한국환경과학회지 제8권(제1호), 45~50, 1999
J. of the Korean Environmental Sciences Society

Permeation of Organic Chemicals through Gasketed Cast Iron Pipe

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(Manuscript received 2 October 1998)

Four cast iron pipe sections containing 3 styrene butadiene rubber (SBR) gaskets (1 joint and 2 end caps) were filled with water and maintained at approximately 40 psi internal pressure. The pipe sections were placed inside 16 gallon drums filled with initially clean sand. Three of the tanks were subsequently contaminated with gasoline, gasoline spiked with pyrene and naphthalene, and toluene. The forth tank served as a control. The water inside each pipe was monitored over time for organic chemical contamination. Permeation of organic chemicals into the water inside the pipe systems was found to occur in all 3 contaminated pipe systems after approximately 100 days as measured organic chemicals concentrations were significantly above those in the uncontaminated cell. Flushing experiments in which the water inside the contaminated pipes was replaced with initially clean water showed that organic chemical concentrations inside the pipe rapidly (12 days) reached their preflushing levels.

Key words : organic chemicals, gasketed cast iron pipe

1. Introduction

Numerous incidences of drinking water contamination due to organic chemicals through water piping system in contract with contaminate soil have been reported. Groundwater contamination by sources such as leaking underground storage tanks has been currently receiving significant attention by media, by regulatory agencies, and by research institutions. The most obvious health risk present by soil and groundwater contamination is contamination of drinking water wells. An area receiving less attention but having perhaps an even greater potential of widespread serious health risk is contamination by contact with water distribution systems. In many settings, gas station underground storage tanks are in close proximity to water distribution pipes.

There have been over one hundred reported incidences of drinking water contamination due to permeation in the United states[1]. Recently it has been found that some plastic piping and rubber gasket materials used in the water industry are susceptible to attack by organic chemicals. and as a result, potable water was contaminated with them. Plastic pipe such as poly vinyl chloride (PVC), polybutylene (PB), and acrylonitrile-butedien-styrene (ABS) are used widely in the water industry. Advantage claimed ffor plastic pipes include immunity to corrosion, ease of use, ductility, and durability. As a result, numerous studies have been completed pertaining to the susceptibility of plastic piping to permeation by various volatile organic chemicals likely to be encountered in contaminated soil. The results of this research have been conclusive; plastic piping is highly susceptibility to permeation and should not be used where the possibility of contact organic chemical contaminated soil is high.

In location where contamination is detected or where the probability of cantamination is high, such as in the vicinity of packing lots or gas station, metal piping is typically recommended for use. For water mains, this typically means using jointed ductile iron pipe. Unfortunately, however, there has been scant research aimed at determining how well jointed iron pipe resist permeation.

Previous research suggests that all types of jointed pipes used in water distribution systems are susceptile to permeation by organic chemicals such as those found in gasoline or common commercial and industrial wastes. While ductile iron is resistant to permeation, the gasketed joints between pipe segments have proven to be sus-

ceptible to permeation. Drinking water contamination caused by gasket permeation would likely go unreported by users because the contamination level might not ever exceed the taste or odor threshold. This is due the fact that the gaskets represent a small percentage of the total piping system area. Despite this, the contamination may exceed those limits which have been set by regulatory agencies and which have been determinated to have adverse human health effects. This subject should be of great interest to eater utilities because state and federal statutes covering drinking water quality apply to water quality as the customer's tap, not at the source of distribution.

Permeation is the penentraction of contaminates (organic chemicals) through the plastic pipe wall by a three-step physciochemcal process.

Organic chemicals in the medium (soils) surrounding the plastic pipe partition between the soil and the plastic pipe well.

Organic chemicals diffuse the plastic pipe well.

Organic chemicals partition between the plastic pipe and the water inside the pipe. So this study was carried out to identify the pathway of organic contaminations found in tap water.

Permeation of organic chemicals through gasketed joints.

