Soil desiccation rate integration into empirical dust emission models for polymer suppressant evaluation

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Abstract

Dust constitutes an environmental and human health menace in many regions of the world. The rate of soil desiccation is a significant determinant of the availability of fine soil particles for entrainment in air as dust. Dust suppressants such as polymer solutions can reduce soil desiccation rate, thereby reducing dust emission factor. Herein, a dust emission estimation methodology that involves the integration of desiccation time curves to find the average desiccation rate is formulated. This is combined with soil characteristics, stressor (environmental and possibly vehicle) characteristics and liquid content in soil to estimate potential emission factors. Using this methodology, the dust suppression potential of aqueous polyethylene oxide (PEO) solution was investigated experimentally with Na-montmorillonite (Na-mmt) as the model dust-generating material. PEO with a molecular weight of 8×10^6 and at aqueous concentrations ranging from 0.5 to 10 g/L, was mixed with 10 g of Na-mmt (surface area = 31.82 ± 0.22 m^2/g) and desiccated for 700 h in a specially designed chamber at 25 °C and 30% relative humidity. The results show that generally, aqueous PEO is superior to distilled water as a dust suppressant for Na-mmt at concentrations in the range of 0.5–2.0 g/L. The experimental data obtained are introduced into the formulated estimation methodology, and potential emissions of dust from PEO-admixed Na-mmt are determined.
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1. Introduction

1.1. Necessity for dust control

Dust is defined as fine soil that is transmitted to the atmosphere from ground sources. Soil-derived anthropodust can cause health problems such as asthma and some forms of cancer, especially if the dusts are laden with contaminants. Peters et al. [1] reported that human exposure to fine particles such as PM-2.5 could be the cause of frequent hospital admissions and visits of people to the emergency room for heart and lung disease treatment. Generally, fugitive dust comprises particles that primarily fall within the PM-10 range (particles of 10 μm or less in diameter), and can have very diverse mineralogy. Several studies [2–5] have been performed to characterize the geochemistry of dusts,

often, with the objective of determining their source. Cancado and Peres [5] found quartz, iron oxides and muscovite to be the major mineral phases in dust generated by mining operations in the Iron Quadrangle region of Brazil.

Fuel-derived lead (Pb), a legacy of industrial activities in all countries and the use of leaded gasoline in many developing countries until the last decade or so, is commonly found in dust. Lead fallout rates from dust in Raipur City, India ranged from 0.0065 to 0.4304 kg km^{-2} yr^{-1} [6]. Particle size scaling performed by Sullivan [7] indicates that dust particles cover the range from clay to silt (0.01–100 μm, exceeding PM-10 in coarseness) thereby presenting opportunities for the attachment of contaminants to dust through a range of physico-chemical phenomena. Among these phenomena are cation exchange on clays, and adsorption on both silt and clay. Indeed, it is conceivable that the finer particles of dust present the greater human health risk as inhalable dust with respect to the presence of adsorbed contaminants. An investigation of the mutagenicity of urban particulate matter in Bologna, Italy by Pagano et al. [8]
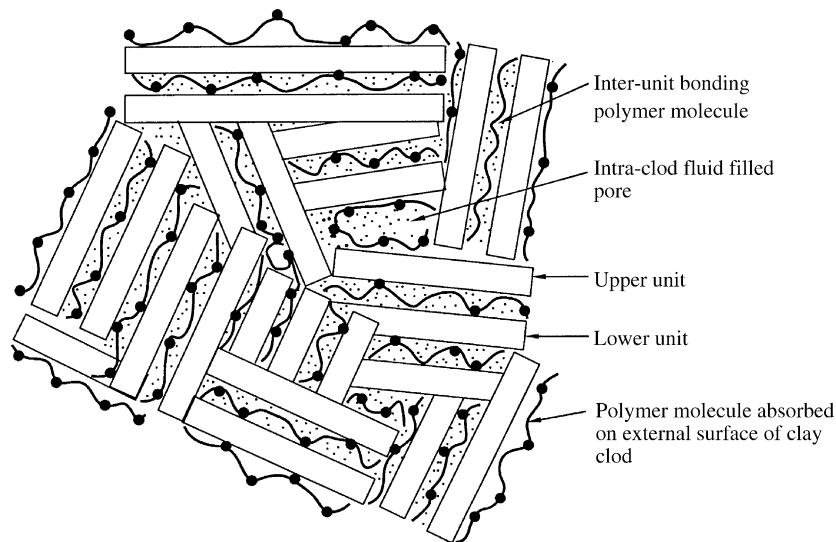

Fig. 1. An idealized schematic illustration of the binding action of polymer molecules on clay platelets within a clay clod.

indicated the existence of inverse proportionality between particle size and mutagenic activity in airborne particulate matter.

