PERFORMANCE EVALUATION OF WATER DISTRIBUTION NETWORK USING HYDRAULIC PARAMETER

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ABSTRACT: : *The water is a scarcer resource and needs to be supplied in sufficient quantity and pressure to the consumer.In this paper, hydraulic performance of water distribution network has been evaluated to understand its behavior in some critical situations such as leakage losses at node, increased roughness in pipe and varied diameter in pipe. Kosad, new north zone of Surat city has been taken asthe study area to analyse its performance. The network is simulated with EPANET software.Leakage losses were simulated at junctionsto analyse network performance under the condition of leakage.Hydraulic parameters are evaluated at various percentage of leakages along with varying diameter of pipe and varying value of pipe roughness. When 50% leakage losses are simulated in the study network, the analysis shows around 60% nodes are not satisfying minimum pressure criteria. The variations in pipe diameter and pipe roughness also have strong impact on node pressure. Results of this study will be helpful to observe the hydraulic performance and to take decision in improvement of performance of water distribution network.*

Key Words: *Performance of water distribution network, Hydraulic parameter, EPANET software, deficient network analysis, WDN network*

Introduction

The water distribution system is an important public utility. Due to the urbanization people are shifting to the newly developed urbanized area hence more number of people need piped water supply. The water distribution system should supply water with good quality, sufficient amount and with required pressure to fulfill system requirements to the consumer. The water distribution systems comprise vast variety of hydraulic, mechanical and electro mechanical components. The conditions of these components get deteriorated with time. As a result of this, the problem such as leakage or variation in pipe roughness coefficient arises this may affect hydraulic parameter of the WDS. This paper focused on evaluation of WDN behavior under leakage condition along with variation in pipe roughness coefficient and pipe diameter.

Background

To evaluate the efficiency, reliability and resilience of the water distribution system, the performance of water distribution system must be assessed. The water supply and waste water sector's performance evaluation is important and it is well established practice (Kanakoudis and T sitsifli, 2010). Different types of performance evaluation methodologies have been used by many authors. Coelho, 1997a used methodology based on three components - state variable, penalty curve and generalization operator. Muranho et al., 2012 integrated evaluation tool and technical performance indicator in WaterNetGen, while Muranho et al., 2014 explained the methodology by 'slack variable', 'constraint violation' and 'number of story' concepts. (R.Dziedzic et al.,2015) proposed efficiency based performance metrics. They represented network connectivity, capacity to deliver demand under uncertainty and ability to recover after emergency. Sometime demand satisfaction rate is directly applied for assessment of network (Di Nardo et al.,2014). As a surrogate measure of network reliability, (Todani, 2000)developed a resilience index which had been adapted by many researchers among which Prasad and Park, 2004 connected diameter uniformity coefficient with resilience index in order to improve reliability of loop. Performance indicator and technical performance assessment tools these are the two main types of performance evaluation tools (Cardoso et al., 2004). Alegre et al., 2000, 2006 have used performance indicators suggested by International Water Association(IWA) to evaluate performance of water utility. To provide adequate service to the customer water supply system performance is evaluated based on mechanical and hydraulic reliability (Ram K. et.al.,

2018) They proposed a physics based probabilistic approach to determine water distribution network's reliabilityandthe failure probability of pipeline. The water distribution's level of service is highly correlated to pressure. H.Ramos et al.,2008determined the performance index varies between a no-service(0%) and an optimum service(100%) situation.According to Creaco et al.,2018, hydraulic reliability determines the probability of providing adequate water pressure at consumer end whereas probability that network component is physically connected determined by mechanical reliability. Hydraulic performance depends on condition of pumping unit, network design, pipe material and age of pipe. As the pipe becomes older corrosion developed internal and external side of pipes. The concept of change in roughness is used to determine hydraulic performance by (seifollahi-Aghmiuni et.al, 2013; Stephen Nyende-Byzkika, 2017). Corrosion inside the pipe increases the roughness resulting in higher amount of head loss. To overcome this, higher amount of power is required (Kandilkar et al. 2005)Internal corrosion also leads to thinner pipe walls which cause higher rate of pipe burst and leakages (Christensen, 2009).

