

NC STATE UNIVERSITY
NC DEPARTMENT OF TRANSPORTATION



Preliminary findings on the effects of contaminated soil and groundwater on subsurface utilities

P. Ghasemabadian¹, M. Pour-Ghaz¹, M. Gabr¹, D. Knappe¹, and C. Parker²

¹Department of Civil, Construction, & Environmental Engineering,
North Carolina State University

² GeoEnvironmental Section, North Carolina Department of Transportation



Geo³T² Conference Tuesday April 11th, 2017 Slide 1 of 30



MOTIVATION

- A portion of the right-of-way might be contaminated during road improvements
- Underground storage tanks, old unlined landfills, abandoned industrial / agricultural operations
- **What is the effect of contamination on the integrity and durability of the subsurface drainage pipes and gaskets?**
- **What to use where?**

Geo³T² Conference Tuesday April 11th, 2017 Slide 2 of 30



RESEARCH OBJECTIVES

- What are the most prevalent contaminants?
- What is the effect of contaminants on the long-term durability of common utility materials?
- What are the most effective hardening methods?
- How fast contaminants migrate through materials?
- What is the effect of subsurface utility installation on the contamination of soil and groundwater?



Establish guidelines on the application of suitable types of materials

Geo³T² Conference Tuesday April 11th, 2017 Slide 3 of 30



 **LITERATURE REVIEW** 

Geo³T² Conference Tuesday April 11th, 2017 Slide 5 of 30



 **CONTAMINATION INCIDENTS IN US WATER SYSTEM** 

Contaminant	Percentage
Gasoline-Range Organics	89%
TCE + PCE	5%
Other	4%
Natural Gas	2%

Note: Trichloroethene (TCE), Tetrachloroethylene (PCE),

After Holsen et al. 1991; EPA 2002



Geo³T² Conference Tuesday April 11th, 2017 Slide 6 of 30



NORTH CAROLINA FIELD DATA

- Department of Environment and Natural Resources
- Compared concentrations with Title 15A of the North Carolina Administrative Code [NCAC Title 15A, Subchapter 2L]
- Compared concentrations with Gross Contaminant Levels (GCLs)

Geo³T² Conference Tuesday April 11th, 2017 Slide 7 of 30





NORTH CAROLINA FIELD DATA

Hydrocarbon contaminated sites

- Among the BTEX compounds, Benzene seems to significantly exceed GCL (5.0 mg/l); several times / highest contamination level among BTEX
- None of the BTEX compounds exceeded their solubility limit

Geo³T² Conference Tuesday April 11th, 2017 Slide 8 of 30





NORTH CAROLINA FIELD DATA

Dry cleaning solvent contaminated sites

- Between TCE and PCE: PCE was observed at higher concentrations
- Very High concentrations of PCE compared to standard limit (0.0007 mg/l) was observed
- In a few cases PCE exceeded its solubility limit (150 mg/l)
- The highest concentration observed (in groundwater sampling data): PCE concentration was 1.9 times higher than its solubility limit – non-aqueous phase liquid (NAPL)

