Modelling of Hydrant Flow Within The Pipeline of Water Distribution System

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Abstract

Since particle accumulation in the pipes is conditioned by the usual daily flow patterns, it is assumed a velocity greater than daily peak value is needed to resuspend. The EPANET software was used to simulate the effect of six hypothetical burst flow (5, 10, 15, 20, 25, and 30) L/s in the pipe of 90 mm diameter in a part of the distribution system in Western Australia and the total number of affected pipes that expose to exceed its maximum conditioning velocity were analysed. Results showed that 15 L/s can adopting as the best flow in controlling the discoloration phenomenon when water companies maintain their distribution systems by carrying out water releases from time to time to minimise the build-up of deposits in the mains and get rid of the sediment in the pipe before it becomes serious problem.

Keywords: EPANET, Velocity, Burst pipe, Discoloration, Hydraulic model, Compliance.

الخلاصة

تعتمد ظاهرة ترسب الجسيمات العالقة في المياه المتدفقة في أنابيب شبكات توزيع مياه الشرب على نمط التصاريف اليومية وسرعة الجريان خصوصا في وقت الذروة، وعليه فان زيادة سرعة الجريان عن السرعة المعتادة نتيجة لزيادة الاستخدام او حدوث كسر في الشبكة يؤدي الى تحريك تلك الترسبات وبالتالي حصول تلون في المياه الواصلة للمستهلك. استخدم برنامج EPANET لمحاكاة تأثير كسر افتراضي في احد انابيب شبكة اسالة قطره (90 ملم) باستخدام 6 تصاريف افتراضية وهي (5، 10، 15، 20، 25و 30) لتر/ثا، وحساب عدد الانابيب التي تجاوزت سرعة الجريان فيها السرعة اليومية في وقت الذروة (اعلى سرعة يومية) كنتيجة لذلك. تم تحليل النتائج التي أظهرت بأن التصريف (15 لتر/ثا) يمكن اعتماده من قبل الشركات المعنية لغرض تنظيف شبكة الاسالة فيما لو تم اطلاقه بين الحين والاخر للسيطرة على ظاهرة تجمع الترسبات والحد منها في انابيب شبكات الاسالة وبالتالي تقليل الشكاوى نتيجة لتلون المياه.

الكلمات المفتاحية:- EPANET، السرعة، تكسر الانابيب، تلون المياه، موديل هيدروليكي .

Introduction

Particles and sediments that are accumulated over the time resuspend by hydraulic forces and carried to the customers. When particles come into the drinking water distribution system (DWDS), they are tending to settle down as if suitable hydraulic conditions are provided in pipes. The settled sediments can be disturbed and resuspended when hydraulic incidence happens.

Suspended solid in water supply systems plays an important role in causing discoloration. Gauthier *et.al.*, (1997 and 2001) reported that the total suspended solid load increased from the treatment plant to the distribution system.

Boxall *et.al.*, (2001) carried out theoretical analysis of the interaction of particles of the size found to predominate in discoloured water samples with respect to the hydraulic forces generated within distribution networks, concluding that forces and mechanisms above and beyond gravity settling forces must be in effect to inhibit particle movement.

Polychronopoulos *et.al.*, (2003) indicated that it might be potential to decrease water usage and improve flushing efficiency flow rate from the typical 10L/s or higher to 5L/s to avoid water wasting and extra sediments entrainment from upstream.

Kivit (2004) concluded that the observations comply with the hypothesis that sediment resuspends during periods of a hydraulic event, such as an increase in demand. Measurements show that the velocity does influence the particle concentration most likely is due to an increase in shear stress caused by increased velocity of the water flow.

In his research, Qing (2006) applied the RPM procedure to simulate resuspension and sedimentation phenomenon in drinking water distribution systems (DWDS) in Jar test. The results showed that sediment resuspension behaviour is related to a series of factors related with each another such as flushed velocity, pipe type and water source.

Vreeburg and Boxall (2007) found the PODDS model and the resuspension potential method (RPM) can support decision making on the need for maintenance operations. Also, they recommended a self-cleaning method to prevent the accumulation of material within pipes.