Fugitive dust can be generated by vehicular action on unpaved roads, and wind action on the ground surface at sites that are exposed to weather elements by agricultural, construction, and mining operations. It is estimated that each year, as much as 1000–1500 metric tons of fugitive dust is entrained in the atmosphere [9]. Dust storms are common in regions of dry climate, exemplified by the southwestern areas of the United States, where such storms frequently reduce visibility and cause automobile accidents.

1.2. The role of liquid retention in dust suppression

Liquids can be held as thin films in tension around soil particles. The greater the amount of liquid, the greater the thickness of the films that surround the soil particles. These films can bind soil particles together. Even when the thickness of these liquid films is diminished by soil desiccation processes, dusts may not be immediately generated if particle uplift forces are inadequate. The forces of interaction among soil particles must be overcome by uplift forces before entrainment of soil particles into the atmosphere as dust can occur. As the airflows over exposed ground, tiny particles are dislodged and moved.

Experimental observations and models of dust generation rates [10–14] indicate that dust generation is favored by low liquid retention in soil, high content of clay and silt in soil, sparse ground coverage and high intensity of stressing processes such as vehicular action, material processing operations and wind action. In another study [15], dust generation potential was found to be related inversely to moisture and organic content of exposed soil. Then a potentially successful approach to suppressing dust generation from the source material must be one that inhibits the occurrence of one or more of the conditions or processes that favor dust release from trafficked and/or exposed ground surfaces or material piles. For exposed ground surfaces, which are the focus of this paper, one of the practical options of dust sup-

pression is frequent wetting of the ground surface with liquids to retard desiccation that would eventually powder the ground surface, making soil particles readily available for entrainment into the atmosphere as dust. In dry climates, water is usually used as a dust suppressant. Unfortunately, many applications of water may be required. The cost of energy and labor to frequently spray water in rapid drying situations is quite high. Liquid binders such as aqueous solutions of lime, and polymers can be effective in reducing the drying rate of soil and thus requiring less frequent application of suppressant on exposed surfaces. Even a small reduction in drying rate can produce a very significant decrease in the energy and labor costs of dust suppression over large areas and long duration. However, any material selected must be non-toxic, biodegradable and inexpensive.

Chemical dust suppressants reduce dust in a variety of ways: surrounding and adhering to adjacent particles, thereby making it more difficult to dislodge them; attracting and trapping moisture from air to keep the surface moist; adhering to and cementing soil particles; acting as a clay dispersant to make clay more plastic; and producing heavy agglomerations of fine particles. An idealized, schematic illustration of this possible phenomenon is presented in Fig. 1. The resulting agglomerates of soil particles may become too heavy to be uplifted and entrained in the atmosphere as dust. Chemical suppressants may provide long-lasting retention of liquid and offer effective cohesion of soil particles. Usually, they provide a durable water-resistant surface. Polymers suppress dust by cementation of soil particles and may provide some control against moisture change.

2. Analytical approach

2.1. The estimation of dust emission factors for unpaved roadways

The entrainment of particles into the atmosphere may occur when the lift forces on the particles imposed by airflow exceeds the adhesion force between particles and the surface that

Table 1
Constant for a and b of Eqs. (1) and (2), which is provided by US EPA [16]

Constant	Industrial roads (Eq. (1))			Public roads (Eq. (2))		
	PM-2.5	PM-10	PM-30	PM-2.5	PM-10	PM-30
k (lb/VMT)	0.23	1.5	4.9	0.27/0.26	1.8/1.7	6.0/6.4
a	0.9	0.9	0.7	1/0.8	1/0.8	1/1
b	0.45	0.45	0.45	NA	NA	NA
c	NA	NA	NA	0.2/0.2	0.2/0.2	0.3/0.4
d	NA	NA	NA	0.5/1	0.5/1	0.3/1

generates them. The airflow which imposes a bending moment on the particle replaces the moment of adhesion force on the particles. Then, the particles roll and become airborne. Only when uplift potential of particles is less than the adhesiveness can the particles escape from the surface. While wind action alone can generate the lift necessary to entrain particles in the atmosphere, in some cases, vehicular action induces the lift forces. This is particularly the case on unsurfaced roads and other exposed ground surfaces that are trafficked by vehicles.

