REVISED METHOD FOR RAPID ASSESSMENT OF EXPOSURE TO PARTICULATE EMISSIONS FROM SURFACE CONTAMINATION SITES

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ABSTRACT

The focus of this paper is one portion of the inhalable dust pathway for exposure to contamination. The current method of estimating the amount of contaminated dust raised into suspension by wind, the inhalable particulate source term, is outdated. This paper describes an expanded capability and updated predictive modeling tool to serve as a pre- or post-processor in a multimedia model. The method may also be used more readily in cases where a risk manager must quickly assess the implications of wind blown contamination on at-risk populations.

INTRODUCTION

The original environmental fate and transport computer models of the 1980's focused on single pathways and sources (also called single media). Multimedia fate and transport models have been developed to overcome the limitations of the original single media models. Updated versions of the original single pathway models are usually coupled to form the multimedia algorithms. The single path models are, in effect, source terms within the multimedia models' compartments. The more accurate the single pathway model, the better the results of the multimedia modeling will be. There is, then, a need to continue refining single media fate and transport models used in risk assessments and management.

The current method of estimating the amount of contaminated dust raised into suspension by the wind, the inhalable particulate source term, is outdated. This paper describes an expanded capability and updated predictive modeling tool to serve as a pre- or post-processor in a multimedia model. It may also be used as a single media estimator when rapid assessments of exposure to wind blown, inhalable dust are needed.

THE CURRENT MODEL

In the Environmental Protection Agency (EPA) document RAPID ASSESSMENT OF EXPOSURE TO PARTICULATE EMISSIONS FROM SURFACE CONTAMINATION SITES[1] (hereafter referred to as **Rapid Assessment**), the authors presented an approach for determining whether (1) a recently discovered abandoned hazardous waste site or (2) a new spill site requires emergency cleanup or immediate area evacuation because wind blown contaminated dust presents an unacceptable threat to humans.

Two equations for the PM_{10} emission factor, $E_{10,}$ are given for the cases of wind erosion of limited and unlimited erosion potential surfaces. Cowherd and Gillette, two of the principal researchers of **Rapid Assessment**, noted that highly wind erodible surfaces have threshold friction velocities below 75 cm/sec. Those surfaces with higher threshold velocities are composed of course, nonerodible aggregates with a small amount of erodible material, and crusts that are resistant to erosion. Cowherd and Gillette then used their earlier research (see **Rapid Assessment**, pages 21 - 22, for a discussion) to develop the emissions factors for limited ($u_t^* > 75$ cm/sec) and unlimited erosion potential sites, and roadways.

The limited erosion potential equation is derived from Cowherd's research on dust emissions from coal piles. It takes the form:

$$\mathbf{E_{10} = (0.83(fP(u^+))(1\text{-}V))/(PE/50)^2} \qquad \text{(Eqn. 1)}$$

where:

(a) E_{10} = annual average PM10 emission rate per unit area of contaminated surface in mg/m^2-hr

(b) f = frequency of disturbances per month

(c) u^+ = observed or probable fastest wind speed for the period between disturbances (m/s),

(d) $P(u^+)$ = erosion potential in g/m2, where $P(u^+) = 6.7(u^+ - u_t)$ for $u^+ >= u_t$, or zero when $u^+ < u_t$

(e) u_t is the erosion threshold wind speed (in m/s) measured at a typical weather station sensor height of 7 m. (The threshold wind speed is found from: $u_t / u_t^* = 2.5 \ln (z / z_o)$ where: z = height above surface in centimeters (700 cm), u_t^* = threshold friction velocity (m/sec), z_o = surface roughness height (cm))

(f) V = fraction of contaminated surface area covered by continuous vegetative cover

(g) PE = Thornthwaite's Precipitation Evaporation Index used as an average soil moisture estimate.