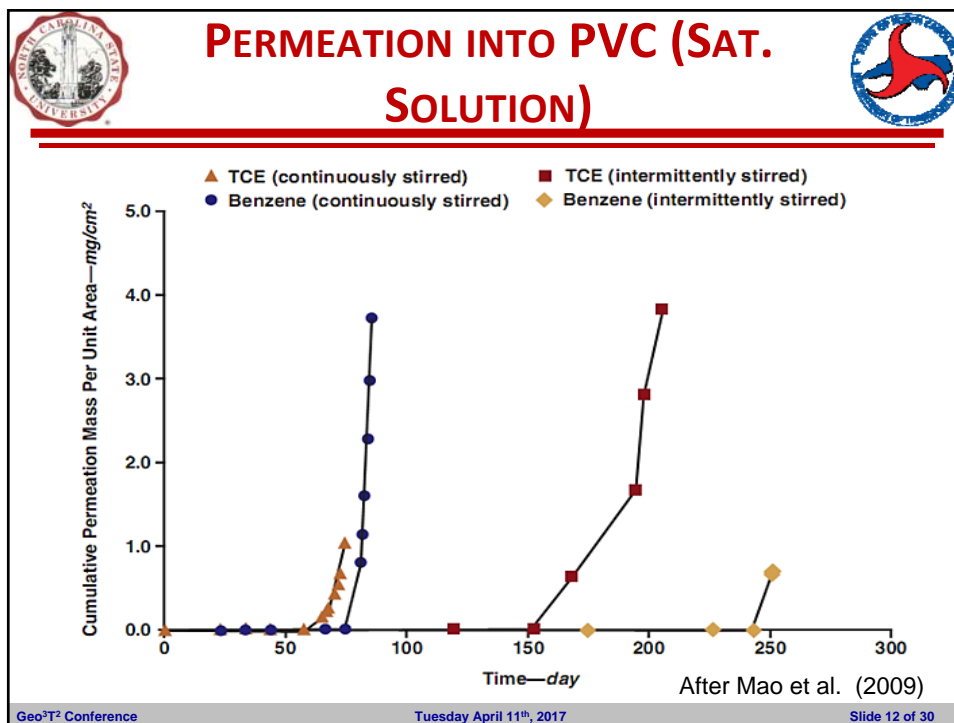
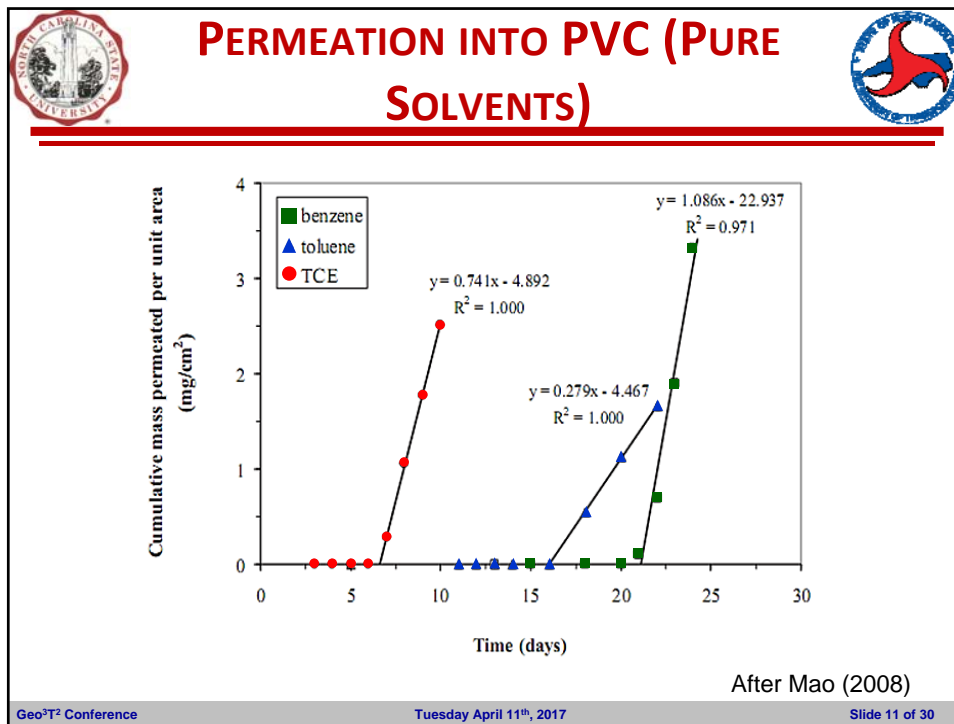
Geo³T² Conference Tuesday April 11th, 2017 Slide 9 of 30