Dust emission potential can be assessed through the use of Eq. (1). This empirical equation is adapted from US EPA [16] and produces estimates of dust emission in pounds of size-specific particulate material from an unpaved source, per vehicle mile traveled (VMT) as follows:

$$E_f = k \left(\frac{P_s}{12} \right)^a \left(\frac{W_v}{3} \right)^b \tag{1}$$

where E_f is the emission factor (lb/VMT), k is particle size multiplier for particle size range and units of interest which is given by US EPA, a and b are empirical constants, P_s is silt content of surface material (%), and W_v is the weight of mean vehicle (tons). Eq. (2), adapted from US EPA [16] is amenable to use for estimating dust emission rates for traffic that is dominated by light duty vehicles on publicly accessible roads

$$E_f = \frac{k \left(\frac{P_s}{12} \right)^a \left(\frac{V_v}{30} \right)^d}{\left(\frac{P_m}{0.5} \right)^c} \tag{2}$$

where V_v is the mean vehicle speed (mph), d is empirical constant, and P_m is the moisture content of surface material (%). The constants for a, b, c, d of Eqs. (1) and (2) are shown in Table 1. These numbers are specific to different aerodynamic particle sizes such as PM-10 and PM-2.5. The parameters of P_s, W_v, and P_m are source characteristics and can be used for adjusting the emission estimates to local conditions.

2.2. Analytical approach adopted in this research

From previous experimental work [17–20], it was noted that high liquid loss rates during soil desiccation processes can lead to dust generation. However, for an extended time period of desiccation in the field, it is important to use an average value from a liquid retention curve such as the one that is schematically illustrated in Fig. 2. The average value can be estimated using Eq. (3) for introduction into Eq. (2) for use in computing potential
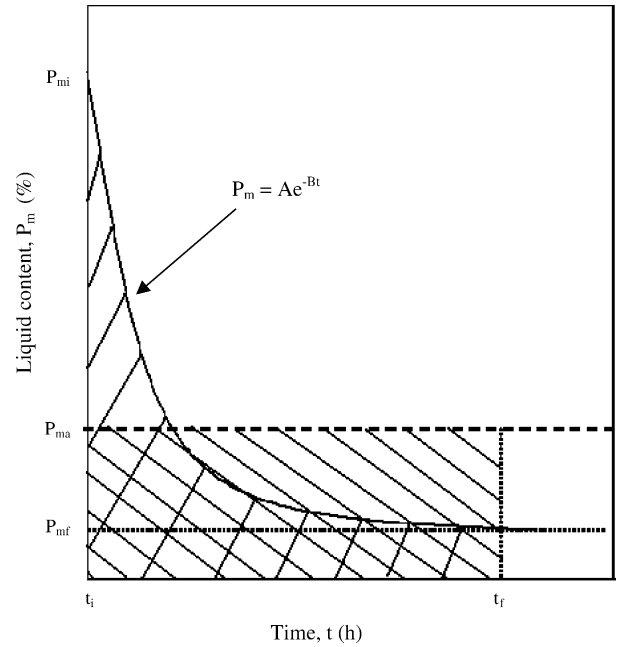

Fig. 2. Schematic illustration of liquid retention during desiccation process.

dust generation rates. This analysis focuses on the methodology for doing this and incorporating the results into a reformulated dust emission model.