Contaminations before and after flushing.

Suggestion for remedial actions.

2. Materials and Methods

Permeation experiments. Lengths of 4in. diameter, thickness class 52, ductile iron pipe manufactured in accordance with ANSI/AWWA C 151/A21.51 and SBR gaskets manufactured in accordance with ANSI/AWWA C11 1/A21.11 and Federal specification WWP421D were purchased on the open market. The bell and spigot ends of the pipe were cut off approximately 1ft from the ends and then joined together using a tyton joint that utilized a styrene butadiene rubber (SBR) gasket. Both ends of the assembly were sealed using a mechanical joint and cap that also utilized an SBR gasket. The entire assembly was secured by two threaded rods. Inlet and outlet water valves, a water pressure gauge, and associated plumbing were attached to one end (Fig. 1). The pipe assembly was placed inside a 16 gallon drum and covered with fine grain sand that was purchased from a masonry supply house. The insides of the drums were clean when purchased. The outsides of the drums were painted with red primer.

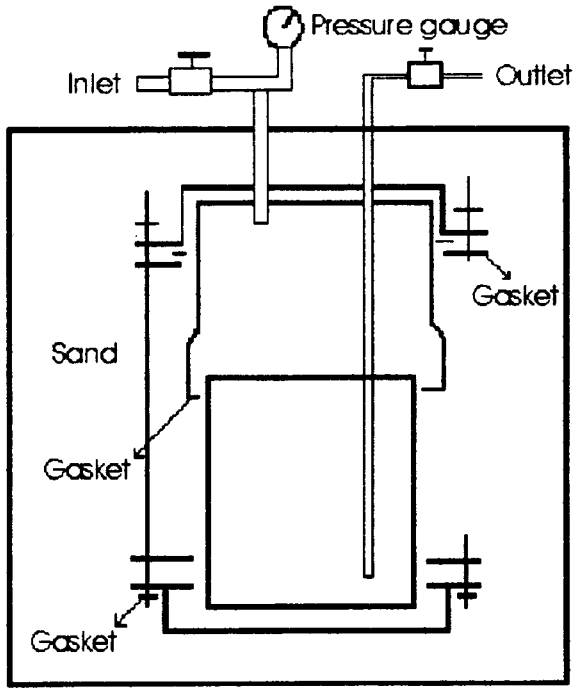

Fig. 1. Experimental set up for organic permeation through gasketed iron pipe.

To fill the tanks with water, a tygon tube was connected between the city water valve and the inlet pipe with a quick connect fitting, the city water turned on and the tank valves opened, After water started flowing out of the outlet pipe, the outlet valve was closed and the tank was allowed to pressurize before the inlet valve was closed and the water supply tubing disconnected. To start the experiments chemicals were added to the sand, the lids secured to the top of the drums and the holes through which the plumbing exited the drums sealed with silicone caulk. All four tanks used in the experiment were stored in a temperature controlled room (20 + 1 ℃). The water pressure inside the pipes remained fairly constant at about 40 psi between sampling. The sampling procedure involved connecting the pressurized water hose to the inlet valve then opening both the inlet and outlet valves. Approximately 200 mL of water was flushed from the outlet valve before the sample was taken to ensure that the sample was representative of the water inside the pipe assembly. After sampling, the outlet valve was shut, then the inlet valve was shut, and finally the pressurized water tubing was removed.

Table 1 lists the pipe water volume, volume of sand added to the drum, and the type and

Table 1. Characteristics of tanks A, B, C, and D

Tank	Water Volume (L)	Sand added (L)	Chemical added	Volumn added (mL)
A	4.14	49	None	-
B	4.51	49	Gasoline	1,000
C	3.72	50	Gasoline	1,000
			Napthalene	50 g
			Pyrene	40 g
D	3.46	50	Toluene	500

amount of each chemical added are recorded in the table.