To evaluate system behavior in different operating and hydraulic condition simulation of the system is developed using EPANET 2.0 (Rossman 2000). Simulation of water distribution system is developed generally in steady state or extended period. The extended period simulation is developed by combining several simulations having different operating condition. It reflects changes in nodal demand, tank levels, pump operation, valve regulation, leakage occurrence (H. Ramos et al.,2008; Giustolisi and Doglioni, 2007). EPANET 2.0 hydraulic simulation gives the data of pressure at each node as output data. It also gives velocity and roughness value for pipes of the network. It is very important to understand how internal surface wall roughness, texture and its spatial distribution affects the flow of fluid in pipeline for real time exact estimation of head loss (D.A.Shah et al., 2015).

Reliability of water supply system is its ability to satisfy the required demand under sufficient pressure during normal and abnormal operating conditions. Abnormal condition can occur due to pipe failure, leakage, excess of demand, etc.(T. Massoud et al., 2003). Many other researcher have used reliability as measure to evaluate level of service for example (Cullinance et al.,1992; Gupta and Bhave, 1994; Tabesh, 1998)Gupta and Bhave found reliability of water distribution system based on available nodal flow. They considered intermediate stage through partial flow to develop a condition that nodal supply is between the required flow and no flow.

The percentage of leakage losses does not remain same all the time in real water distribution network. Theleakage rate depend on physical parameters such as Age of pipe, pipe material, types of joints, size and number of splits, hydraulic parameter mainly pressure along the pipe network and some external factors such as temperature, vehicle and soil load above pipe, soil characteristic surrounding pipe, etc.To make the analysis of studied water distribution network more realistic, this paper propose its analysis in two situation, first 'no leakage condition' and second at 'gradually increasing percentage of leakage loss condition'.

Methodology

In this paper, study has been conducted for WDN under different percentage of leakage at various locations. Leakages were simulated starting from 0% to 50% at various nodes of the network in the simulation software EPANET.Along with increasing amount of leakage, reduction in Hazen william coefficient C is also a significant sign of aging infrastructure. So the second step is to understand leakage – pressure relationship at varying leakage rate along with reduced Hazen william coefficient C. To understand effect of varying pipe diameter on performance of existing water distribution network diameter of some pipes are increased or decreased and its effects were analysed on node pressure along with various percentage of leakage losses.The methodology of the study conducted is shown in flowchart as per Figure 1.

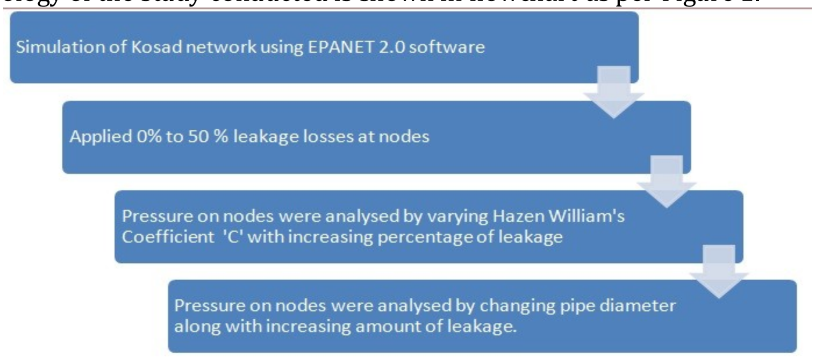

Figure 1. Flowchart for methodology

The water distribution network is simulated for0% to 50% leakage losses of total flow at tail end nodes 11,12,21,25 and 28. The roughness coefficientC for study area is proposed 140 by Surat Municipal Corporation. The value of coefficient C reduces as the pipes become old. In this study value of C is reduced to 130, 120 and 100 to analyze its effect on pressure at junctions in the water distribution network. Effect of pipe diameter on node pressure is observed by varying diameter of some tail end pipes in the network.

Case study

The Suratmunicipal corporation initiated continuous water supply scheme at Kosad area of New North Zone, Surat, Gujarat, India as pilot project. In this paper it has been selected as case study area. The analyses of network behavior in different situation will be useful to identify critical junctions and pipes with deteriorated performance. More than 20,000 EWS (economyically weaker section) flats built under Jawaharlal Nehru Urban Renewal Mission (JnNURM) scheme in Kosad had been given priority by urban planners for providing 24 hour uninterrupted water supply. Three district metered areas of Kosad having ESR are namely K1,K2 and K3. In this paper pipe where water is supplied by ESR K1 is simulated using open assessed software EPANET.

