DIOXIN CONTAMINATION FROM AGENT ORANGE AND INDUSTRY IN VIETNAM: ENVIRONMENTAL LEVELS AND SOURCES

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Introduction

Southern Vietnam has long been considered as well known region where Agent Orange was extensively sprayed in the Ranch Hand mission during the American War, resulting in severe environmental contamination over the past 3 decades (see review by Minh et al.[1]). The former US Army's airbases such as Bien Hoa, Da Nang and Phu Cat Airbase where former storage, loading and washing areas of the herbicides are located, have been considered as "hotspot" of dioxin contamination. Understanding the environmental levels and sources of the contamination is among key objectives of recent studies dealing with these contaminated hotspots in southern Vietnam.

In addition to the issue of Agent Orange, dioxin derives from unintentional production from thermal processes of many industries are also a matter of concern. There are 17 different industrial source categories defined in the Stockholm Convention on Persistent Organic Pollutants (POPs) (Article 5, Annex C), which have comparatively high formation and releases of dioxins and furans into the environment. While a number of extensive investigations have been conducted to deal with the issue of Agent Orange/Dioxin contamination in hotspots in Vietnam, very little information is available for dioxins and furans (PCDD/Fs) releases from industrial sources. Analysis of the samples from similar geographical locations but from different anticipated sources may provide insights into the characteristics of potential sources of PCDD/Fs.

In this study, we use Bien Hoa as a case study for examination of dioxin and furans in the Bien Hoa Airbase, a well known Agent Orange/Dioxin hotspot area, and samples from industrial sources to elucidate the magnitude of contamination and accumulation pattern of those originated from different sources. Results from other industrial sources categories were also included for comparison and further understand the baseline situation of the unintentional production releases of PCDD/Fs in Vietnam.

Materials and methods

Surface soil samples were collected from 0-30 cm within the contaminated area of the Bien Hoa Airbase. Excavated soil was homogenized and a fraction about 100g was placed in clean glass jar. The sediment samples (0-5cm) were collected by Erkman dredge in drainage ditch running from paper factory, chemical factory, metal smelting factory and a general drainage ditch which collect sewage from several other factories in Bien Hoa industry zone I. In addition, industrial samples such as soot samples in scrubber and bottom ash were also collected in stack and stove of municipal waste incinerators and wood processing factory. Bottom ash were also collected in a steel making and a paper production industrial enterprise for chemical analysis of PCDD/Fs. All samples were preserved in ice for transport and kept at -20^0C once arrived at laboratory until chemical analysis.

Soil and sediment samples were analyzed following EPA method 8280A with slight modifications. Briefly, 80g of each sample is extracted by Soxhlet apparatus using toluene solvent for 24 hours. The sample extract is concentrated, re-dissolved in hexane and cleaned up by concentrated H_2SO_4 acid and solutions of NaCl 5%, KOH 20%, dried by Na_2SO_4. The liquor is then further cleaned up by multilayer column which contains silica, silica impregnated in 40% of concentrated H_2SO_4, silica impregnated in 20% of KOH and Na_2SO_4. PCDDs/Fs fraction is separated from the AX21 activated carbon and the neutral Al_2O_3 columns. Verification of this

analytical procedure was done by UNEF inter-laboratory program[2]. Concentration of PCDD/Fs is the total concentrations of seventeen congeners using WHO-TEF.

Results and discussion

Dioxin levels in Agent Orange/Dioxin contaminated hotspots and industrial samples

Sediment samples collected from ponds and lakes in the contaminated hotspots in Bien Hoa Airbase contained elevated concentrations of PCDD/Fs, ranged from 73 - 4860 pg/g TEQ dry wt (mean: 1069 pg/g TEQ dry wt) (Fig. 1). PCDD/Fs concentrations in most of the sediment samples exceeded standard levels for dioxins in sediment such as 100 pg/g TEQ from ASTDR, Japan; and Vietnamese standard of 150 pg/g TEQ. TEQ concentrations of dioxins in soils within Bien Hoa Airbase varied largely in a range of 39 - 5129000 pg/g dry wt. Particularly, a soil sample excavated under a concrete basin contained extraodinary high TEQ level, the highest concentration ever found in Bien Hoa. This site may be used for collection of run-off water from the Ranch Hand operation, resulting in long term accumulation of dioxin contaminated herbicides in the basis. It should also be noted that PCDD/Fs concentations in both sediment and soil samples exhibited relatively large variability, suggesting complex pattern of dioxin contamination in Bien Hoa Airbase.