2.1 Flushing experiments

The pipe assemblies were flushed with approximately 40 L of tap water (approximately 10 pipe volumes). Samples were then taken over time and analyzed by the procedures outlined below.

2.2 Gaskets and organic chemicals tested

SBR was the only type of gasket material investigated during the experiment. This type of gasket is used in the vast majority of pipe installations. SBR has better water resistance than natural rubber, and has fair to good resistance to acids and bases but is unsuitable for use with gasoline, oils and solvents[2]. A total of four tanks was used in the experiment. No organic chemicals were added to Tank A, which served as a control. Tank B, C and D were contaminated with gasoline, gasoline spiked with pyrene and naphthalene, and toluene, respectively. Enough organic chemical was added to each of the tanks to insure that initial soil pore concentrations were near saturation levels. The organic chemical concentrations in the water samples were analyzed with a gas chromatograph (Varian Model 3700) equipped with a SP1500 column and FID detector connected to a Hewlett Packard Model 19395A Headspace Analyzer. The pipe water samples taken from the pipe assemblies were analyzed for benzene, toluene, pxylene. These chemicals are a few of the many different compounds that are normally found in gasoline. They are also the compounds most commonly chosen to indicate the presence of gasoline in soil or water analyses. According to Johnson et al.[3] The three chemicals are present in gasoline on a mole fraction basis of: 0.0093, 0.0568, and 0. 0858, respectively.

3. Results

3.1 Permeation experiments

The results show that SBR gasket material is susceptible to permeation under the conditions

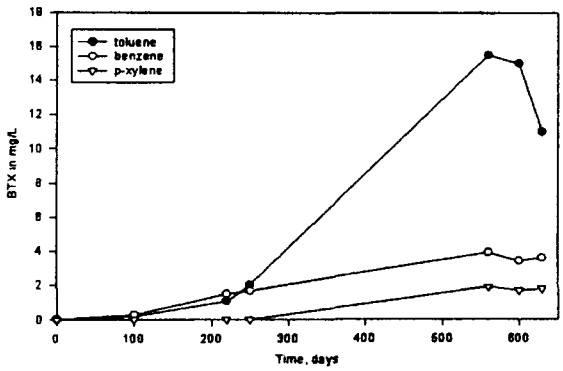

Fig. 2. BTX concentration of tank B.

used in the experiments. Figures 2 through 4 illustrate the accumulation of benzene, toluene and p-xylene were accumulated in the pipe water of tanks B, C, and D, respectively. Toluene permeated the gasket material to a greater extent than either benzene or p-xylene. Tanks B and C that contained gasoline had similar breakthrough times of about 100 days at which time the detectable concentrations of the 3 organic chemicals were near 0.5 mg/L. Tank D, which contained only toluene, also had a breakthrough time of about 100 days with a detectable concentration of about 0.5 mg/L. In all three tanks, the concentration of organic chemical reaches a maximum and then starts to decline. This decline in concentrations over time is probably due to decreasing organic chemical concentrations external to the pipe due to uptake by the gaskets and pipe water and losses to the atmosphere. Additional chemical was lost from the system with each sampling event. It is possible that maximum organic chemical concentrations reached inside the pipes occurred somewhere between days 250 and 500 during which time no samples were taken. Table 2 summarizes the analytical results of the last water sample taken before the pipe assemlies were flushed with tap water. The source of the phenol and isophorone which was found in all 4 pipes may have been either the gaskets or the coating on the interior of the pipes. It appears that the gasoline

Table 2. *Pipe water concentration of semivolatile organic chemicals*

Tank	Organic chemical	Concentration(μg/L)
A	Phenol	35.9
	Isophorone	75.6
B	Phenol	194.0
	2-methylphenol	32.0
	Isophorone	529.0
	Naphthalene	76.4
	2-methylnaphthalene	4.5
C	Phenol	44.3
	2-methylphenol	23.5
	Isophoroene	142.0
	Naphthalene	149.0
	2-methylnaphthalene	22.9
D	Phenol	93.9
	2-methylphenol	7.0
	Isophenol	467.0

