Estimation of Emission and Concentration of PCDDs/PCDFs in Urban Areas using a Gridded Multimedia Fate Model

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Introduction

Chronic exposure to chemical substances has adverse effects on the human body and the environment. Persistent pollutants could be transported over wide areas. Therefore, it is necessary to estimate the long-term average concentration of substances that have been continuously discharged over a wide region. The emission sources of chemical pollutants are often found in highly populated regions in the urban environment, Waste incinerators are the main source of polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in Japan. Many small-scale waste incinerators exist in high population density regions since much of the waste is incinerated. Therefore, it is necessary to apply a gridded type model to evaluate exposure from two or more sources. For some species of hazardous chemicals, including dioxins, it is indispensable to evaluate various exposure routes. The model should be of a multi media type to be able to treat material transport among media.

A gridded multimedia-type model was developed and applied to estimate the concentrations of PCDDs and PCDFs. The spatial distribution of the concentrations of dioxins could be discussed using the model. The results, combined with demographical and epidemiological data, are an essential for the risk management of PCDDs and PCDFs.

Materials and Methods

Model overview

In order to evaluate various exposure routes, the model should be able to treat material transport among environmental media (i.e., air, river water, seawater, soil particle, suspended solids and sediment). However, it is difficult to express all environmental compartments in only one numerical scheme because the timescale of physical processes such as transport and diffusion largely differs for each medium. Therefore, the model was designed to have four submodels consisting of atmosphere, soil, river and sea. The model overview is shown in Figures 1 and 2.

For air submodel, the gaussian plume and puff model was adopted as the dispersion process. It included the process of import (volatilization) and export (dry and wet deposition) to other media, dissipation to upper sky and degradation. The chemical concentrations in water, soil, suspended soil and sediment could be estimated by calculating the material balance between any adjoining grids. These submodels included the process of import (atmospheric deposition etc.), export (outflow to other media), and degradation.

The validation of the air submodel was conducted by comparing calculated and observed trichloroethylene and tetrachloroethylene concentrations in the atmosphere. The observed values were obtained from a monitoring survey conducted over several weeks in summer and winter in the Kanto region. The model is capable of estimating the long-term (e.g., monthly) average concentration distribution of chemicals over a wide flat area such as the Kanto plain[1,2].

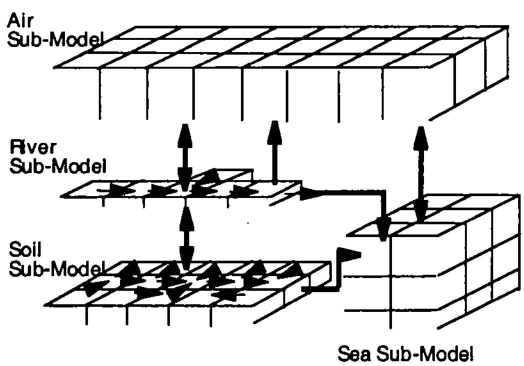

Fig. 1: Overview of gridded multmedia fate model

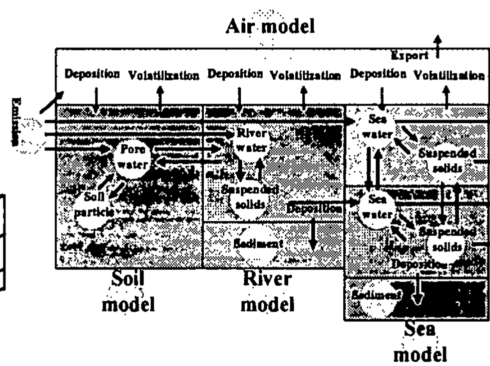

Fig. 2: Treated media in the model

Emission inventory

The gridded emission inventory of PCDDs/PCDFs in the analytical domain was compiled based on published monitoring data on exhaust gas[3], the amount of municipal solid waste (MSW)[4] and the location of each municipal incineration plant[5]. The monitoring data for the simulation were collected in 1997. The data would be changed in a later survey. Figure 3 shows the process flow to estimate PCDDs/PCDFs emission from MSW incineration plants. Sources other than MSW incineration (emission from industrial waste and medical waste incineration, industrial processes, exhaust gas of automobiles and impurities in PCP, etc.) were not estimated because they had many uncertainty factors. PCDDs/PCDFs emissions were converted to the emission of 2,3,7,8-TCDD equivalent (TEQ) using a toxicity equivalent factor (TEF) and environmental transport calculations were conducted for 2,3,7,8-TCDD. It was assumed that all dioxins/furans behave in the environment in the same manner as 2,3,7,8-TCDD. Figure 4 shows the emission map of PCDDs/PCDFs over the Kanto area.

Model calculation

The model was applied to the entire Kanto district (including the Tokyo metropolitan area). The area has more than 30 million inhabitants and more than 200 incineration plants. The analytical domain with a scale of 276 x 224 km was discretized into 40 x 60 grids with 5 km space increments. Automated Meteorological Data Acquisition System (AMeDAS) data were used in the simulation as meteorological input data (i.e., wind velocity and direction, and precipitation). Calculation was conducted for 20 years using meteorological data collected in 1993, and the final year calculation result was used to evaluate the long-term average concentration.