Eq. (3) represents the liquid loss pattern in a desiccating soil. The liquid content, P_m (%), shows an exponential decrease during the desiccation period

$$P_m = A \, e^{-Bt} \tag{3}$$

Herein, A is the slope of exponential curve, and B is the constant when Eq. (3) is linearized. P_m can be considered to be the average liquid content during the desiccation period. The integral of P_m divided by duration of soil drying experiment $(t_f - t_i)$ provides the average liquid content, P_{ma} (%), during the desiccation period

$$
P_{ma} = \frac{\int_{t_i}^{t_f} P_m}{(t_f - t_i)} = \frac{\int_{t_i}^{t_f} A \, e^{-Bt} \, dt}{(t_f - t_i)} = \frac{A \int_{t_i}^{t_f} e^{-Bt} \, dt}{(t_f - t_i)}
$$
$$
= \frac{A[-e^{-Bt_f} + e^{-Bt_i}]}{B(t_f - t_i)} \tag{4}
$$

The constants A and B can be obtained from experimental data plotted as liquid content (%) versus drying time of soil samples, t_f is the time at the end of the drying experiment (h), t_i is the time at the beginning of the experiment (h), P_{mi} represents liquid content (%) at the initial time and P_{mf} is the liquid content (%) at the end of the experiment (%) as illustrated in Fig. 2. When P_m given by Eq. (4), is substituted into Eq. (2), the final equation for estimation of the emission factor is derived as Eq. (5)

$$E_f = \frac{k \left(\frac{P_s}{12} \right)^a \left(\frac{V_v}{30} \right)^d}{\left(\frac{A[-e^{-Bt_f} + e^{-Bt_i}]}{0.5B(t_f - t_i)} \right)^c} \tag{5}$$

From Eq. (5), three variables are the major parameters that control dust emission: silt content of surface material; weight

of mean vehicle; and liquid content of surface material. Possible control options are vehicle restriction, surface improvement, and surface treatment. The volume and type of vehicular traffic on unpaved road or mean vehicle speed may alter emission rate but are difficult to enforce. For road surfaces that are designed, silt content is dependent on soil mix design. Many unpaved road surfaces are not designed. Consequently, control of surface soil particle size distribution has limited potential practically. Control of liquid content is more feasible than the other two control approaches. Surface treatments can be divided into two types: wet suppression and chemical stabilization. Through watering or use of aqueous solutions or concentrated liquids, road surfaces may be kept wet to control emissions. Chemicals in solution or concentrated forms can produce desirable changes in the physical characteristics of the exposed soil surface.

2.3. Estimation of liquid duration under environmental conditions

In order to indicate how liquid loss is analyzed in this paper, formulations for estimating rate constants from measured parameters are presented as Eqs. (6)–(8). Liquid retention by clay during desiccation processes can be determined as follows:

$$P_l = \frac{W_t - W_s}{W_s} \times 100 \tag{6}$$

where P_l is the liquid retention by clay (%), W_t is the weight of the wet solid (clay + liquid) at time t (g), and W_s is the weight of dry solid (g).

If the plot of the natural log of the final quantity of PEO solution versus time gives a straight line, then the desiccation is known to follow first-order kinetics. The rate constant, k', and half-life $(t_{1/2})$ can be determined from the plot of the natural log of the final quantity of PEO solution versus desiccation time

$$\ln(Q_t) = \ln(Q_0) - k't \tag{7}$$

In Eq. (7), Q_t is the final quantity of liquid in the sample (g), Q_0 is initial quantity of liquid in the sample (g), k' is desiccation rate constant (g/h), and t is the duration of the desiccation (h). From the slope of linear equation, the rate constant, k', can be obtained. The half-life, which is the time required for half of the PEO solution to evaporate from the wet soil, can be calculated from the rate constant as follows:

$$t_{1/2} = \frac{0.693}{k'} \tag{8}$$

3. Materials and methods

The use of this approach to estimate dust emission reduction is demonstrated herein, using the results of desiccation experiments on clay material with PEO at various concentrations. These materials are used for illustrative purposes only. The methodology is intended for use in evaluating any liquid dust suppressant when once the desiccation rate that applies is known. Being that the clay is expected to retain liquids introduced to it

at various levels under controlled environmental conditions, an opportunity is provided to use this method to determine the liquid retention value for each aqueous PEO concentration. The impact of the liquid retention on dust emission can be estimated using Eqs. (2)–(5). It should be noted that the purpose of the experimental section of this paper is not to determine the proportionality of liquid retention to PEO aqueous concentration at various intermediate desiccation time instants. The focus herein is to obtain desiccation trend lines for each concentration, covering the entire desiccation period for use in demonstrating the assessment methodology developed and presented.