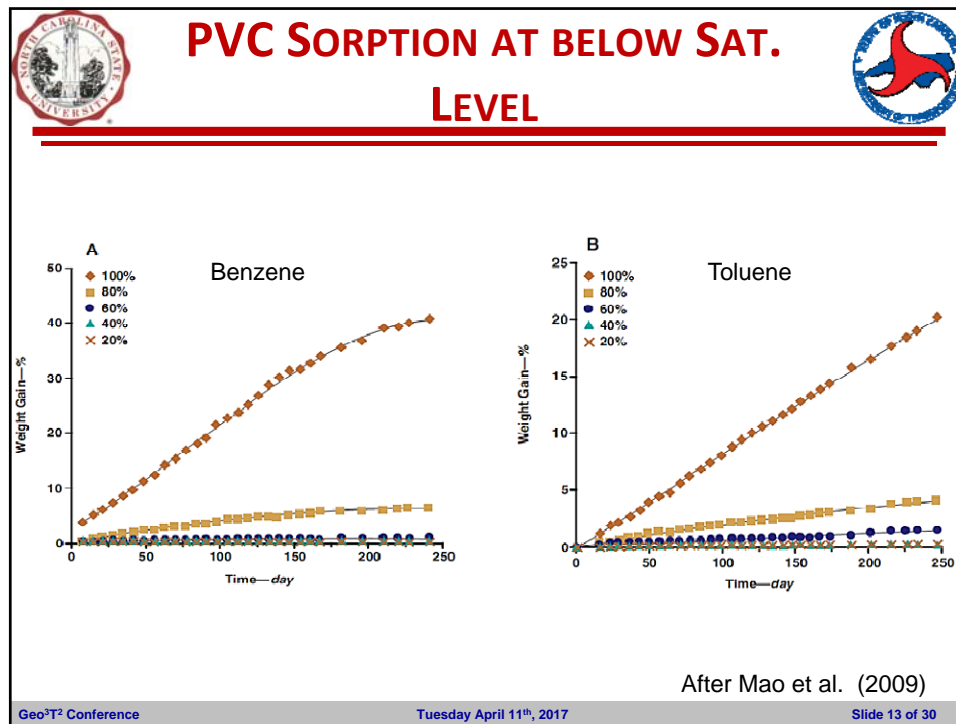


THE EFFECT OF CONTAMINANTS ON PVC PIPE

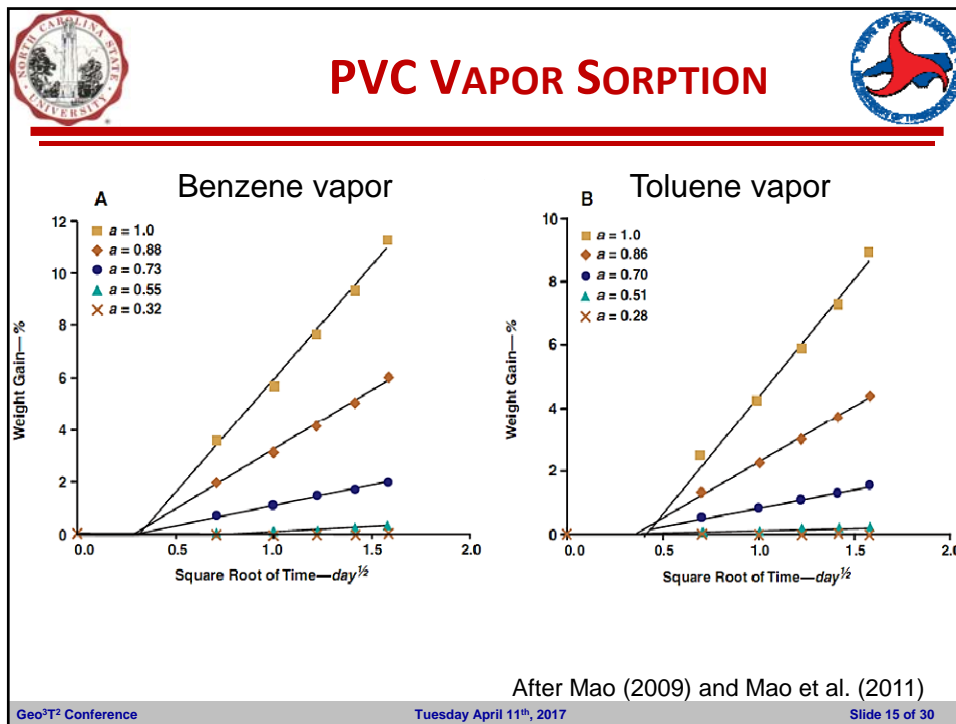
- PVC pipes have been among the most common pipe materials in the US since 1970s
- PVC pipes are generally impermeable to environmental organic contaminants-concern is related to gaskets
- Permeation through PVC pipes can be expected in heavily contaminated sites
- PVC pipes (glassy structure) are significantly less permeable as compared to PE pipe (semi-crystalline)

