# Potential of polyethylene oxide solution as a fugitive dust palliative

Sunyoung Bae

Global Institute for Energy and Environmental Systems (GIEES)

University of North Carolina Charlotte

# Fugitive Dust

- Air pollutant called PM such as dust emitted in the atmosphere

- Generated by
  - Vehicular action
  - Wind action
  - Construction sites
  - Mining operations

- Fugitive dust from soil under dry condition

# Why clay?

- PM-2.5 is categorized in the fine fraction of soil-derived fugitive dust that is named as clay particles

- Soil derived anthropodust causes health problems
  - breathing difficulties
  - respiratory symptoms
  - heart and lung diseases
  - inflammation of the ears

# General approaches to dust control

- Water spraying
- Vegetative covers
- Gravel covers
- Chemical, non-toxic dust suppressants
  - salts, wood fibers, petroleum emulsions, polymers

# Objectives of research

- Understanding the desiccation with polyethylene oxide solution at the fundamental for prediction of dust control potential
- Index PEO potential for retaining liquid on clay through the experiments data
- Provide the PEO concentration ranges for dust control at field

⇒ A key parameter is the desiccation rate of PEO solution of various known conc. from soil

# Experiments

- Chamber desiccation tests
- Viscosity measurement
- Dielectric constant measurement

# Materials

- Na-montmorillonite

| Chemical composition | % | Chemical composition | % |
|---|---|---|---|
| $SiO_2$ | 62.9 | $CaO$ | 1.68 |
| $Al_2O_3$ | 19.6 | $Na_2O$ | 1.53 |
| $TiO_2$ | 0.09 | $K_2O$ | 0.53 |
| $Fe_2O_3$ | 3.35 | F | 0.11 |
| $FeO$ | 0.32 | $P_2O_5$ | 0.05 |
| $MnO$ | 0.01 | S | 0.05 |
| $MgO$ | 3.05 | $CO_2$ | 1.33 |

- Polyethylene oxide

$-[-CH_2CH_2O-]_n-$

$M_w$: $8 \times 10^6$

# Chamber desiccation test

- Provide data on the extent and rate amount of liquid loss from clay samples at known temperature and humidity

•10 g of Na-mmt + 50 mL PEO

-> hydrate for 24 hrs

-> place into environmental chamber at 25 $^{o}$C and 30% R.H.

-> measure the weight until the cumulative liquid content approaches 100%

# Viscosity and Dielectric constant measurements

- Investigate the influence of viscosity and dielectric constant on desiccation of PEO on Na-montmorillonite

