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COMPARATIVE STUDY ON FLOW THROUGH PVC PIPES

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Abstract- With the advent of polymeric or plastic material pipes into fluid transport, the usage of PVC pipes has abundantly increased over the past four decades, replacing metallic and concrete pipes in various fluid flow situations. A polyvinyl chloride (PVC) pipe is made from a plastic and vinyl combination material. PVC is a versatile engineering plastic having so many advantages over the all other traditional pipe materials. Due to this reason the use of plastic pipes has increased tremendously in the recent past for water supply and distribution systems both on the domestic and irrigation front.

The present study aims to study the effect of pipe material on scale deposition and biofilm formation. Migration of lead, iron and vinyl chloride monomer from drinking water pipes, especially from unplasticized PVC pipes has been considered. In the present study the hardness of water, pressure drop in the pipe and age of the pipe are considered as the main factors influencing the scale formation in the pipes. The values of Hazen-Williams Coefficient (C), and Manning's Resistance Coefficient (n) for PVC pipes were compared with Cast Iron pipes. The control of leaching of vinyl chloride into drinking water is also suggested. A detailed comparison is made between PVC and other pipe materials in all aspects along with the advantages and disadvantages of PVC pipes over the others.

***Index Terms:* Drinking water, Biofilm formation, Vinyl chloride monomer, Friction factor**

I. INTRODUCTION

In the planning and design of domestic water supply systems, it is important to select the suitable type of pipe material. The selection of pipe is a major technological challenge to the water industry. A large proportion of capital is to be invested on pipes while designing water supply distribution system. The domestic pipes are available in several types and sizes. They may be classified into three groups according to the material used in their manufacturing as Metallic pipes such as CI pipes, Steel pipes and GI pipes; Cement Pipes such as Asbestos cement (AC) pipes, and cement concrete pipes; and Plastic pipes such as Un-plasticized PVC (UPVC) pipes, Polythene pipes (low density).

Due to light weight, good mechanical strength even with low wall thickness and improved manufacturing techniques, more flexibility, durability, reliability at continuously changing pressures, resistance to atmospheric and working conditions PVC pipes are the best choice for domestic use. Even though PVC pipes are available in wide range of diameters, for domestic use the size is mostly limited to 26mm and 40mm.

A polyvinyl chloride (PVC) pipe is made from a plastic and vinyl combination material. The pipes are durable, hard to damage, and long lasting. A PVC pipe does not rust, rot, or wear over time. For that reason, PVC piping is most commonly used in water systems, underground wiring, and sewer lines. Due to the ability of PVC pipe to withstand extreme movement and bending, it is also increasingly used in earthquake prone areas. PVC pipe can withstand the rigorous shaking of the earth without experiencing any damage. The smooth surface of the PVC pipe is also resistant to bacterial contamination, such as E. coli. Therefore, many water companies rely on PVC pipe in their systems in order to keep them free of contamination.

And send data to group members, joins a receiver that wants to receive data for the group and, forwards data to group. The BSR receives RP router advertisement messages from the candidate RPs and adds the RP router with its group prefix to the RP set.The BSR periodically sends bootstrap messages containing the complete RP set to all routers in the domain. The BSR ensures that all PIM-SM routers send join/prune and register packets.

In this paper we will describe our simulation results of multicasting for SDN network by using Opnet simulator . This paper is organized as follows: The second section describes literature survey of PIM-SM multicasting. The third section describes the architecture of SDN.The fourth section describes the simulation results and the fifth section describes the conclusion.

II. BRIEF DESCRIPTION OF PVC PIPES

A polyvinyl chloride (PVC) pipe is made from a plastic and vinyl combination material. These pipes are durable, hard to damage, and long lasting. A PVC pipe does not rust, rot, or wear over time. For that reason, PVC piping is most commonly used in water systems, underground wiring, and sewer lines. PVC was discovered as early as 1835, but the first definite report of the polymerization of vinyl chloride did not come until about 35 years later.

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PVC is a versatile engineering plastic having so many advantages over the all other traditional pipe materials. The physical properties of PVC pipes have been described in the table 2.1.