Geo³T² Conference Tuesday April 11th, 2017 Slide 10 of 30







-
- PVC SORPTION AT BELOW SAT. LEVEL**
- Significant sorption at 100 and 80% saturation levels
 - Weight gains for 60, 40, and 20% saturated less than 2% after eight months
 - Weight gain at 20% saturation level was statistically similar to control experiment (deionized water)
 - Sorption is negligible for levels below 20% saturation for both toluene and benzene
 - 20% saturation is considered a high level of environmental pollution in contaminated groundwater
- Geo³T² Conference Tuesday April 11th, 2017 Slide 14 of 30



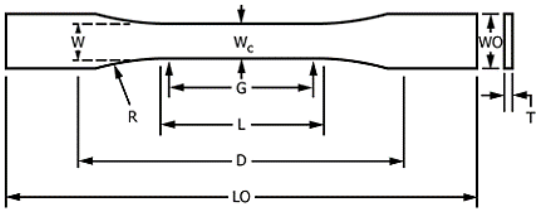
-
- PVC VAPOR SORPTION**
- Sorption of BTEX from gasoline saturated water is negligible due to low concentrations of BTEX (18%)
 - After two years of measurement, no detectible BTEX (from gasoline) was observed inside PVC pipe; PVC pipes are resistant to permeation by commercial gasoline (for 2 years)
- Geo³T² Conference Tuesday April 11th, 2017 Slide 16 of 30



PROPOSED MECHANICAL TESTING OF PVC




- Three different temperatures
- Multiple contaminants (common)
- Different durations




TYPES I, II, III & V

GeoT² Conference
Tuesday April 11th, 2017
Slide 17 of 30




PERMEATION FROM GASKET




The most widely used gasket materials in the water distribution system

- Ethylene propylene diene monomer (EPDM)
- Chloroprene rubber (CR; neoprene)
- Styrene-butadiene rubber (SBR)
- Nitrile rubber (NBR; Buna-N)
- Fluoroelastomer rubber (FKM; Viton)




© Steve Moore Distributed by Universal Uclick via CartoonStock.com
7-6
CARTOONSTOCK.com
Search ID: smb090705

GeoT² Conference
Tuesday April 11th, 2017
Slide 18 of 30




PERMEATION FROM GASKET




- Organic chemicals are 5 to 100 times more permeable in gasketed pipelines
- However, most permeation events do not involve gaskets
- The mass transfer area associated with gaskets is considerably smaller than that associated with pipelines
- Gaskets are usually installed in areas where flow is continuous and flow velocities are high, which increases the dilution effectiveness

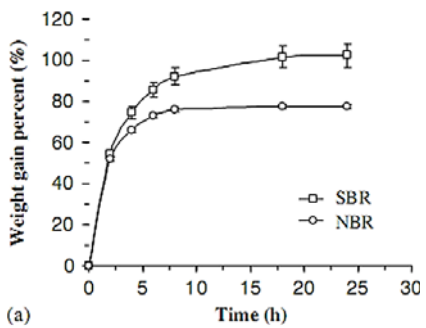
Geo³T² Conference
Tuesday April 11th, 2017
Slide 19 of 30



SORPTION BY GASKETS

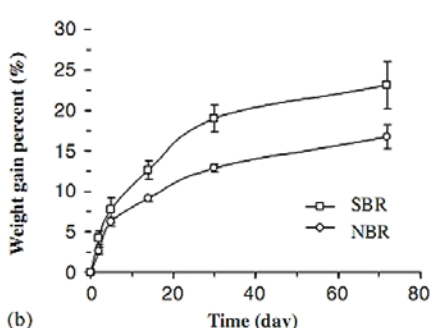


Pure Gasoline



(a)


Gasoline-Saturated Solution




(b)

After Mao et al. (2011)

Geo³T² Conference
Tuesday April 11th, 2017
Slide 20 of 30




SORPTION BY GASKETS




- Sorption of EPDM, CR, SBR, NBR, and FKM in the pure gasoline
- EPDM gaskets had the highest sorption (127% weight gain)
- Viton (FKM) gaskets had the lowest sorption (about 0.65%)

Cheng et al. (2012)