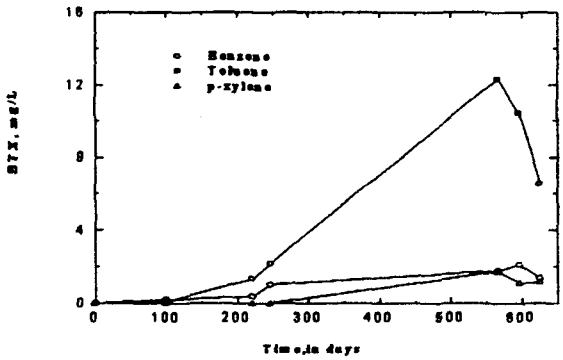

Fig. 3. BTX concentration of water sampled from tank C.

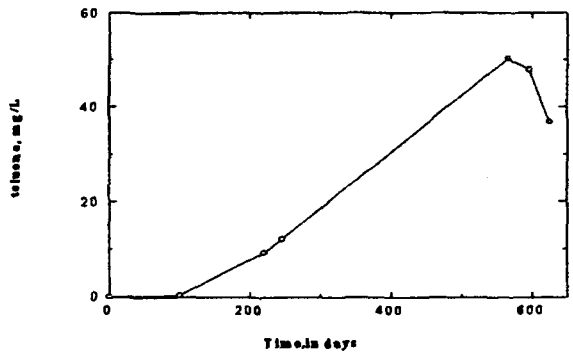

Fig. 4. Toluene concentration of water sampled from tank D.

was the source of the 2-methyl phenol and naphthalene found in pipes B and C although 2-methyl phenol was also found in pipe D which was exposed to toluene only. As expected the naphthalene concentration in pipe C in which the gasoline was spiked with naphthalene was higher than its concentration in Pipe B which was exposed to pure gasoline. Pyrene was not found in any of the samples.

The results of these permeation experiments are similar to the results reported by previous investigators. Battelle Columbus Laboratories (1983) performed similar experiments on gasketed ductile iron pipe that was exposed to hexane, toluene, and 1,1,1trichloroethane. The type of gasket material used in the experiments was not reported. Their results indicated that two separate sections of gasketed iron pipe experienced breakthrough times of 6 and 13 days and 4 and 8 days for toluene and 1,1,1-trichloroethane respectively. Hexane did not permeate the pipe sections after 6 weeks. The difference in the toluene permeation times reported in their study than those reported in this study were probably due to 1) the sensitive analytical technique (purge and trap) they used which would detect permeation earlier than the technique used in this study and 2) exposure of the pipe section to pure toluene as opposed to toluene contaminated sand.

Glaza and Park[4] also conducted similar experiments using SBA gaskets and ductile iron pipe. Their pipe segments were exposed to liquid gasoline over a period of about a year. Benzene was the First compound detected and had the highest Final concentrations in each of their test pipes. Benzene was first detected about day 50 at a concentration of approximately 20 mg/L. They reported a maximum benzene concentration of about 30,000 mg/L after approximately 200 days. Toluene breakthrough lagged slightly behind ben-

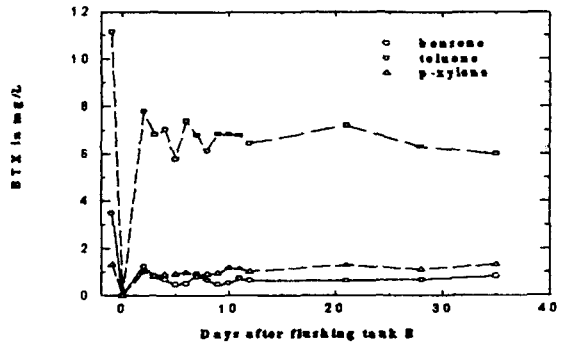

Fig. 5. BTX concentration in water from tank B after flushing with tap water.

