Health Risk Assessment of Human Exposure to Fugitive Dust during Soil Excavation in a Dioxins and Mercury Contaminated Site

Lee CW[1], Chen HC[1], Chao CC[2], Lin KH[2], Kung PY[2]

[1]Department of Safety, Health and Environmental Engineering, National Kaohsiung First University of Science, Kaohsiung; [2]Sustainable Environment Research Center, National Cheng Kung University, Tainan

Abstract

The objective of this study was to evaluate the potential health risks caused by human exposure to fugitive dust during excavation in a dioxins and mercury contaminated site, China Petrochemical Development Corporation (CPDC) An-Shun site, in Tainan, Taiwan. In the current study, soil excavated area of 2,500 m^2 was assumed to be a potential dust source in future remediation works. Case-specific exposure parameters used in this evaluation conservatively assume that the nearby site worker will be exposed to contaminated dust. The computer models selected for this project are incorporated as modules in the American Petroleum Institute's Exposure and Risk Assessment Decision Support System (API-DSS). The equation developed by Cowherd was used in API-DSS for estimation of annual average emission rate of 10 microns in size or smaller (PM_{10}) due to wind erosion. Gaussian Dispersion Model was used to estimate the concentration of chemicals downwind from the source. Estimated results show that cancer risks exceed the generally accepted benchmark of 10^{-6} within distance of 300 m on the downwind side of the dust source. The noncarcinogenic hazard index also exceeds the reference level of unity within distance of 100 m. From risk management point of view, the risk evaluation presented above indicates that the dioxin and mercury present in soils at CPDC An-Shun site may pose significant risks to human receptors potentially exposed via the fugitive dust media. A more extensive dust control plan should be undertaken to protect workers or population living in nearby areas.

Introduction

From a contaminated site risk management point of view, a health risk assessment is an essential tool to address the adverse effects of the remediation technologies on human health. The objective of this study was to evaluate the potential health impacts caused by fugitive dust emissions during excavation process of site remediation works. The study was undertaken in a heavily contaminated site, China Petrochemical Development Corporation (CPDC) An-Shun site, in Tainan, Taiwan. The CPDC An-Shun site is a multi-contaminated site with a complex mixture of dioxins and mercury due to the manufacture of caustic soda, hydrochloric acid, liquid chlorine and pentachlorophenol since 1942. The plant was closed down in 1982 and pollutants were left behind without proper control and treatment[1]. At the request of the Tainan City Government, CPDC plan to start remediation action in the near future. Potential emission sources during remediation include point sources of treatment residuals, volatile chemicals and area sources of fugitive dusts from the disturbed surface of a contaminated land area. The amount of emissions released from a fugitive dust is directly related to the site environmental conditions (e.g., ambient temperature, wind speed above the surface, etc.) and the extent of mechanical disturbance. In this study, a human health risk assessment was conducted to evaluate the potential health impacts caused by human exposure to fugitive dust due to wind erosion during remediation.

Materials and Methods

The framework of the risk assessment of this study is shown in Figure 1. In this study, both cancer and non-cancer risks for the human exposure to the fugitive dusts during excavation process of site remediation were assessed. Based on the Taiwan EPA reports, high contents of dioxins (36,000 ng I-TEQ/kg) and Hg (0.212–12,000 mg/kg) in soil were detected within the site[2]. A scenario that accounts for the excavation of soil has been established. It was assumed that the soil excavation area of 50 m×50 m and excavated surface is not covered by grass. Potential receptors may be exposed via inhalation of contaminated dust due to wind erosion at the site. Case-specific exposure parameters used in this evaluation conservatively assume that the nearby site worker will be exposed at a frequency of 250 days per year over a 10-year period. The computer models selected for this project are incorporated as modules in the American Petroleum Institute's Exposure and Risk Assessment Decision Support System (API-DSS). API-DSS incorporates a number of fate and transport models for estimation of receptor point concentrations using site-specific data[3]. The equation developed by Cowherd was used in API-DSS for estimation of annual average emission rate of 10 microns in size or smaller (PM_{10}) due to wind erosion[4].

$$E_{10} = 0.83\ f\ A\ P(u^{+})(1-V) / (PE/50)^2$$

where

E_{10} = PM_{10} annual average emission rate, mg/hr

f = frequency of disturbances per month (1/month for abandoned sites or sites with no activity)

A = area of contaminated soils, m^2

$P(u^{+})$ = erosion potential,

$P(u^{+}) = 6.7(u^{+} - u^{t})$; u^{+} = fastest mile wind speed, m/s

u^{t} = equivalent threshold value of wind speed at 7 m anemometer height, m/s

V = fraction of contaminated surface with continuous vegetative cover (equals 0 for bare soil)

PE = Thornwaite's Precipitation-Evaporation Index used as a measured soil moisture content

Gaussian Dispersion Model was used to estimate the concentration of chemicals downwind from the source. For modeling, meteorological input includes wind speed, atmospheric stability and wind direction. The meteorological data was obtained from Chigu station, which is the closest weather station from the CPDC An-Shun site. The average concentration at the receptor is computed by frequency-weighting the concentrations for each stability class. Cancer risks of toxins were calculated by timing the lifetime exposure to the carcinogenic slope factors. In this study, dioxins are the chemicals assessed as human carcinogens. The US EPA provided the values of cancer slope factor (CSF) for carcinogenic effects and reference dose (RfD) for non- carcinogenic effects. USEPA[5] recommended a cancer slope factor (CFS) of 156,000 $(mg/kg\text{-}d)^{-1}$ for 2,3,7,8-TCDD. Table 1 summarized the exposure factors and model input parameters for exposure and risk assessment.