The unlimited erosion potential equation is:

$$\mathbf{E_{10} = 0.036\ (1\text{-}V)\ ([u] / u_t)^3\ F(x)} \qquad \text{(Eqn.2)}$$

where:

(a) [u] = mean annual wind speed (m/s)

(b) F(x) = an empirically derived function whose plot is provided in **Rapid Assessment** at Figure 4-3., "Graph of Function F(X) Needed to Estimate Unlimited Erosion"

The contaminant emission rate (assumed constant) is given by

$$\mathbf{R_{10} = (MF_{10})\ (E_{10})\ (A)} \qquad \text{(Eqn. 3)}$$

where MF_{10} is the mass fraction of contaminant in PM_{10} emissions and A is the areal source extent. R_{10} is then used in a simplified, hand held calculator compatible version of the Industrial Source Code - Long Term model used at the time **Rapid Assessment** was written to predict downwind contaminant concentrations. Short-term worst-case concentration estimates are performed using a method derived from a screening model available at that time. These downwind contaminant concentrations are then evaluated against risk criteria to determine emergency cleanup or evacuation procedures.

REVISIONS TO RAPID ASSESSMENT

The current **Rapid Assessment** method for determining whether a site has limited or unlimited potential does not take into account many of the factors that effect erosion potential, particularly soil composition. The Limited Erosion Potential equation is also based on mining site research, not the much broader study done by Fryrear and colleagues for the Revised Wind Erosion Equation[2]. Using their Erodible Fraction concept with the Unlimited Erosion Potential equation (Eqn. 2) should provide a better estimate of initial suspension rate.

A site's threshold friction velocity is also not constant over time. The average Unlimited Potential Equation rate can be calculated in a Monte Carlo simulation taking into account the Cumulative Distribution Function of threshold friction velocity, u_t^*, derived from Gillette's data[3,4,5] by Stewart and Liljestrand.[6]

The current **Rapid Assessment** methodology does not account for dry or wet deposition and resuspension. Dispersion models available now can be used to incorporate the results of dry and wet deposition.

REVISED METHODOLOGY

For dispersed emissions from a site, the initial site review will retain many of its current features and add the soil assessment needed to complete the Erodible Fraction estimate. The non-erodible ground cover and vegetative cover estimates, as well as the contaminant concentration are still required. The non-erodible cover fraction will be used, as in **Rapid Assessment**, to adjust the required threshold friction velocity. The amount of vegetation will also be factored into the Unlimited Erosion Potential equation as in the original version.

The basic steps in the Monte Carlo simulation leading to an estimate of ground level PM10 concentrations at receptors are:

1. Select and properly format the appropriate meteorological data set for the site. If available, use a five-year data set. Load the data into a spreadsheet.
2. Randomly select a threshold friction velocity, u_t^*, from the cumulative distribution function derived by Stewart and Liljestrand from Gillette's field data.
3. Use u_t^* to calculate u_t for the appropriate anemometer height.
4. If the adjusted u_t is less than the first observed wind speed, record $E_{10} = 0$ and go on to the next hourly data set. If not, proceed.
5. Solve the Unlimited Erosion Potential equation for E_{10}.
6. Iterate through the entire set. Calculate the Average E_{10} for all the hourly values in the simulation set.
7. Adjust E_{10} by the Erodible Fraction for the soil at the site, and for the amount of non-erodible and vegetative cover.
8. Use the average E_{10} value and the areal extent of the polluted site in the ISC Short Term model to calculate average ground level concentrations at receptors of concern. A volume source should be examined in “dry and wet deposition” mode.

TESTING THE REVISED METHODOLOGY

The U.S. Department of Energy operates a nuclear weapons assembly and disassembly plant near Panhandle, Carson County, Texas, generally known as the PANTEX plant, or simply PANTEX. The safety of the plant’s immediate neighbors is ensured through a variety of strictly enforced agreements between the U.S. Department of Energy and the State of Texas, and by permits under a number of Federal and Texas laws. Atmospheric emissions of nuclear materials and toxics are the primary concerns of the neighbors. Surprising to most people is the fact that there are very few sources of either type of contaminant at the plant. Nuclear material is not refined or otherwise processed at the plant. The burning of waste explosives from disassembled weapons is the closest thing to an emissions process involving nuclear materials. The focus of citizen concern, then, is usually the disposal of explosives and other materials at the plant’s burn ground and firing site where, conceivably, nuclear material and toxics could be released.