The network has total 27 nodes, 39 numbers of pipes, 1 ESR and 1 reservoir to supply water. Ductile iron pipe are used with diameter varying from 150mm to 600mm.

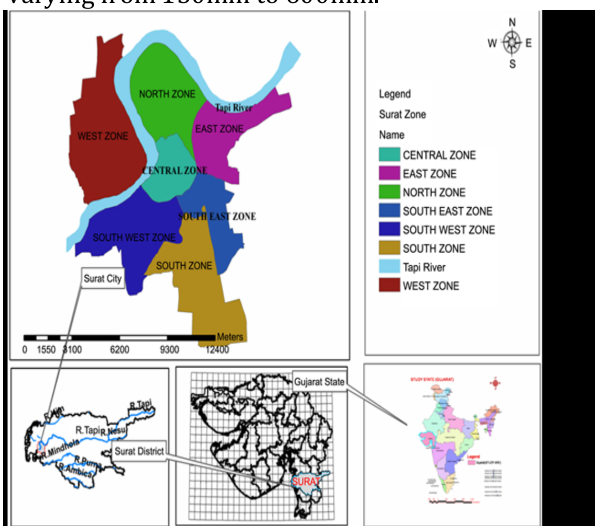

Figure 2. Image of study area Kosad,Surat New North zone(Gujarat, India). (www.surat municipal.gov.in)

Water distribution network of DMA with ESR K1 is simulated using EPANET software. The Hydraulic department of Surat Municipal Corporation provided all necessary data for this simulation model. Figure3 shows the network drawn by EPANET software. Notation P-1 to P-39 show pipes, numbers 2 to 28 indicate nodes and number 1 indicates ESR of case study water distribution network.

Leakages are applied at junction number 11,12,21,25 and 28.The rate of leakage is varying from 5 percentage to 50 percentage of total flow. Leakage applied in the present analysis is for tail end nodes.

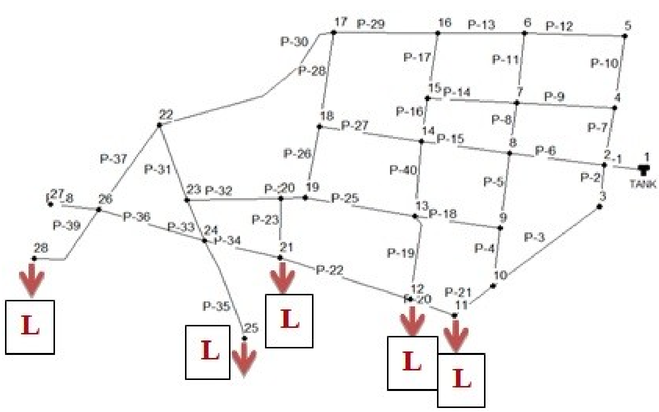

Figure 3.Kosad- K2 water distribution network

Results and discussion

The leakages are applied at junctionand it shows directeffectson pressure observed in the entire network. Figure4 shows the effect of varying percentage of leakage on pressure at all nodes.