3.1. Experiment design and rationale

In order to control the environmental parameters that affect liquid loss from wet soils, desiccation tests were performed in a chamber in which temperature and relative humidity could be controlled. Aqueous concentrations of PEO were produced at the following concentrations: 0.5, 1, 2, 3, 4, 6, 8, 10 g/L. Free liquid loss was determined through measurements of weight loss during sample drying, under the controlled environmental conditions. PEO solutions were also characterized through measurements of their solution viscosities and dielectric constants using procedures briefly outlined below.

3.2. Materials tested and justifications of their selection

Na-mmt was used in this research as the model soil although it is recognized that real soils contain a wider distribution of mineralogies and particle sizes. The use of Na-mmt was considered necessary because it is common in soils and can produce significant textural responses that can impact upon dust generation. Besides, as a clay material, its fine particles are amenable to easy entrainment in air as dust. The Na-mmt that was used in this research was obtained from the University of Missouri-Columbia, Missouri Clay Minerals Repository. The repository is the source of well-characterized clays that are frequently used by researchers nation-wide. This provides the opportunity for researchers to compare the results of their investigations on the same materials. The Na-mmt consists of 62.9% SiO_2, 19.6% Al_2O_3, 3.35% Fe_2O_3, 3.05% MgO, 1.68% CaO, 1.53% Na_2O, 0.53% K_2O, 0.32% FeO, 0.111% F, 0.090% TiO_2, 0.05% S, 0.049% P_2O_5, 0.006% MnO, and the rest is loss on ignition. The cation exchange capacity (CEC) is 76.4 meq/100 g. Sodium (Na^+) with minor amounts of calcium (Ca^{2+}) is the principal exchange cation. The surface area (using nitrogen adsorption method) was measured at 31.82 ± 0.22 m^2/g as provided by the vendor.

PEO ($-[-CH_2CH_2O-]_n-$) is a neutral polymer and is typically produced as a clear solid powder. It is a hard and waxy water-soluble polymer. PEO was supplied by Polysciences, Inc. (Warrington, PA) and has a molecular weight of 8,000,000. The configuration of the PEO molecule indicates that hydrogen bonding is likely the means of attachment of PEO onto clay. It has been used as a retention aid for high-yield pulps. Distilled water was used in all the experiments as the solvent for this polymer.

3.3. Test protocols

3.3.1. Chamber tests

Ten grams of Na-mmt was mixed with 50 mL of PEO solution and transferred to polystyrene tubes (22 mm internal diameter × 145 mm height). Then, the tube was weighed with a balance that is sensitive to 10^{-4} g and left at room temperature to hydrate for 1 day. After 24 h of hydration, the samples were placed in an environmental chamber (Watlow Series 922, designed by Bryant Manufacturing Associates) that maintained temperature at 25 °C and 30% relative humidity. Weight measurements were then made at various time intervals until the cumulative loss of liquid from each sample approached 100%. The measurements were made at 1-day intervals and several times until the change in weight became less than 0.0100 g. From these measurements, the envelop of desiccation times to attain reasonably complete liquid loss was found to be about 700 h although the rate of drying (desiccation rate) within this time-frame varied for various concentrations as discussed in Section 4 of this paper.

3.3.2. Measurement of viscosity and dielectric constant

The viscosity of intergranular pore fluid in soil affects the rate at which the fluid moves under various gradients. Being that polymer solutions of different concentrations have different viscosities, polymer solution viscosity was measured in this research to index the effects of polymer concentration and the results. The viscosity of PEO solutions was measured using a rotational viscometer (Cole-Parmer, Vernon Hills, Illinois). For each test, an aliquot of 35 mL PEO solution was transferred into a polystyrene tube. The rotor was immersed in the PEO solution up to the groove marked on the rotor shaft. The value of viscosity was taken on the display panel after 1 min to ensure that stabilized readings were recorded. Capacitance measurements were performed to determine the dielectric constants of PEO solutions. Solution dielectricity is an important parameter as regards physico-chemical interactions between the solution and soil solids that may influence the texture of the soil. In turn, soil textural parameters such as porosity, pore size distribution and tortuosity have impacts on desiccation rate. These tests were performed using a LCR (Inductance, Capacitance, and Resistance) Meter (Hewlett-Packard, Model 4261A) at a frequency of 1 kHz and a test signal of 1 V. A sample cell made of parallel plates (30 mm width × 0.9 mm length × 15 mm height) was filled with PEO solution. Then, the silver alloy-sided section was attached to internal surfaces of the sample cell, and the other side was attached to electrodes that connected the sample cell to the LCR meter. Before measuring the capacitance of the PEO solutions, the capacitances of air and water were measured for calibration of the measurements. The ratio of the capacitance of water to that of air was taken to be 78 at 25 °C.