The burning operations are done in accord with permits issued by the Texas Commission on Environmental Quality (TCEQ). Because of concerns about the permitted burning and other activities, an agreement between the Department of Energy and the State of Texas directs the installation and operation of a string of monitoring stations within the boundaries of the plant. These stations are equipped with a variety of samplers. The monitoring system has been in place for a number of years. Both the plant operator and Texas government specialists analyze samples. Summaries of findings from the monitoring system are published regularly by the TCEQ. While not presenting a perfect way of verifying the revised **Rapid Assessment** approach, it appears quite clear that this site can be assessed using the new technique, and the results can be compared with actual sample data from the monitoring system. The resulting judgments may be used to verify the basic technique, and drive further development.

MODELING WIND BLOWN CONTAMINATED DUST AT THE PANTEX FACILITY

One hundred seventy daily PM10 sample results were chosen from those collected from the TCEQ and PANTEX samplers at the site. Weather observations for each of the sampling dates were collected with the assistance of the meteorology team at TCEQ. The meteorological values were reformatted for use in a spreadsheet. Spreadsheets were then set up and run to estimate E10 values for each sampling day for both the revised Rapid Assessment method and the original Cowherd-Gillette version.

The principal air dispersion model used for this research was EPA's "Industrial Source Code Short Term 3." The version used was BEE-Line Software's "BEEST For Windows, V8_18. The model was set up for three area sources of wind blown particulate matter: the firing site, the burning ground, and the cropland immediately adjacent to the burning ground. The coordinates for two PM10 (The TCEQ #5 and PANTEX stations are collocated.) monitoring stations, TCEQ numbers 4 and 5, were entered into the model as receptors. The unit emission rate run in the model was 0.0005 gram/square meter-second, the E10 value calculated for December 18, 2000 using the revised methodology. The model was then run for results at the receptors. The E10 values for each sample day were normalized against those for December 18, 2000. The normalized values were then multiplied by the receptor value of interest. To complete the spreadsheet, the actual observed concentrations from the monitored sites were recorded on that same line as the estimates.

Figure 1 shows the estimated concentrations derived using the revised **Rapid Assessment** and original Cowherd-Gillette techniques plotted against the actual observed values. Two conclusions are apparent in looking at this plot. First, neither the revised nor the original methods provide estimates that correlate significantly with the observed values, even when outliers are discarded. Second, the original method predicts results substantially less than the observed values, while the revised **Rapid Assessment** method generally over predicts the actual results.

The second result suggested a check of the average and range of values for both the modeled and actual results. Discarding three outlying observed results that appear to have been affected by nearby construction activity, the average observed value is about 19 micrograms per cubic meter. The predicted value using the revised method is about 34 ug/m3. The range of observed values is 4 – 68 ug/m3. The range for the revised **Rapid Assessment** method is 0-48 ug/m3.

The results for the average and range of values suggest that the revised **Rapid Assessment** method results could be useful in making decisions about wind blown hazardous material. The fact that the revised method somewhat over predicts the average concentration of PM10, while generally predicting the same range of values, indicates the method is useful and could be even more so with refinement. These parameters are of meaning to both the risk assessor and the risk manager.

SUMMARY

Single media exposure modeling should be updated when appropriate to recognize newer understandings of the processes involved and to capture technological advances. In this case, the method for estimating exposure from wind entrained contaminated dust benefits from using Monte Carlo techniques, computer power, and the incorporation of additional studies on threshold wind velocity and the erodible fraction of soils. The method shows an acceptable level of utility when tested with data from the PANTEX nuclear weapons facility.

REFERENCES

1. Cowherd C, Muleski G E, Englehart P J, Gillette D A, **Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites**, EPA/600/8-85/002, Environmental Protection Agency, Washington, D.C., February, 1985.

2. Fryrear D W, Krammes C A, Williamson D L, Zobeck T M, Computing the Wind Erodible Fraction of Soils, *Journal of Soil and Water Conservation*, V 49, n2, pp 183-188.

3. Gillette D A, Adams J, Endo A, Smith D, Kihl R, Threshold Velocities for Input of Soil Particles into the Air by Desert Soils, *Journal of Geophysical Research*, V_85, nC10, pp 5621-5630, 1980.

4. Gillette D A, Adams J, Muhs D, Kihl R, Threshold Friction Velocities and Rupture Moduli for Crusted Desert Soil for the Input of Soil Particles into the Air, *Journal of Geophysical Research*, 87, pp 9003-9015, 1982.