Table 2.1: Physical properties of PVC pipes

Colour	Grey, Dark Grey, White, Blue, Green
Unit weight	1.38g/cm^3
Water absorption (% in 24 hrs @ 23°C)	0.05%
Compressive Strength (Mpa)	66 Mpa
Tensile Strength (Mpa 26°C)	52 Mpa
Modulus of Elasticity in Tension (@23°C)	3400 Mpa
Flexural Strength (izod) (kgf.m)	0.098 kgf.m
Specific Heat (Cal / g 1°C)	Approx 0.25
Coefficient of linear thermal expansion	5 X 10^{-5} ^{0}C
Maximum Operating Temperature (Under Pressure)	60^{0}C
Softening temperature (BS 2782)	78°C
Electrical Resistance	Greater than 1014 ohm.com
Thermal Conductivity	16 X 10° wm 1°c1
Heat Resistance at continuous Drainage (°C)	(66°C)
Density	1390 kg/m3[1]
Young's modulus (E)	2900-3300 M Pa
Tensile strength(σt)	50-80 M Pa
Elongation at break	20-40%
Notch test	2-5 kJ/m^2
Melting point	100–260 °C[1]
Heat transfer coefficient (λ)	0.16 W/(m ·K)
Effective heat of combustion	17.95 MJ/kg
Linear expansion coefficient (α)	8 X 10^{-5}/^{0}K
Specific heat (c)	0.9 kJ/(kg ·K)

III.EFFECT OF PIPE MATERIAL ON SCALE DEPOSITION

There is a significant effect of various pipe materials on biofilm formation and its growth. Hence the relationship between pipe material and biofilm formation was established in this section. Investigation of gypsum scale formation on piping surfaces and the effect of PVC and iron materials on Mn deposition in drinking water distribution systems were also discussed

Maggy NB Momba and N Makala(2004), compared the effect of various pipe materials on biofilm formation in water systems. Their investigation indicated the colonisation of all test pipe materials (PVC, uPVC, MDPE, cement and asbestos cement) by coli forms and heterotrophic plate count bacteria within 20 min under chlorination treatment. The time factor also cannot be ignored in determining the effect of pipe materials on biofilm formation in potable water distribution systems.

C.J. Kerr, K.S. Osborn2, G.D. Robson and P.S. Handley (1999), have established a relationship between pipe material and biofilm formation using a laboratory model system.The aim of this study was to compare biofilm accumulation and heterotrophic bacterial diversity on three pipe materials-.cast iron, medium density polyethylene (MDPE), and unplasticized polyvinyl chloride (uPVC) - using a laboratory model system run over a short period (21 d) and a longer period (7months). In conclusion, MDPE and uPVC support the lowest numbers of bacteria in a steady state biofilm in the short term (21 d) and over a longer term (7 months). The diversity of heterotrophic bacteria was greatest on cast iron.

There is an empirical equation to quantify the inhibitory effects of free chlorine and decrease of temperature on biofilm growth. With water having total organic carbon concentrations in the range 1.5–3.9 mg/l, a free chlorine residual of 0.2 mg/l was needed to reduce biofilm concentration to below 50 pg ATP/cm^2. Pipe material influenced biofilm activity far less than chlorine with mean biofilm activity being ranked in the order glass (136 pg ATP/cm^2) < cement (212 pg ATP/cm^2) < MDPE (302 pg ATP/cm^2) < PVC (509 pg ATP/cm^2). (N. B. Hallam et al., 2001)

A pilot pipe distribution study conducted over one year under various blended waters (i.e. blends of ground, surface and saline waters) showed that iron release from aged pipes varied with blended water qualities as well as aged pipe materials. Aged pipe materials also affected iron release: the order of aged pipe material on total iron release was unlined cast iron > galvanized steel >> lined ductile iron > PVC, which demonstrated the importance of pipe surface characteristics on iron release (Zhijian Tang et al., 2006)

The effect of PVC and Iron materials on Mn(II) deposition in drinking water distribution systems was observed by Cerrato JM et al., (2006). The influence of iron and PVC pipe materials on the concentrations of soluble iron and manganese and the composition of scales formed on PVC and iron pipes were determined. Total Fe concentrations were highest in water from iron pipes. Water samples obtained from PVC pipes showed higher total Mn concentrations and more black color than that obtained from iron pipes. The PVC pipes contained a thin surface scale consisting of white and brown layers of different chemical composition. The brown layer was in contact with water and contained 6% manganese by weight. Mn composed a greater percentage by weight of the PVC scale than the iron pipe scale. The PVC scale was easily dislodged by flowing water.