4. Results and discussion

4.1. Desiccation test

The aqueous PEO concentrations presented were obtained from triplicate measurements of solution viscosity. This was
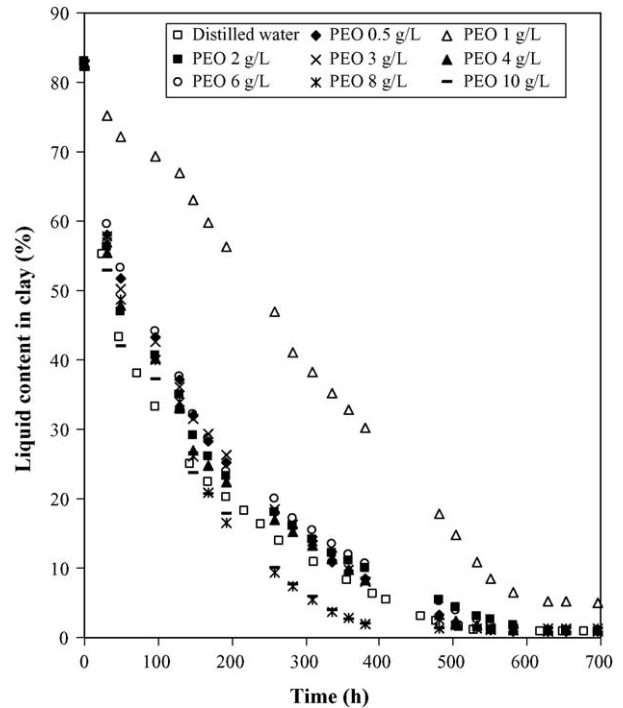

Fig. 3. Relationship between liquid content retained in Na-montmorillonite amended with polyethylene oxide at various concentrations during a desiccation period of 700 h.

observed at all aqueous concentrations of PEO. During a desiccation duration of 700 h, about 99% of the initial liquid content was lost from Na-mmt samples. However, within this duration, there were drying rate variations for various PEO concentrations. Plots of liquid retention versus time are shown in Fig. 3 for various PEO aqueous concentrations. The results show that Na-mmt amended with PEO solutions, lost liquid exponentially. This is a first-order reaction in which the quantity of PEO liquid decreases exponentially at least, within the first 500 h. The rate constants are determined from the plot of the relationship between the natural logarithm of liquid quantity and time, t (Fig. 4). The lowest slope of the plot is −0.0056 g/h for an aqueous PEO concentration of 2 g/L and the highest slope is −0.0081 g/h for an aqueous PEO concentration of 8 g/L. Distilled water has a slope of −0.0072 g/h. It is observed that the liquid loss is slower with 2 g/L solution than with distilled water within 500 h of desiccation. The rate constants that are obtained from the slopes of the graphs are summarized in Table 2. The lowest rate constant among various concentrations of PEO is 0.0056 g/h with 2 g/L PEO while the control sample which involved drying of soil with distilled water produces a value of 0.0072 g/h. The calculated half-lives of aqueous PEO desiccation from Na-mmt are also summarized in Table 2. The corresponding half-lives of various PEO concentrations are 96.2 h for distilled water while 2 g/L of PEO has 123.7 h. These results imply that the PEO concentration of 2 g/L was retained the most by Na-mmt although this observation is more obvious in the early (0–250 h) stages of desiccation.