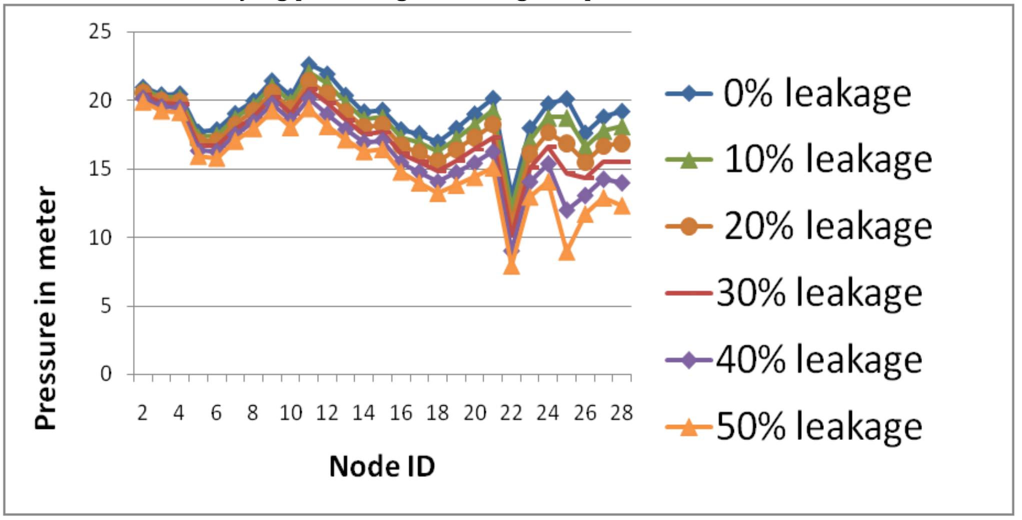

Figure 4.Node ID Vs Pressure at varying % of Leakage, (N.C.Pandya et.al.,2019)

This graphical representation is helpful to sort out those nodes which are not fulfilling minimum required pressure limit set by water supply authority. As per Central Public Health and Environmental Engineering Organization manual on water supply and treatment, water should be supplied with minimum 17m pressure head at all nodes. When amount of leakage is 0%, only one nodei.e 3% node has pressure head less than 17 m while at 50% leakage loss, total 17 nodes out of 27i.e. 60% nodes were not fulfilling minimum pressure head criteria.

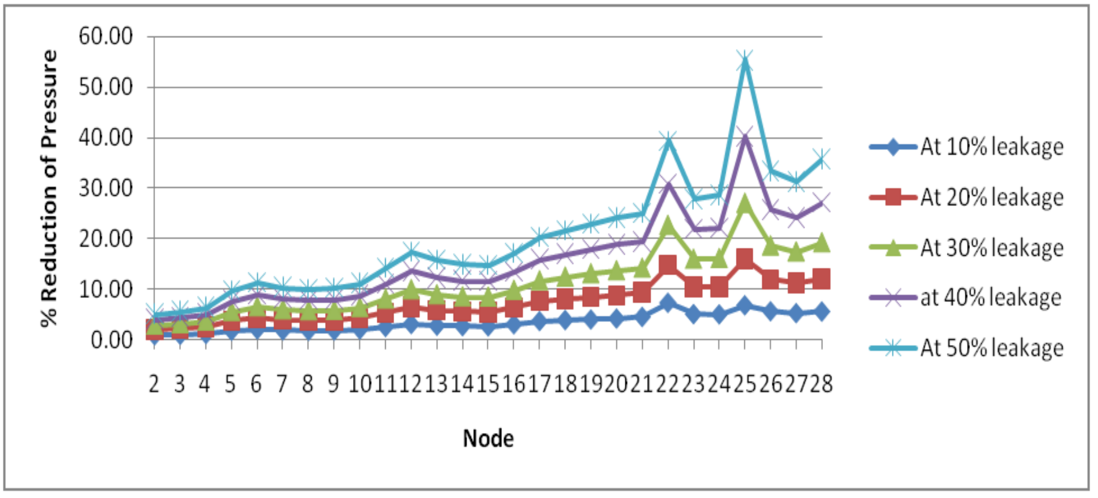

Figure 5: Percentage Reduction in Pressure at varying rate of Leakage

The percentage reduction in pressure is different at nodes of the water distribution network. As distance increase from source of water supply, the amount of pressure reduction increase. Here leakages are simulated at tail end nodes of the network and as a result of this node no. 22 and 25 are more affected compare to other nodes.

The pressure head at various nodes were further reduced with increasing pipe age. Decreasing value of roughness coefficient C indicate pipe's internal surface becomemore roughand generally pipe age is the main reason for it.The effect ofvarying value of roughness coefficient C along with various percentage of leakage losses on node pressure are shown in figure 5,6,and 7.