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IV. MIGRATIONS OF METAL STABILIZERS FROM DIFFERENT PIPES

Total dissolved solids (TDS) and pH of water were found to affect the release of VCM from uPVC pipes. Diffusion rate of VCM was predicted as a function of pH or TDS values. (Muhammad H. Al-Malack et al.,)

The effect of water quality parameters, such as water pH, temperature, and total dissolved solids (TDS), and direct exposure to UV-radiation on the migration of lead, tin and other metal stabilizers, such as calcium, cadmium, and barium from unplasticized polyvinyl chloride (uPVC) pipes were investigated by Muhammad H. Al-Malack (2001). The results on the effect of water quality parameters showed that water pH, temperature, TDS, and time of water circulation were all having an effect on the migration of lead, tin, and other metal stabilizers. On the other hand, exposure to UV-radiation was seen to promote the migration of lead, tin, and other metal stabilizers. A lead concentration of about 0.8 mg/l (ppm) was detected after 14 days of exposure to the UV-radiation

It has been studied that, the effect of stagnation time, pipe age, pipe material and water quality parameters such as pH, alkalinity and chloride to sulfate mass ratio on lead and iron release from different types of pipes used for drinking water supply. In general, GI pipes showed to be the most effected by water quality parameters and the highest iron release. PVC pipes are the most lead releasing pipes while PP pipes are the least releasing (Lasheen MR et al, 2008).

V. HYDRAULIC LOSSES IN VARIOUS PIPES

The determination of frictional head losses in pipelines is an important engineering factor in the design of pipe networks that affects total cost as well as the hydraulic balance of the network. Pipe sizing in a network is dependent on the magnitude of allowable frictional losses set by the pipeline designer. Operating cost is inversely affected by pipe diameter. As the pipe diameter increases for a given flow and pressure head, frictional head losses per unit length decrease, thus lowering the pump energy requirement.

Many pipeline and irrigation engineers use empirical equations such as Hazen-Williams (H-W) and Manning (Mn) to determine friction head losses due to their mathematical simplicity rather than the more theoretical equation of Darcy-Weisbach (D-W). However, one major limitation of these empirical equations is that a single roughness factor is usually assumed for all pipe sizes and flow velocities. Due to such an assumption of a constant friction factor, head losses calculated by these empirical equations may differ significantly from those calculated by the D-W equation, in which the friction factor varies with the flow conditions. This may influence the selection of pipe diameter and consequently, the estimated pumping requirement.

Since all friction equations require some input parameter to characterize pipe interior roughness, they all share the uncertainties involved in such a measurement. However, the D-W equation accounts for other variables that influence the hydraulic frictional losses in pipe flow. A survey of the literature for pipe friction coefficients showed that there are significant differences among the suggested friction coefficient values for certain pipe materials. Table 5.1 presents a summary of the reported friction coefficients for PVC and cast iron.

It is noted that the change of Hazen-Williams Coefficient *C* and Manning's Resistance Coefficient *n* is greatest for the velocity range 0.3-1.5 m/s, which is most commonly encountered in irrigation and municipal networks. Therefore, when high accuracy of calculation is needed, pipeline engineers should exercise utmost attention in selecting *C* and n-values for the velocity range 0.3-1.5 m/s. The C-values for PVC increased as the flow velocity increased from 0.3-1.5 m/s and then started decreasing with increased velocity, while that of cast iron decreased with increased flow velocity over all ranges. Also, the *C* and n-values increased with increasing pipe diameter for both PVC and cast iron for a given flow velocity. In order to minimize the differences in calculated h_f between the various equations, the values of C and *n* should vary with the flow conditions. The *C* and n-values for PVC and cast iron in the flow range of 0.3-1.5 m/s were averaged and presented in Table 5.2.(Fadi Z. Kamand, 1988)

Table 5.1: Values of Hazen-Williams Coefficient (C),and Manning's Resistance Coefficient *(n)* for PVC and Cast Iron

Reference	PVC		Cast Iron	
	C	n	C	n
Addink et al. (1983)	150	--	--	--
Giles (1962)	--	--	110-130	--
Hansen et al. (1979)	--	--	--	0.011-0.013
Hughes & Jeppson (1978)	133	--	--	--
Jeppson (1976)	150	0.008	130	0.014
King (1954)	140	--	100	0.012-0.014
Nelson (1976)	--	--	130	0.013-0.015