- Measure the capacitance of air and water

$$\text{å}_r = \frac{C}{C_O}$$

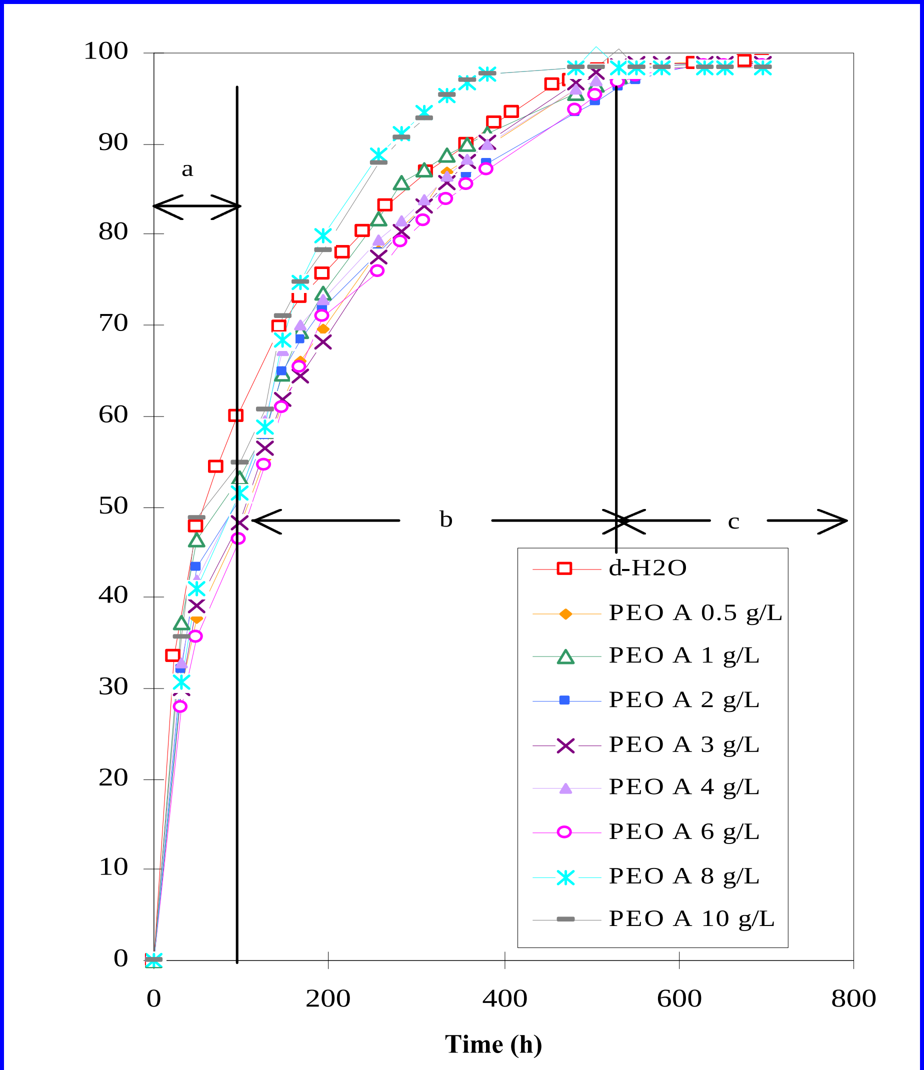
where:

$\varepsilon_r$= relative permittivity

C= capacitance with sample (F)

$C_o$= capacitance without sample (F)