5. Gillette D A, Adams J, Endo A, Smith D, Kihl R, Threshold Velocities for Input of Soil Particles into the Air by Desert Soils, *Journal of Geophysical Research*, V_85, nC10, pp 5621-5630, 1980.

6. Stewart D F and Liljestrand H M, Monte Carlo Simulation of Fugitive Emissions From land Disposal Sites: Threshold Wind

Friction Velocities of Particles Smaller Than One Millimeter, *Proceedings* of the AWMA 89th Annual meeting, Nashville, June, 1996.

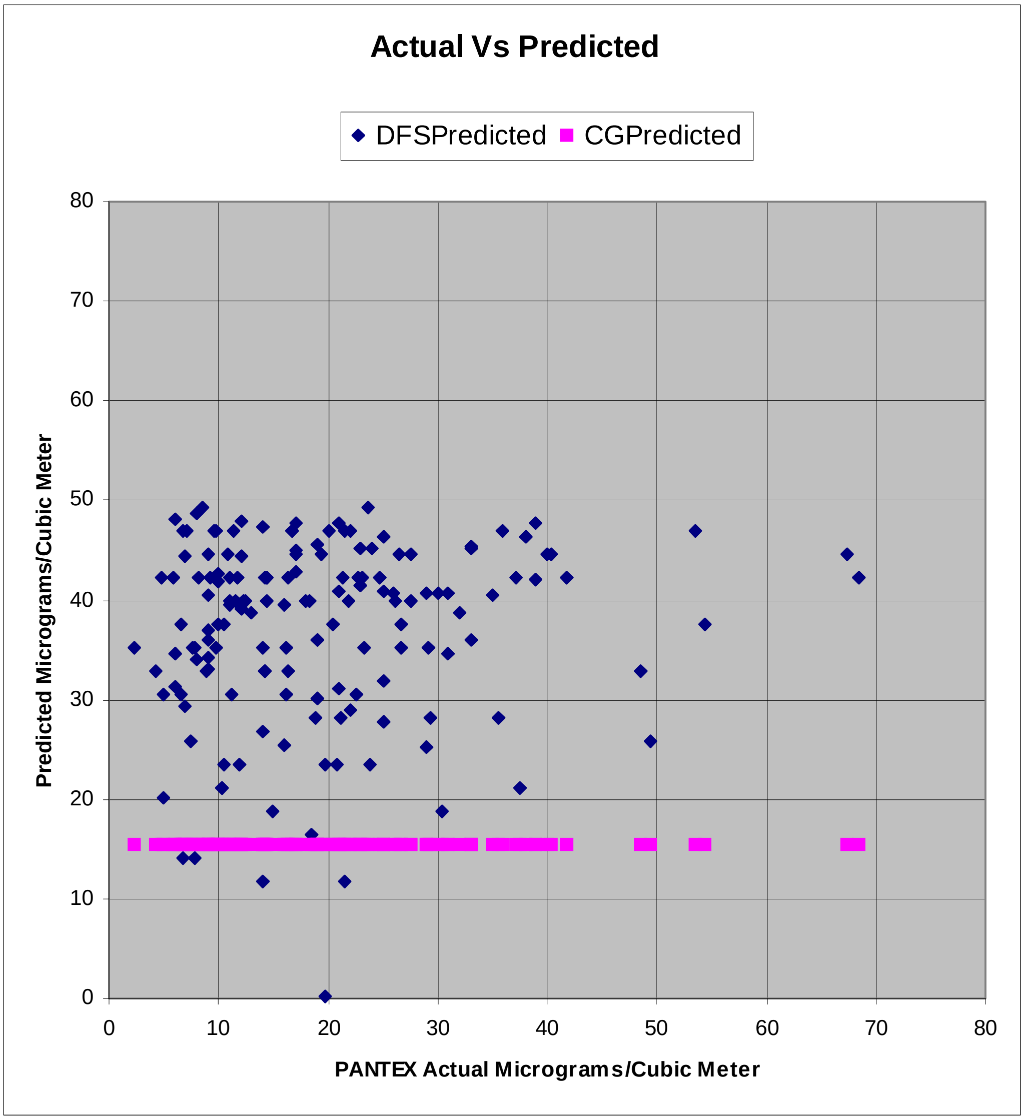

Figure 1: Predicted Versus Actual Concentrations, PANTEX Plant