Table 5.2: Average *C* and n values to be used in design for PVC and Cast-iron Pipes

Inside Diameter (mm)	PVC		Cast Iron	
	C	n	C	n
25	134	0.0083	111	0.0099
50	139	0.0085	118	0.0100
75	141	0.0087	121	0.0100
100	143	0.0088	123	0.0101
125	144	0.0089	125	0.0102
150	145	0.0090	126	0.0102
200	146	0.0092	128	0.0103
250	147	0.0093	129	0.0104

The various dissolved particles like salts, present in water, generally tend to deposit on the walls of the pipes. Such salt deposits may strengthen over a period of time, thus hindering the flow as well as the friction factor. In the case of PVC pipes, it is observed that as the usage increases, the diameter of the pipe is getting reduced because of the deposits that are taking place along the inner walls of the pipes. The deposition of salts again influenced by the factors such as quality of water (presence of salts), velocity of flow, diameter of the pipe, temperature changes etc., The Hazen-William coefficient may be varying with the age of the pipe as the deposits are increasing within the pipe. The H-W coefficient for new PVC pipe may be observed as 150 and for 10 years aged pipe, it was 133 and 6 years aged pipe it was observed to be 142.

The various other pipes were compared with the PVC pipe in the aspects of their corrosion resistance, health criterion, thermal expansion, and UV resistance. The joining techniques, availability of fittings, ease in installation and flow properties for friction were also compared and illustrated in table 5.3

Table 5.3: Comparison of various piping materials with PVC Pipes

CRITERIA	GI PIPE	COPPER PIPE	HDPE PIPE	PVC PIPE
Effect of hard water	High scale formation	scale formation is prohibited due to smooth bore	Scale formation is prohibited due to smooth bore	Scale formation is prohibited due to smooth bore
Effect of soft water	Gets corroded	Gets corroded due to acidic nature of water	No Effect	No Effect
Health criterion	Low due to lead content and corrosion	Good with ferrule but lead content in solder is bad for health	Very good	Very good
Jointing techniques	Threaded	Soldered/Ferrule	Fusion Weld	Solvent cement
Corrosion resistance	Very Low	Low	No Effect	No Effect
Thermal strength property at 60^0 C temperature	Very good	Very good	Limited	Not Recommended
Availability of fittings	Very good	Average	Low	Good
Thermal expansion	Low, good for concealed piping	Low, good for concealed piping	Very High, not to be used for concealed piping	Very special care is required for concealed piping
UV resistance	Very good	Very good	Very good	Low
Ease in installation	Low	Average	Low	Good
Flow properties for friction	Low	Very good	Very good	Very good

VI. SUMMARY AND CONCLUSIONS

1. Internal corrosion in water pipes is one of the major contamination sources of tap water. Internal corrosion in distribution networks has a close relation with the quality of water flowing through the pipe. Corrosion rates of water pipes decreased as the concentration of hardness increased.
2. Biofilms were found to comprise a complex mixture of microorganisms, viz. fungi, yeasts, protozoa, free amoebae and bacteria (up to 10^6 cells/cm^2)
3. The main constituents forming scale in salt water environments are calcium carbonate, calcium sulfate and magnesium hydroxide.
4. In the present study the hardness of water, pressure drop in the pipe and age of the pipe are considered as the main factors influencing the scale formation in the pipes. It is observed that the scale thickness has been increased linearly with increase in the hardness of water and age of the pipe whereas it decreased linearly with increase in pressure drop.
5. There is a significant effect of water quality parameters such as pH, temperature and total dissolved solids (TDS) on the migration of lead, tin and other metal stabilizers from unplasticized polyvinyl chloride (uPVC) pipes Total Fe concentrations were highest in water from iron pipes. Water from PVC pipes showed higher total Mn concentrations
6. In general, GI pipes showed to be the most effected by water quality parameters and the highest iron release. PVC pipes are the most lead releasing pipes while PP pipes are the least releasing
7. Industrial Cleaners such as Barium nitrate, glycine, phosphoric acid, and sulphuric acid, High Pressure Steam, High Pressure Jet Washer and a concentrated solution of White Vinegar are some of the most commonly applying tools for removal of scale from the internal surface of the existing pipes.

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