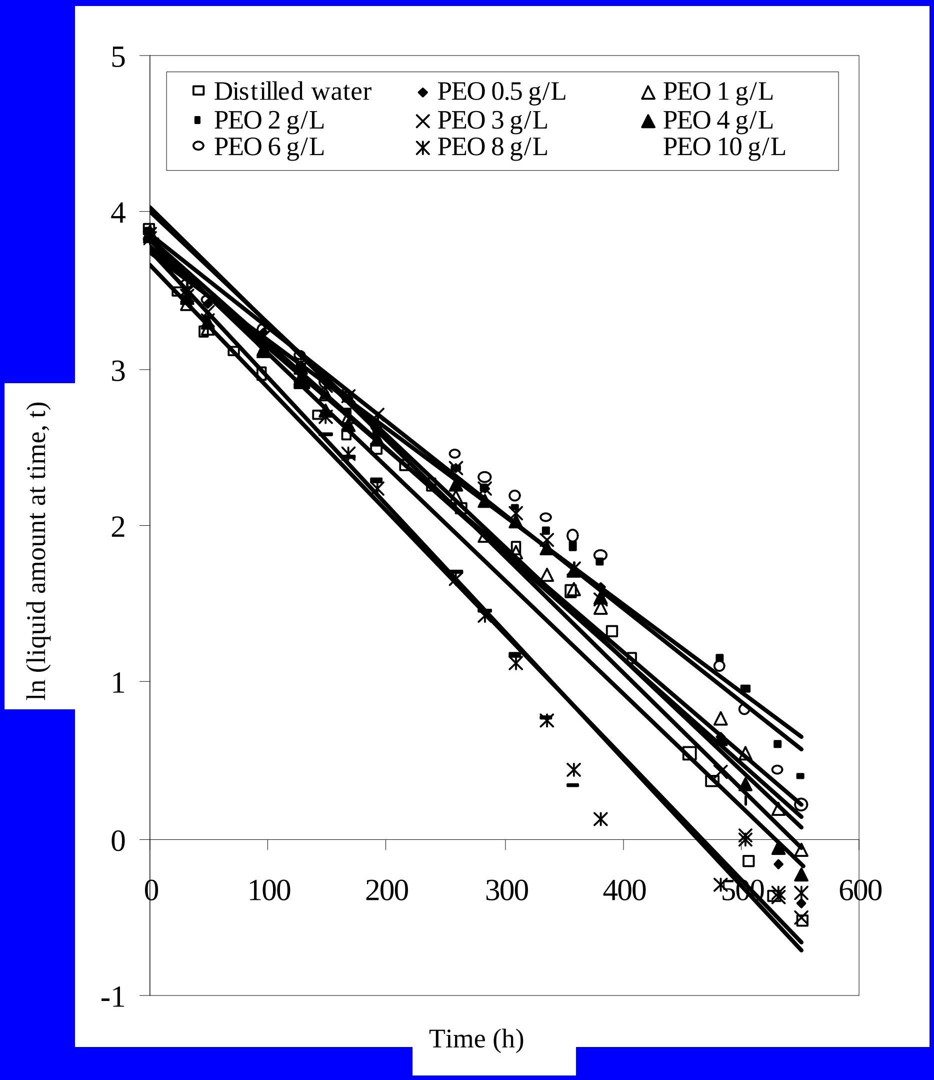
# Desiccation Results




$$W_c = \frac{W_i - W_t}{W_i - W_s} \times 100$$

- 99% of initial liquid content lost during about 890 hrs

# First order reaction




$$\ln(Q_t) = \ln(Q_o) - kt$$