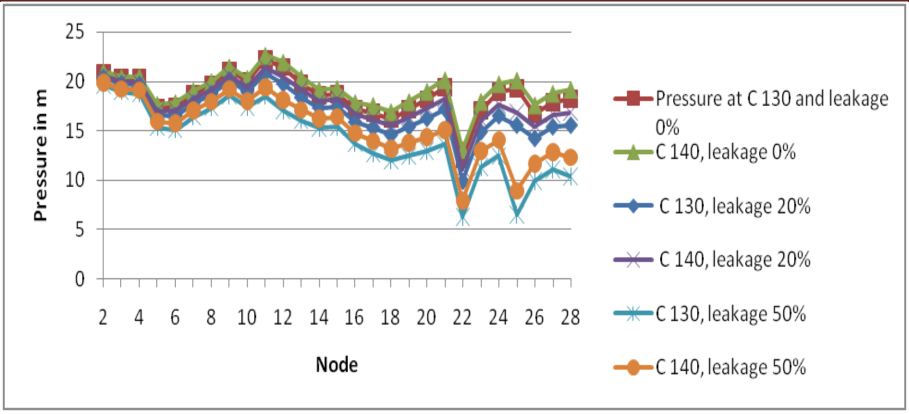

Figure 6. Node Vs Pressure at varying leakage with effect of pipe roughness coefficient C changed from 140 to 130

At roughness coefficient C 140 and C130, node pressures are observed in three different condition, 'no leakage i.e. 0% leakage', 20% leakage and 50% leakage. The same procedure repeat to plot graph which compare node pressure for C140 to C 120 and C 140 to C 100. Node pressure in pipes having roughness factor 140 gives higher node pressure while pipes having roughness factor 130, 120 and 100 give lower node pressure subsequently.As the pipe become rough, it tends to increase frictional head losses and due to this pressure deliver to the user decrease (Stephen Nyende-Byzkika, 2017).

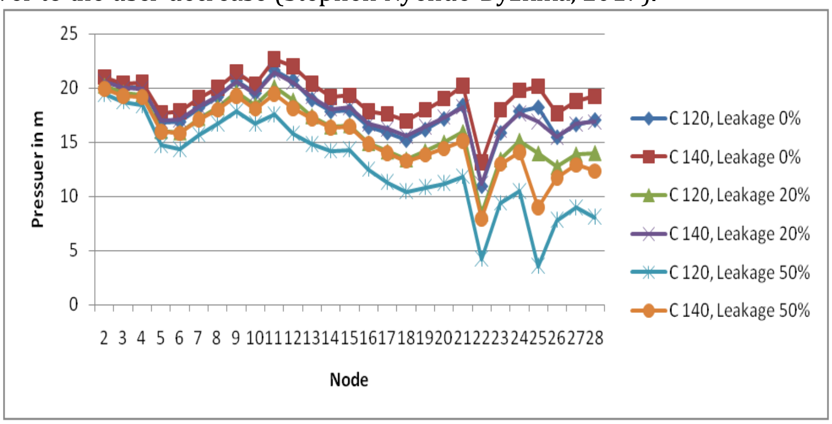

Figure 7.Node Vs Pressure at varying leakage with effect of pipe roughness coefficient C changed from 140 to 120.

More number of nodes fail to fulfill minimum pressure head criteria indicates reduction in hydraulic performance of the system. Study related to pipe roughness is useful to estimate time of intervention required in any water distribution system. It also helps to identify critical pipes or joints needs to be rehabilitated in the water distribution system.

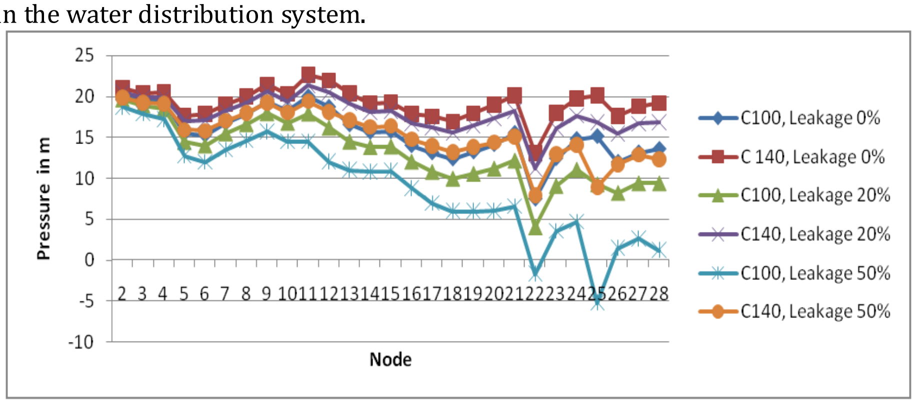

Figure 8.Node Vs Pressure at varying leakage with effect of pipe roughness coefficient C changed from 140 to 100