In health risk characterization, cancer risks of dioxins were calculated by timing the lifetime exposure to the CFS**.** EPA codified a range of acceptable risks (i.e., 1×10^{-4} to 1×10^{-6}) as a basis for remediation of Superfund sites[6]. Non-cancer risks of toxics expressed by hazard index (HI), were determined by dividing the lifetime exposure to the RfD. Exposure to chemicals with a HI > 1.0 is considered likely to result in adverse non-cancer health effects over a lifetime of exposure.

Results and Discussion

Table 2 consists of an evaluation of the potential risks associated with a nearby site worker being exposed to the dioxins and at the site. It is assumed that potential receptors are exposed to fugitive dust via inhalation. Based on the scenario, it is estimated that risks exceed the generally accepted benchmark of 10^{-6} within distance of 300 m on the downwind side of the dust source. The noncarcinogenic hazard index also exceeds the reference level of unity within distance of 100 m from the source. From risk management point of view, the risk evaluation presented above indicates that the dioxin and mercury present in soils at CPDC An-Shun site may pose significant risks to human receptors potentially exposed via the fugitive dust media. Wind speed data obtained from nearest Tainan Chigu weather station shows that the CPDC An-Shun site is located in the area with strong coastal wind, especially in the winter and spring seasons. Usually, the winter and spring time are dry seasons in southern Taiwan. The coincidence of dry season and a strong wind regime brings more fugitive dust due to wind erosion. Therefore, a more extensive dust control plan, including fugitive dust prevention from vehicles and construction equipments, should be developed to protect workers or population living in nearby areas. The results of this study could provide important risk management information that will help decision makers determine what additional dust control actions may be necessary to reduce potential health and environmental impacts in the future remediation efforts at the site. For a more accurate risk assessment, further specific estimations of the changes in environmental conditions due to the construction of the remediation facilities will be required; and more over, the effects of the pollutants to the ecosystem will also need to be evaluated.

References

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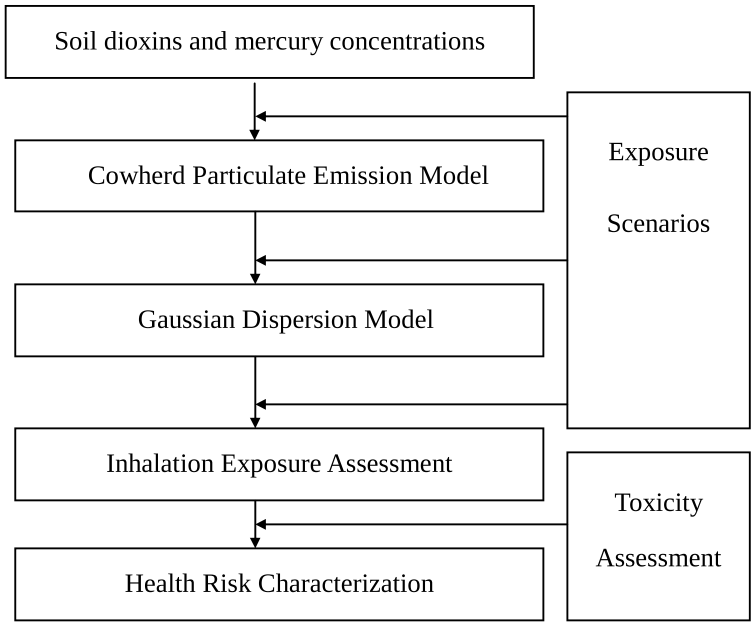

Figure 1. The framework of the risk assessment of human exposure to fugitive dust during excavation process of site remediation.

Table 1. The exposure factors and model input parameters for exposure and risk assessment

Gaussian Dispersion Model		Particulate Emissions Model	
Wind Speed [m/s]	4.4	Monthly Freq of Disturb [1/mo]	3
Freq. Wind blows to Recp. [-]	0.3	Fastest Mile Wind Speed [m/s]	15
Distance to the Receptor [m]	100 to 500	Erosion Threshold W Speed [m/s]	1
Area of the Source [m^2]	2500	Fraction of Vegetative Cover [-]	0
		PE Index (Thornwaite)	30
		Area of contaminated soil [m^2]	30.0
Intake Parameters			
Lifetime (yrs)	70	Average Weight (kg)	65
Exposure Frequency [days/yr]	350	Inhalation Rate [m^3/hr]	0.833
Exposure Duration [years]	3	Time Outdoors [hours/day]	4
Bioavailability	1		

Table 2. Evaluation of the potential risks associated with a nearby site worker being exposed to the dioxins and mercury at the site.

Down Wind Distance(m)	Dioxins Inhalation Cancer Risk	Mercury Inhalation hazard index (HI)
100	1.411E-5	2.88
200	3.65E-6	0.74
300	1.71E-6	0.35
500	6.74E-7	0.13