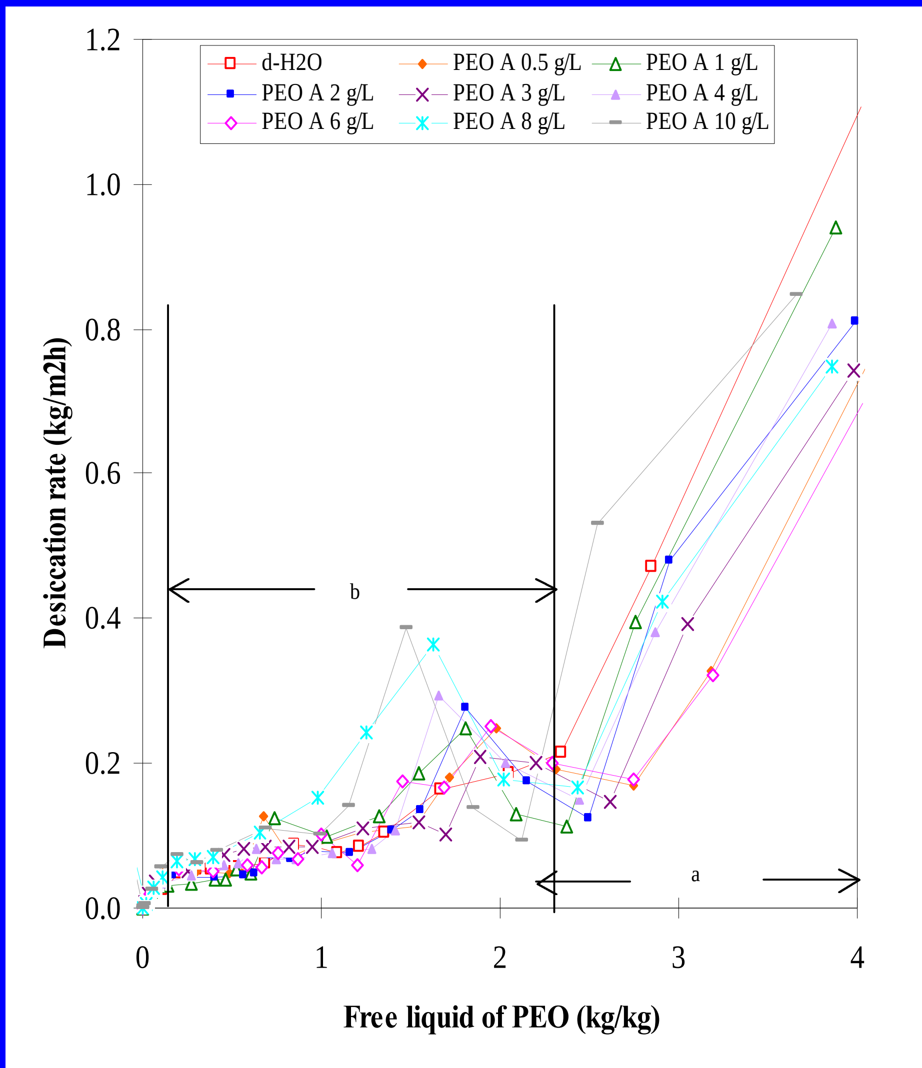
| Conc. (g/L) | Rate constant (g/h) |
|---|---|
| d- water | 0.0072 |
| 0.5 | 0.0071 |
| 1 | 0.0065 |
| 2 | 0.0056 |
| 3 | 0.0074 |
| 4 | 0.0067 |
| 6 | 0.0060 |
| 8 | 0.0081 |
| 10 | 0.0079 |