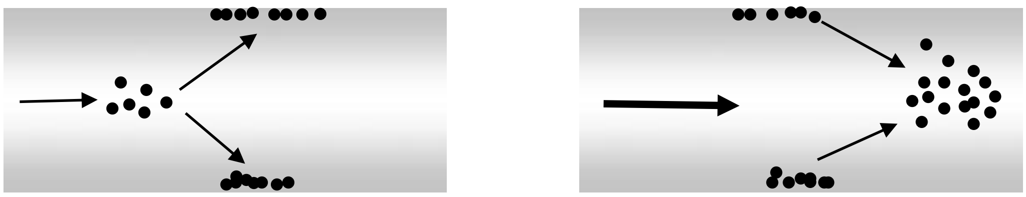
Based on an laboratory results, Husband *et.al.*, (2008) reported that the fine particles, conditioned by the usual daily flow patterns within the system, were eroded as a result of changes in shear stress at the pipe wall due to change in demand such as a burst or the opening of a fire hydrant.

Husband and Boxall (2010) used an iron and plastic pipes to verify the ability of the PODDS modelling approach to predict the turbidity response to changes in hydraulic conditions for various pipe diameters and different networks across the U.K.

Husband and Boxall (2011) stated that the rate of the material layer development is a function of water quality and the discolouration incidents is dominating by hydraulic conditions. They proposed that network hydraulic management is a potential strategy in reducing discolouration risk.

Depending on the total length affected of the pipes where velocity was more than the conditioning velocity, Al-Bedyry *et.al.*,(2016) demonstrated that the breakage of a smaller diameter pipe (90mm) caused more widespread disturbance. They utilised EPANET in modelling five pipes with different diameters and locations in Perth.

In normal flow the particles stay in their place and do not affect the aesthetic quality of the water. Increases in flows and disturbance caused by events such as increased demand from customers, burst water mains, leakage, the use of fire hydrants and construction activities lead to scouring forces and shear stress increase consequently can unsettle the sediments causing dirty water in localised areas. A mass balance model is aim to identify the different sources of particles accumulating in the pipe and the mobility of these particles (Figure 1).



Accumulation during normal flow — Mobilization due to above normal flow

Figure 1: Processes leading to the occurrence of discolouration within water distribution systems (after Vreeburg and Boxall (2007)).

In this research, EPANET software was used to simulate six different burst flows in one pipe of 90mm diameter during the peak daily time to find the flow that has the best effect in the network cleaning policy.

Materials and Methods

To find the best flow in Network cleaning policy, six burst flows during the peak daily demand were modelled for EPANET in the pipe of 90mm diameter within the studied area (Figure 2).

The proposed discharges (5, 10, 15, 20, 25 and 30 l/s) were added separately to the node that located downstream of the chosen pipe (burst pipe) for two hours (from 6:00 to 8:00 (peak time)) which would represent a scenario of increasing the water demand (burst event). The hydraulic time step for the required results was set to 15 minutes during the operation period (24 hrs).

The value of the conditioning maximum velocity was denoted by (V_{max}) and for the maximum burst event velocity by (V_{bmax}). The division of these maximum velocities is represented by V_r, which:

$$V_r = V_{b\max} / V_{\max}$$

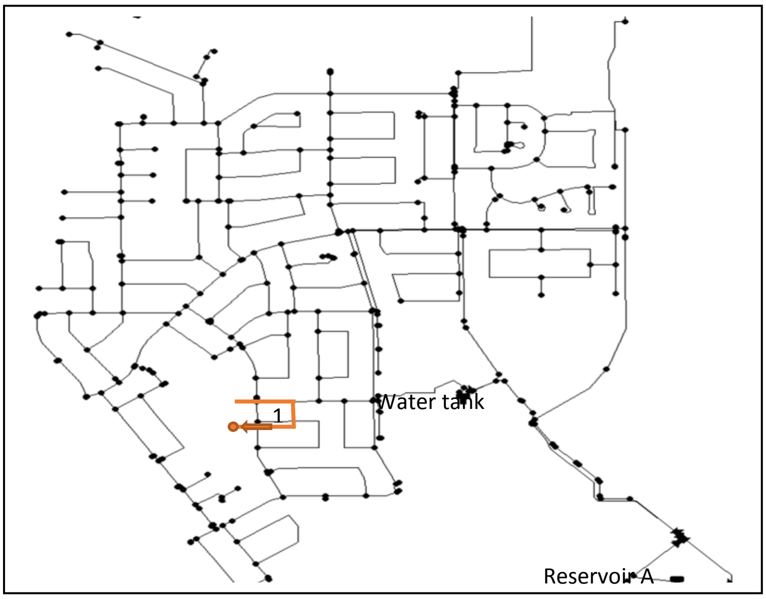


Figure (2): Studied area showed the modelled burst pipe (After Al-Bedyry *et.al.*, 2016)

Results and discussion

The total lengths of the affected pipes with maximum velocity ratio V_r > 1, 2 and 3 are shown in table 1 and figure 3.

Table 1 shows the existence of increase in the total lengths of the affected pipes for the most affected ratio Vr >2 with the burst flow increase. The percentage of the lengths increase for both flows 10 L/s and 15 L/s compared with other burst flows showed the preference of using the 15 L/s as a cleaning flow in the network than 10 L/s. This is because the flow value 15 L/s would decrease the differences in total affected pipes length for other flows which mean an increase in pipe lengths that will subject to the process of cleaning from the sediment. This percentage for 2<Vr≤3 was from 29.24, 48.15 and 92.08 for 10 L/s to 0.15, 14.77 and 48.8 for 15 L/s and for Vr>3 it was from 86.95, 135.43 and 173.09 for 10 L/s to 24.5, 56.9 and 82.0 for 15 L/s. An increase in flow by 5 L/s will increase the sediment removal from pipes by more than 50 % which means high efficiency of the cleaning process.

Table 1: Total length of affected pipes (m) for each burst flow depending on the maximum velocity ratio

Q (L/s)	1<Vr≤2	2<Vr≤3	Vr>3
5	16059.51	1946.5	672.3
10	15026.31	2603.8	2719.8
15	12582.71	3361.1	4081
20	11953.31	3366.3	5084.8
25	10486.91	3857.5	6403.3
30	8594.61	5001.5	7427.6

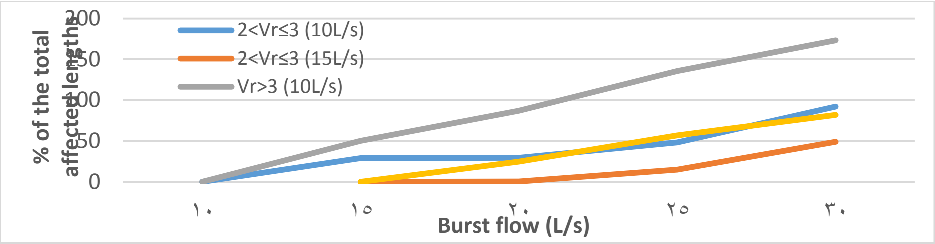


Figure (3): Percentage of the total affected lengths

On the other hand, this fact is confirmed by the results of the comparison of the same flows (10 L/s and 15 L/s) and Vr>2 on the affected pipe lengths depending on their diameters (D<100, 100<D<200 and D>200) that illustrated in table 2 and figures 4 and 5.

The 5 L/s increase for the hydrant flow (from 10 L/s to 15 L/s) results in increase in the cleaned pipes with diameter <100 mm (the most sensitive diameter because its related directly with the customer) by 13, 10 and 14% of the total affected lengths that subjected to velocity ratio 2<Vr≤3 and by 45, 60 and 70% with Vr>3 for flows 20, 25 and 30 L/s respectively. While the pipes with 100<D (mm) <200 are increased by 60, 68 and 72% for 2<Vr≤3 and >200% for pipes with Vr>3 for flows 20, 25 and 30 L/s respectively.

Therefore, for best sedimentation removal from pipe network the flow with 15 L/s can be used.