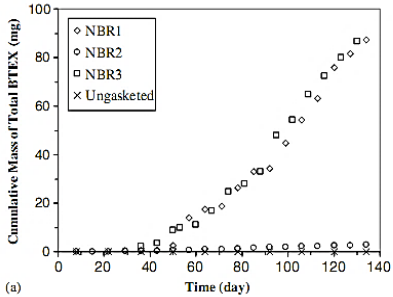
Geo³T² Conference
Tuesday April 11th, 2017
Slide 21 of 30



PERMEATION THROUGH GASKET IN JOINTED PVC PIPES

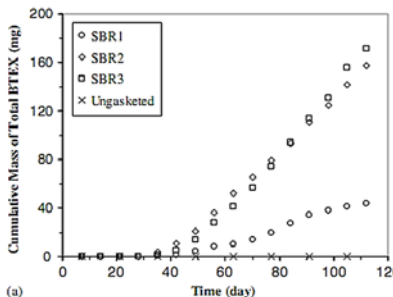


NBR (Nitrile)



(a)

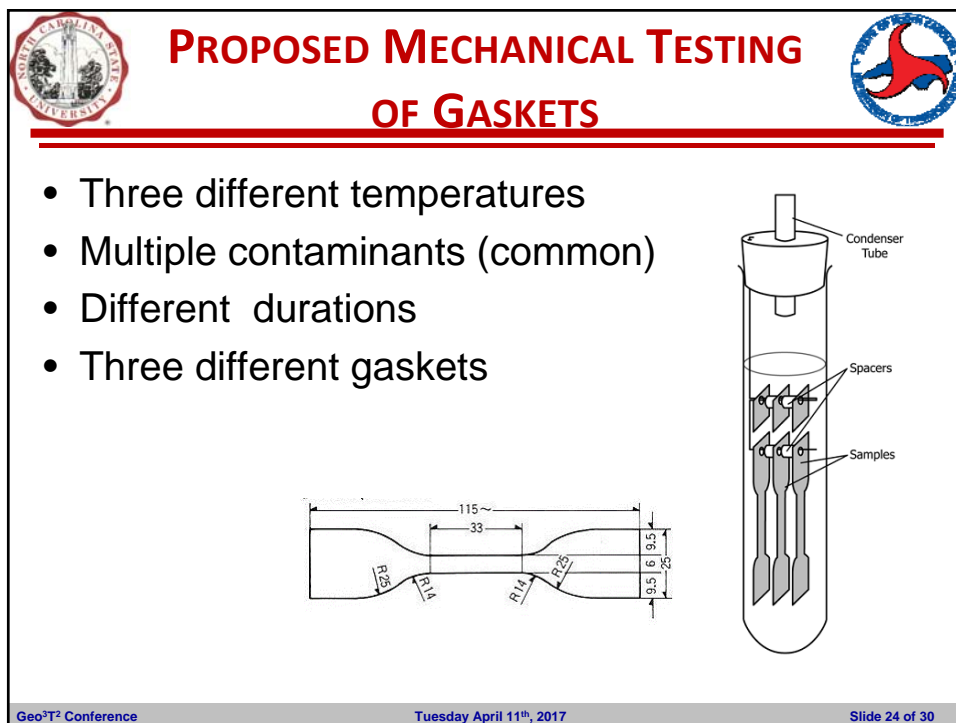
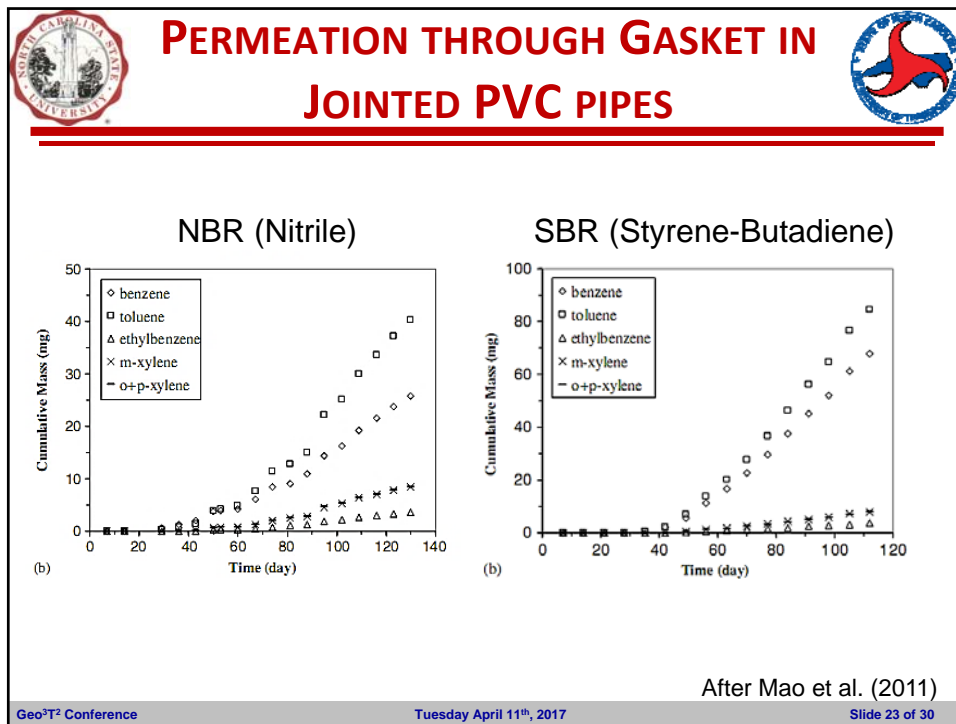
SBR (Styrene-Butadiene)