As shown in Fig. 3, soil drying rates change with time. Greankoplis [21] reported that the unsteady state adjustment

Table 2
The linear equation of cumulative liquid loss ($\ln(Q_t)$) of PEO on Na-montmorillonite against time (t), rate constant, and half-lives obtained from the linear Eq. (7)

Concentration of polymer solutions (g/L)	Linear equation	R^2	Rate constant (g/h)	Half-life (h)
Distilled water	$\ln(Q_t) = -0.0072t + 3.8224$	0.9701	0.0072	96.2
0.5	$\ln(Q_t) = -0.0071t + 4.0097$	0.9649	0.0071	97.6
1	$\ln(Q_t) = -0.0065t + 3.7779$	0.9887	0.0065	106.6
2	$\ln(Q_t) = -0.0056t + 3.7390$	0.9854	0.0056	123.7
3	$\ln(Q_t) = -0.0074t + 4.0289$	0.9559	0.0074	93.6
4	$\ln(Q_t) = -0.0067t + 3.8404$	0.9717	0.0067	103.4
6	$\ln(Q_t) = -0.0060t + 3.8567$	0.9768	0.0060	115.5
8	$\ln(Q_t) = -0.0081t + 3.7588$	0.9730	0.0081	85.5
10	$\ln(Q_t) = -0.0079t + 3.6664$	0.9621	0.0079	87.7

period is usually quite short relative to the other two stages. The constant-rate period is shown in the middle of the desiccation graph. Subsequent to constant-rate desiccation, the rate of desiccation falls more rapidly until the free liquid content equals zero. Bae and Inyang [17] have identified distinctive desiccation rate periods during the drying of aqueous polyethylenimine (PEI) solutions from Na-mmt.

4.2. Emission factor (E_f)

Emission factors were computed using Eq. (5). Data on typical silt content, traffic and vehicular weight were obtained from EPA AP-42 [16]. For computation of PM-10 and PM-2.5 emissions, 0.01% and 20 mph were chosen as the silt content of surface material and for mean vehicle speed, respectively. Only the average liquid content is obtained from experimental data using Eq. (7). The average liquid contents of PEO on samples and computed emission factors are summarized in Table 3. The average liquid contents vary from 15.2% with distilled water to 77.0% with 1 g/L of PEO solutions. The concentration of 1 g/L PEO has the lowest emission factor for PM-10, (0.229 g/h) while distilled water has 0.317 g/h. For PM-2.5, PEO 1 g/L has the lowest emission factor, (0.0344 g/h) while distilled water has 0.0475 g/L. These results indicate that PEO suppressant can improves liquid retention in soil samples and potentially reduce the emission rates of dusts. Fig. 5 shows the effect of polymer concentration on reductions in emission factor. The concentration of 1 g/L of PEO solution has the highest average liquid retention in soil, (77.0%), which is more than twice of that of distilled water (control) during desiccation period. The corresponding decrease in emission factor for PM-10 is from 0.317 to 0.229 g/h.

4.3. Practical applications of the results

In terms of practical application, the interest is to find the minimum aqueous concentration of PEO that could be effective in dust suppression. If flocculation is retarded through increase in dielectric constant, then the pore size distribution in the drying clay is likely to be skewed toward smaller pores. Coupled with the attachment of polymer molecules to pore walls, the flow of liquid upward to the drying surface could be constrained predominantly to the central section of the pores. This restriction improves liquid retention capacity and hence, delays dust generation processes that rely on clayey soil powdering: a phenomenon that is commonly induced by excessive liquid loss. Depending on the type of polymer and clay characteristics, high
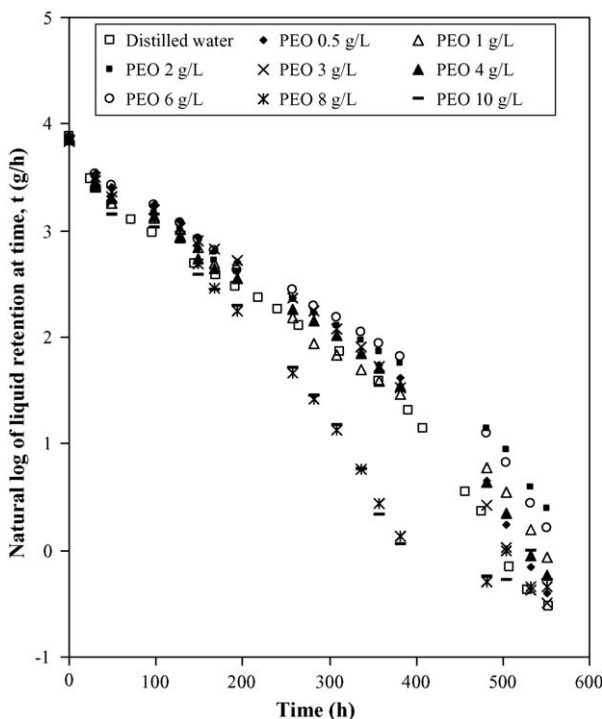