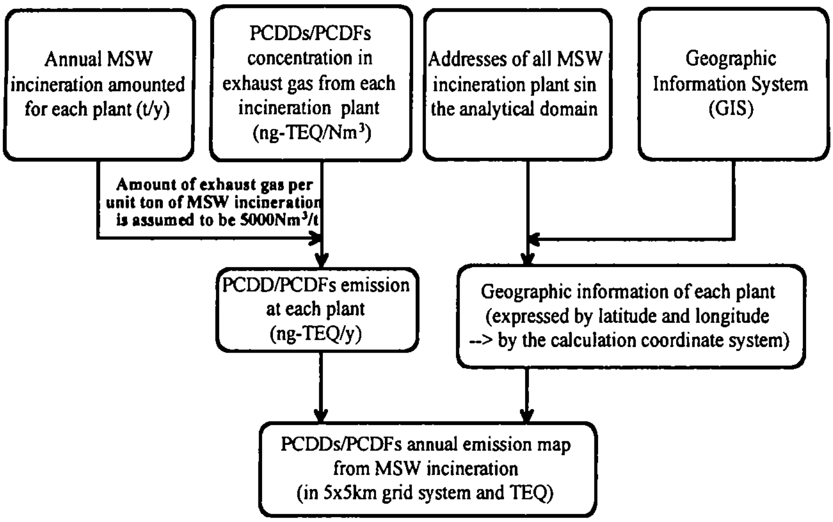

Fig. 3: Process flow to estimate PCDDs/PCDFs emission from MSW incineration plants

Results and Discussion

The spatial distribution of concentration of PCDDs/PCDFs in atmosphere is shown in Figure 5. Highly polluted areas include the middle of Kanto plain (around the border between Tokyo and Saitama Prefecture), the grid including Choshi City and the grid including Kimitsu City. The pollution in the middle of Kanto plain was due to emission and meteorological factors. Many incineration plants exist in this area. Although the concentration of dioxins in the stack flow was low in this area, the large amount of waste incinerated and the large number of incinerators made the concentration of dioxins high. As a meteorological factor, stagnation often occurs around this region, particularly during winter because of the influence of land and sea breeze. Both Choshi and Kimitsu Cities have incineration plants that emit high concentrations of dioxins. However, because the plants in these two cities were greatly improved in the next year's survey, the present concentration seems low.

The simulated maximum concentration in the atmosphere is 0.4 pg-TEQ/m^3, which is lower than the measured environmental levels in Japan[6] and is also lower than 0.8 pg-TEQ/m^3, the environmental quality standard in Japan. This result is acceptable since the simulation did not take sources other than municipal waste incineration into account.

The model can also be used to determine the concentration distribution in environmental media other than the atmosphere such as water and soil. Most simulated values were one or two orders of magnitude lower than the measured environmental levels in Japan. The simulation of soil and water has many uncertainties compared with the simulation of the atmosphere e.g., sources discharged directly to soil and water (impurities in agrochemicals), and physical and chemical parameters. Further investigation is therefore necessary.

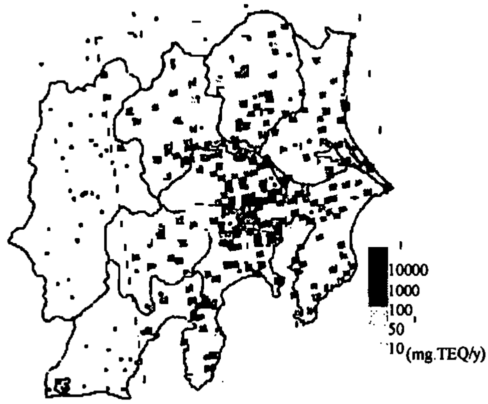

Fig. 4: PCDDs/PCDFs emission map over the Kanto area (dots represent municipal incineration plants)

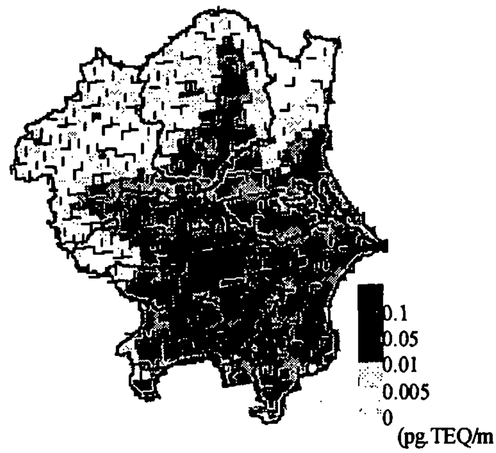

Fig. 5: Estimated PCDDs/PCDFs concentration in the atmosphere over the Kanto area

Conclusion

For the risk management of PCDDs/PCDFs, it is necessary to estimate the concentration of and exposure level to chemicals and to combine them with the population distribution or epidemiological survey data.

As a future approach, individual PCDDs/PCDFs congeners should be treated separately throughout the environmental fate and transport process. It is necessary to investigate the emission inventory and the environmental parameters of congeners, and to change the scheme of the advection and diffusion process.

References

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