The diameter affect significantly on node pressure. If the pipe is replaced with smaller or larger diameter pipe, it causes higher or lower pressure loss at nodes accordingly. As the pipe diameter increase its velocity get reduced. As per Darcy Weisbach equation, Head loss is directly proportional to the square of velocity so the value of head loss is also reduced as the velocity reduce. Hence pipes with larger diameter have less amount of head loss and high amount of pressure head at nodes. In this study diameter of pipe number 4,5,7,16,22,35 and 40 were having diameter 300mm which are replaced by 200mm to understand effect of pipe diameter on node pressure along with varying amount of leakage. The effect of variation in pipe diameter along with increasing amount of leakage losses is shown in Figure10. Higher leakage losses cause more amount of pressure drop if pipe diameter are smaller whereas it is less if pipes are having larger diameter.

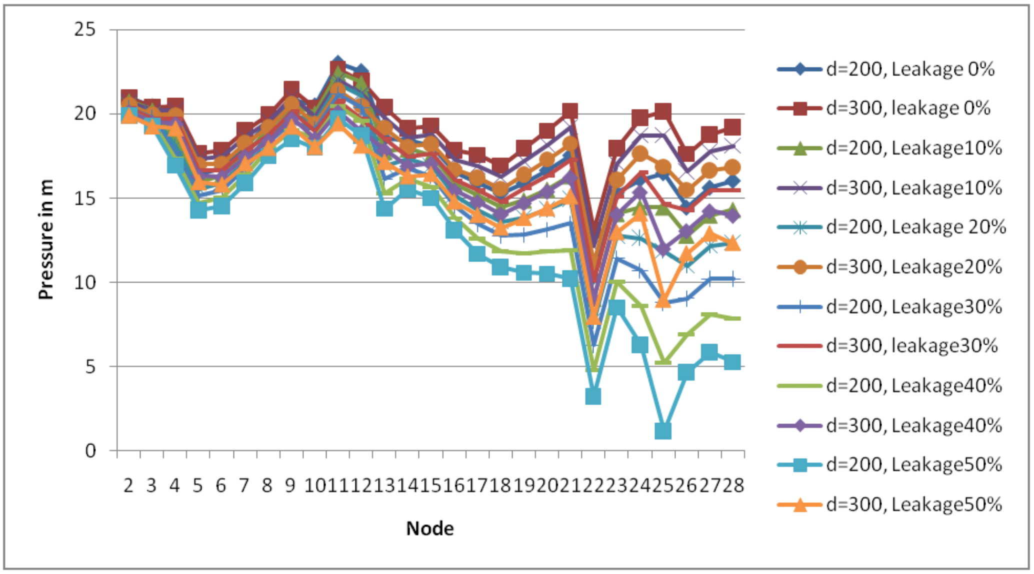

Figure 9. Node Vs Pressure at varying leakage with effect of varying pipe diameter

Figure 9 shows thatwhen amount of leakage loss is 0% and pipe diameter is 200mm, 50% nodes are below 17m pressure head limit while in network with pipe diameter 300mm has only 7% nodes are not fulfilling 17m pressure head criteria. As leakage rate increases pressure developed at nodes get reduced. So total 20 nodes(i.e 71%) are below 17m pressure head limit with pipe diameter 200mm but pipes with diameter 300 mm along with 50% leakage loss gives 17 nodes (i.e. 60%) which are not fulfilling 17m pressure head criteria.

Conclusion

This paper presents performance evaluation of hydraulicparameter of Kosadwater distribution network in case of leakage at junctions along with variation in pipe roughness and pipe diameter. The key findings of the study are leakages reduce pressure at nodes; increase in pipe roughness cause higher frictional head loss which tends to further reduction in node pressure; pressure at node also reduce due to reduction in diameter of pipe.

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