(a)


After Mao et al. (2011)

Geo³T² Conference
Tuesday April 11th, 2017
Slide 22 of 30






THE EFFECT OF HYDROCARBONS ON CONCRETE




- Hydrocarbons in general do not affect hardened concrete since they do not contain any constituents that react chemically with hardened concrete (Lea, 1970).
- Petroleum oils and coal-tar distillates have shown no effect on hardened concrete strength and durability (Wilson et al. 2001, Dobrowolski 1998)

Geo³T² Conference
Tuesday April 11th, 2017
Slide 25 of 30





THE EFFECT OF HYDROCARBONS ON CONCRETE

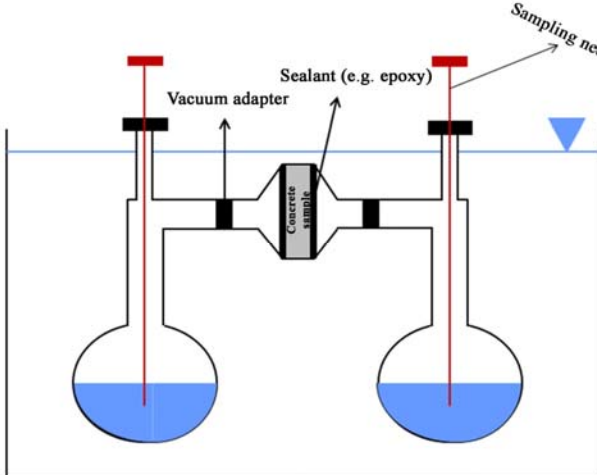


Contaminant	Reduction in strength gain (%)			
	7 days	14 days	28 days	84 days
Water	0	0	0	0
Creosote	13	14	15	20
Diesel	0	0	13	8
Lubricating oil	0	10	15	16



Wilson et al. (2001)

Geo³T² Conference
Tuesday April 11th, 2017
Slide 26 of 30

 **PROPOSED SETUP FOR TRANSPORT MEASUREMENT IN CONCRETE** 





Geo³T² Conference Tuesday April 11th, 2017 Slide 27 of 30

 **CONCLUDING REMARKS** 

- Rigid PVC pipe is an effective barrier against permeation
- The effect of contaminants on the mechanical properties of PVC is not well-understood
- The mechanical properties of concrete is not affected by contaminants
- The movement (transport) of contaminants through concrete is not well-understood



Geo³T² Conference Tuesday April 11th, 2017 Slide 28 of 30



CONCLUDING REMARKS

- Permeation through gaskets is studied previously but the effect of contaminants on the mechanical properties of gaskets is not well-understood

Geo³T² Conference Tuesday April 11th, 2017 Slide 29 of 30



THANK YOU!

Geo³T² Conference Tuesday April 11th, 2017 Slide 30 of 30