Table 2: Total length of affected pipes depending on their diameter and the maximum velocity ratio

Total affected pipes length (m)	**D(mm)<100**			**100<D(mm)<200**			**D(mm)>200**		
Q (L/s)	**1<Vr≤2**	**2<Vr≤3**	**Vr>3**	**1<Vr≤2**	**2<Vr≤3**	**Vr>3**	**1<Vr≤2**	**2<Vr≤3**	**Vr>3**
5	9621.10	1927.40	622.10	2033.30	49.10	20.20	4405.11	0	0
10	1945.70	2166.00	2644.50	2129.70	437.30	75.30	4437.31	0	0
15	6806.50	2345.60	3793.10	1691.80	662.60	287.90	4084.41	352.90	0
20	6401.20	2206.70	4710.90	1512.30	762.10	373.90	4039.81	397.50	0
25	5286.40	2887.90	5287.10	1607.80	877.00	764.20	3592.71	492.60	352.00
30	3314.50	3991.40	6155.10	1777.20	928.20	919.60	3502.51	581.90	352.90

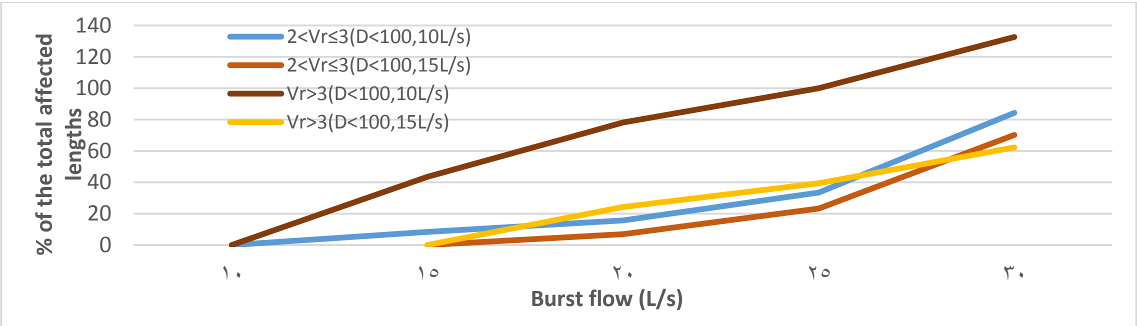


Figure (4): Percentage of the total affected lengths for the pipes with D (mm) <100

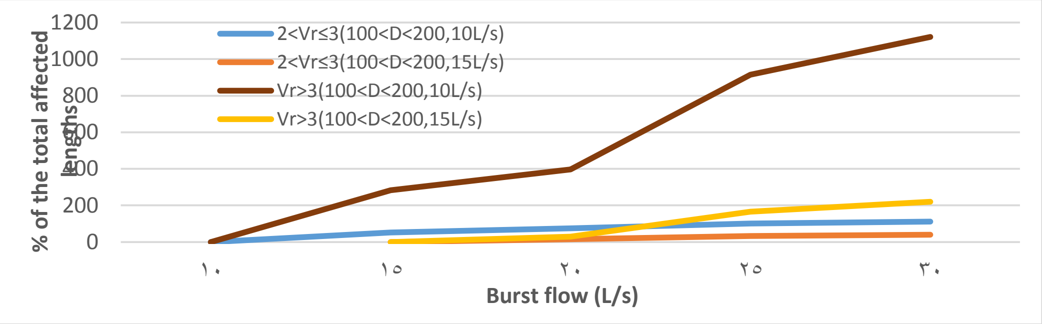


Figure (5): Percentage of the total affected lengths for the pipes with 100<D (mm) <200

Conclusion

Discolouration of drinking water is a major source for customers to complain. Discolouration is associated with mobilisation of accumulated particles from within distribution networks.

The EPANET was executed for increase daily demand (5, 10, 15, 20, 25 and 30 L/s) in the hypothetical burst pipe to getting the results for the study area of this research. The burst event start from the peak demand time (6:00) during the operation day for 2 hours (6:00-8:00) and the hydraulic time step was 15 minutes.

The findings from this research showed that the burst event can used as a pipe network cleaning strategy. For the study area the burst flow 15 L/s gives the acceptable result represented by the total length of pipes that could be cleaned when subjected to it from time to time so this flow can adopted in cleaning policy as a proposed solution for controlling discoloration in pipes (self-cleaning for the operation and maintenance of a pipeline network.

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