# Half-life

$$t_{1/2} = \frac{0.693}{k}$$

| Conc.(g/L) | Half-life (h) |
|---|---|
| d-water | 96.2 |
| 0.5 | 97.6 |
| 1 | 106.6 |
| 2 | 123.7 |
| 3 | 93.6 |
| 4 | 103.4 |
| 6 | 115.5 |
| 8 | 85.5 |
| 10 | 87.7 |

# Desiccation rate vs. free liquid



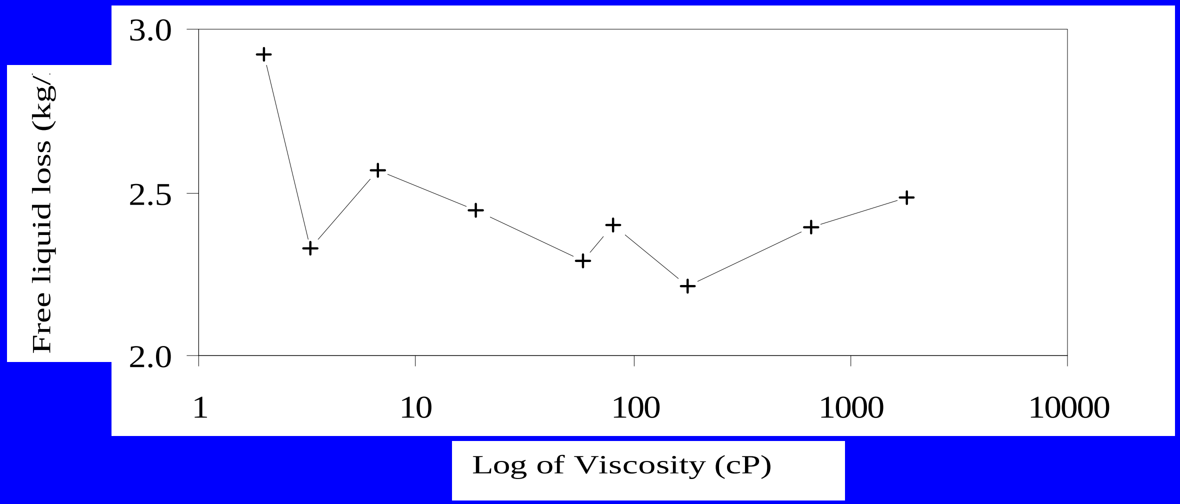

$$R_d = \left(\frac{Q_s}{S_a}\right)\left(\frac{\text{ÄX}}{\text{Ät}}\right)$$

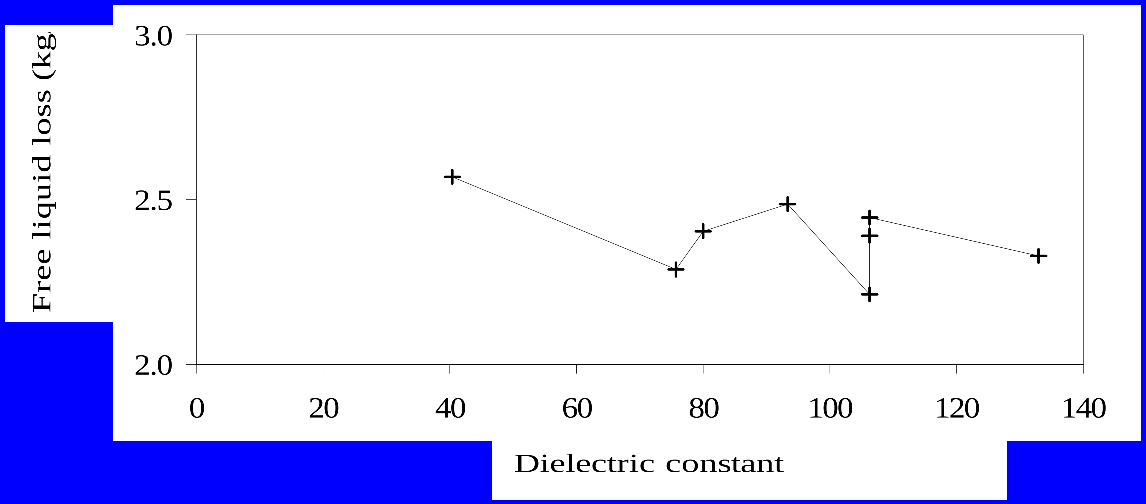
| Conc.(g/L) | Desicc.rate |
|---|---|
| d-water | 0.4899 |
| 0.5 | 0.3484 |
| 1 | 0.4853 |
| 2 | 0.3808 |
| 3 | 0.3388 |
| 4 | 0.3641 |
| 6 | 0.3045 |
| 8 | 0.3358 |
| 10 | 0.4261 |

# Desiccation rate vs. free liquid

- Unsteady state adjustment-period
  : d-water has slope of 0.4899 $kg/m^2h$
  6 g/L has slope of 3045 $kg/m^2h$
- Constant rate-period: 128 hrs-530 hrs
- Falling rate-period: desiccation rate decreases suddenly

# Free liquid loss versus viscosity and dielectric constant



# Continued

- Viscosity

  : As viscosity increases, the free liquid loss decreases

- Dielectric constant

  : As dielectric constant increases, the free liquid loss decreases

# Conclusions

- Aqueous PEO liquid of about 2 g/L shows low liquid loss when the soil is exposed to a temperature of 25 $^{o}$C and relative humidity of 30%
- These results provide a first-level indication of the good potential of low aqueous concentration of PEO as a dust palliative

# Diffuse double layer thickness

$$t_d = \left(\frac{1}{ev}\right)\left[\frac{\varepsilon k T}{8\pi n_0}\right]^{0.5}$$

where:

$T_d$ = the thickness of diffuse double layer

$\varepsilon$ = dielectric constant

$n'_o$ = concentration of polymer solution

k = constant represents unit electronic charge,
valance of the ions in solution,
Boltzmann constant and temperature

| | Polymer of PAM B concentration (g/L) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | 1 | 2 | 3 | 4 | 6 | 8 | 10 | **d-SPACING** |
| $T_d$(Å) | **15525** | **12229** | **8854** | **8319** | **9489** | **10268** | **10222** | **9083** | **14.429** |