Fig. 4. Desiccation of PEO on Na-montmorillonite to determine the first-order reaction.

Table 3
Emission factors of PM-10 and PM-2.5 as a function of polymer concentration as dust suppressant

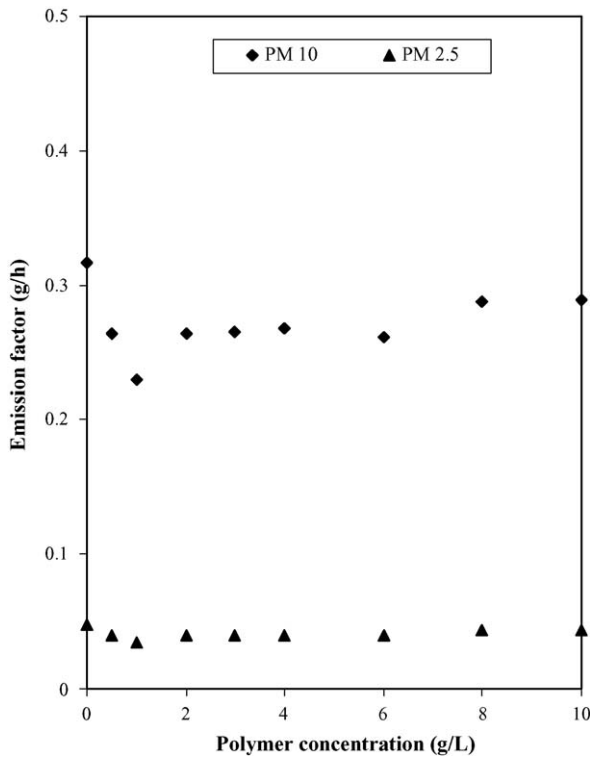| Concentration (g/L)	Average liquid content (%)	Emission factor (g/h)	
		PM-10	PM-2.5
Distilled water	15.2	0.317	0.0475
0.5	37.8	0.264	0.0396
1	77.0	0.229	0.0344
2	37.9	0.264	0.0396
3	37.4	0.265	0.0397
4	35.1	0.268	0.0402
6	40.2	0.261	0.0391
8	24.9	0.287	0.0430
10	24.0	0.289	0.0434

Fig. 5. Emission factors for PM-10 and PM-2.5 as a function of polymer concentration which was obtained from experiment for 700 h.

aqueous concentrations of the polymer may also induce flocculation of the clay thereby causing larger pore spaces that allow intergranular liquid applied to dry out more easily. Testing at various concentrations will enable the appropriate concentration range to be estimated. To satisfy the reader's curiosity, the cost-effective PEO solution would be applied using standard dust-laying processes employed in construction. This involves spraying of the liquid on ground surfaces from a tanker. Increase in liquid retention implies that the number of applications per unit area of the ground surface, and the cost of application to attain a given dust control effectiveness would desirably decrease.

5. Conclusions

Aqueous PEO liquid at a concentration range of about 0.5–2.0 g/L shows low liquid loss when the soil is exposed to a temperature of 25 °C and relative humidity of 30%. This is indicative of a liquid retention capacity that would minimize the potential of dust release from exposed Na-mmt-rich soils in the field. The PEO concentration of 1 g/L mixed with Na-mmt gives the lower emission factor than control, which is with water. Although it is recognized that in an actual soil, many other soil minerals and soil textural forms would be represented, these results provide a first-level indication of the reasonably good potential of PEO, in low aqueous concentrations, as an effec-

tive dust suppressant. Subsequent field research/demonstration is planned as a follow-up to this laboratory-based investigation.

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