.1 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.

5.2 Recommendations

- We measured risk only for leakage. Further risk should be measured from pipe age, pipe diameter , pipe length and jointing , pipe material.
- We measured severity from the number of connection .Further if population data can be found then risk analysis can be more accurate
- Identify the proximity of sewers to water supply mains.
- As DWASA updating their GIS map for each zone of Dhaka city then we can found our target areas more accurately.

References

ADB (2010) Guidance note: Urban water supply sector risk assessment, Mandaluyong City, Philippines: Asian Development Bank. Accessed from **http://www.adb.org/sites/default/files/pub/2009/Guidance-Note-Urban-Water-Supply-Sector-Risk-Assessment.pdf** dated 10 Dec. 2013.

Gajanan Kisan Khadse. "Surveillance of Drinking Water Quality for Safe Water Supply—A Case Study from Shillong, India", Water Resources Management, 10/2011

Gray, N. F. 2008 *Water Technology an introduction for environmental scientists and engineers, 2nd Edition, Elsevier*.

Howard, G. 2001 Challenges in increasing access to safe water in urban Uganda: economic, social and technical issues. In: Safety of Water Disinfection: balancing microbial and chemical risks(Craun, G. F., Huachman, F. S.& Robinson, D. E. eds). ILSI Publications,Washington, D.C., pp. 483–499.

Howard, G. and Bartram, J. (2005) Effective approaches to water supply surveillance in urban areas of developing countries. *Journal of Water and Health*., pp. 31-43.

Howard, G., Bartram, J. K. & Luyima, P. G. 1999 Small water supplies in urban areas of developing countries. In: Providing Safe Drinking Water in Small Systems: Technology, Operations and Economics (Cotruvo, J. A., Craun, G. F. & Hearne, N.eds). Lewis Publishers, Washington, D.C., pp. 83–93.

Hutton, G. and Haller, L. (2004) *Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level.* Geneva: World Health Organization.

Meinzen-Dick, R. and Ringler, C. 2006 Water Reallocation: Challenges, Threats, and Solutions for the Poor.

Perrson, M. K. (2009) Tap, tank or bottle? – aspects of drinking water consumption in Eds. Jonas Forare, “Drinking water – sources, sanitation and safeguarding”, Formas, pp. 113-133.

Tatietse, T. T. & Rodriguez, M. 2001 A method to improve population access to drinking water networks in cities of developing countries. J. Wat. Suppl.: Res. & Technol.-AQUA 50(1), 47–60.

UNCHS 2001 *Cities in a Globalizing World: Global Report on Human Settlements 2001, Earthscan, London.*

UN-Water (2008) Sanitation Is Vital for Health. Factsheet 1. International Year for Sanitation, New York.

Wallace, S., Corinne, J., Grover, V. I., Adeel, Z., Confalonieri, U. and Elliott, S. (2008) *Safe Water as the Key to Global Health*. Hamilton, Canada: United Nations University International Network on Water, Environment and Health.

Wen, T.H., Lin, N.H., Lin, C.H., King, C.C., Su, M.D. (2006). Spatial mapping of temporal risk characteristics to improve environmental health risk identification: A case study of a dengue epidemic in Taiwan. *Science of the Total Environment*, **367** (2-3): 631-640.

WHO (2006) Economic and Health Effects of Increasing Coverage of Low Cost Water and Sanitation Interventions. UNHDR Occasional Paper, World Health Organization, Geneva.

Rachael Miller , Jen Guice and Dan Deere, Risk Assessment for Drinking Water Sources ,
Water Corporation ,CRC for Water Quality and Treatment