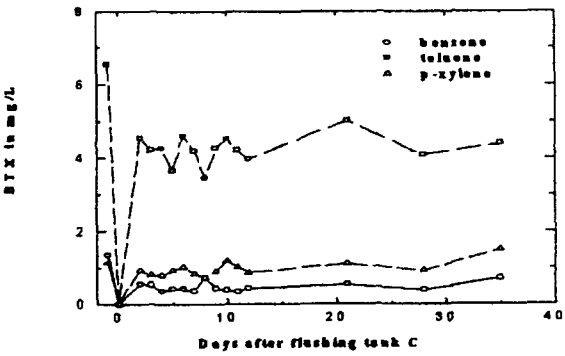

Fig. 6. BTX concentration in water from tank C after flushing with tap water.

zene for all pipes, while the xylenes were detected later and at much lower levels.

3.2 Flushing Experiment

Figures 5 ~ 7 show the concentration of benzene, toluene, and p-xylene in the pipe water as a Function of days after flushing of each tank with approximately 10 pipe volumes of tap water. The measured concentrations of all organic chemicals measured immediately after Flushing were below the detection limits of this study. However, within 12 days the organic chemical concentration in the pipes reached levels similar to their preflushing values.

4. Conclusions

Organic chemicals, specifically the derivatives of

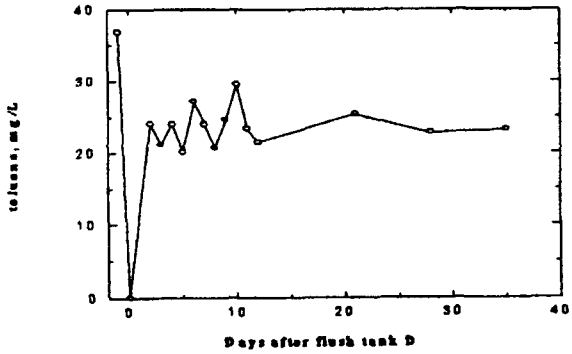

Fig. 7. Toluene concentration in water from tank D after flushing with tap water.

gasoline: benzene, toluene, and p-xylene can permeate through a SBR gasket into a cast iron pipe. In these experiments, it took approximately 100 days For the chemicals to reach detectable levels. In the pipes exposed to gasoline it was found that toluene permeated the gaskets to the greatest degree followed by benzene and pxylene. Flushing the pipes with clean water initially decreased the organic chemical concentration in the pipes to near zero, however, the pipe water rapidly (<2 days) reached preflushing concentrations.

References

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주물 파이프 Gasket을 통한 유기화학물질의 이동

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(1998년 10월 2일 접수)

깨끗한 모래로 채워진 4개의 16갤론 크기 드럼통에 주물 파이프가 설치되었고 각 파이프에는 3개의 styrene butadiene rubber gasket(1개의 joint와 2개의 end caps)을 장치하였다. 각 파이프는 상수로 채워 내부의 압력을 약 40psi로 유지하였다. 첫번째 드럼은 일정량의 휘발유로, 두번째 드럼은 pyrene과 naphthalene을 포함한 휘발유로, 세번째 드럼은 toluene으로 채워졌고, 네번째 드럼은 대조군으로 사용되었다. 외부 오염물질의 이동에 의한 오염을 조사하기 위해 일정 간격으로 파이프 내의 물을 약 2년간 조사하였다. 오염 물질이 투입된 3개의 드럼에서 약 100일 후부터 유기 오염 물질이 검출되었고 외부에 채워진 유기물이 고갈될 때까지 계속적으로 증가하는 추세를 보였다. 이미 오염된 물을 깨끗한 물로 청소한 후에도 오염된 gasket에 남아있는 유기물질이 유출되어 파이프 내의 물이 쉽게 오염되었으며 약 10일 후에는 청소 이전의 농도로 검출되어 gasket에 의한 오염이 오래 동안 지속되는 것으로 나타났다.