Figure 1 describes contamination pattern of PCDD/Fs in various kinds of samples collected from Agent Orange/Dioxin contaminated hotspots and from industrial processes. Our preliminary result indicates that samples from different kinds of waste incinerators (municipal, hazardous and industrial wastes) showed higher dioxin contamination than those from other industrial sources. In Vietnam, solid waste is commonly dumped in open dumping sites without prior incineration[3]. Only recently, few facilities at small scale were established in Bien Hoa City for incineration of certain solid wastes. All the investigated incinerators in this study have scrubber which condense and remove most of dioxin in emission. Samples of ash/soot trapped in scrubber and bottom ash of incinerators contained TEQ concentration of 878, 438 and 173 pg/g dry wt, respectively, which are comparable to incinerators in other contries[5]. Besides, sample of ash from oven of a wood processing factory had concentration of 4.6 ppt TEQ. Samples of sewage from other industrial activities of concern such as paper mill and chemical factory were also analyzed and the results showed that sewage sample from paper mill had 2.0 ppt TEQ while those from chemical factory has 3.1 ppt TEQs. Similarly, waste effluents collected from various stages of the bleaching process in a paper mill factory showed relatively low levels of dioxins (1.98 - 2.76 pg/g TEQ wet wt).

Among industrial samples (fly ash), PCDD/Fs concentrations in ash from waste incinerators were comparable to those from steel making industrial enterprise, while fly ash from paper production industry were 2 orders of magnitude lower. In general, samples in potential industrial sources showed much lower dioxin levels compared to those in Bien Hoa airbase which was contaminated by dioxin from herbicides such as Agent Orange, White Agent and Blue Agent.

Congener profile of dioxins and furans

To understand accumulation characteristic of dioxins and furans in samples collected from different sources, congener profiles are plotted on the basis on percentage contribution of homolog group to total TEQ. Figure 2 compares congener profile of soil and sediment samples from Bien Hoa airbase, which is considered as dioxin contaminated hotspots, and various samples such as ash, sewage and effluents and various industrial processes.

As a result, recent accumulation of dioxins in soils from Bien Hoa Airbase hotspots is still characterized by the predominant contribution of 2,3,7,8-TCDD. Similar result was observed in soils from other hotspots in Vietnam such as Da Nang and Phu Cat Airbase throughout investigations conducted during the past 3 decades. In sediment samples, proportion of 2,3,7,8-TCDD was lower than in soils, and OCDD was predominant congener. Sediment is an environmental matrix that represent long term accumulation of persistent organic subtances. The predominance of OCDD and relatively high TCDD proportion in sediment may reflect long term accumulation pattern of dioxins in contaminated hotspot area.

On the other hand, pattern of dioxin accmulation in industrial samples is dominated by OCDD, which is a typical pattern for environmental sinks[3]. It is interesting to note that in samples collected from industrial sources

categories which have potential for high formation and relases of dioxin such as waste incineration and steel making industry showed pattern resemble typical sources, with higher proportion of higher chlorinated dibenzofurans[4]. In general, homolog profiles of PCDD/Fs suggest that Agent Orange has remained as primary source of dioxin in Bien Hoa Airbase, while pattern of some industrial samples showed different characteristics with higher proportions of hexa-, hepta and octa- chlorinated dioxin and dibenzofurans congeners. Examination of homolog pattern thus may provide insights into the sources and status of formation of PCDD/Fs. Further studies are needed to provide a more detailed baseline situation of PCDD/Fs emission from industry in Vietnam.

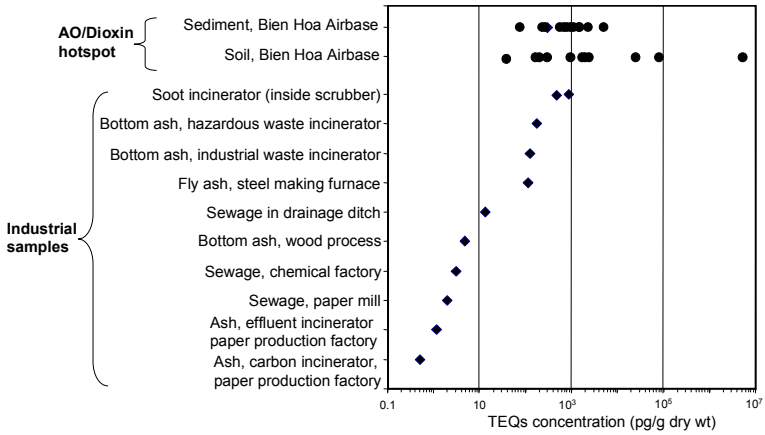

Fig. 1. TEQ concentrations of PCDD/Fs in various samples from Agent Orange/Dioxin contaminated hotspots and industrial sources in Vietnam

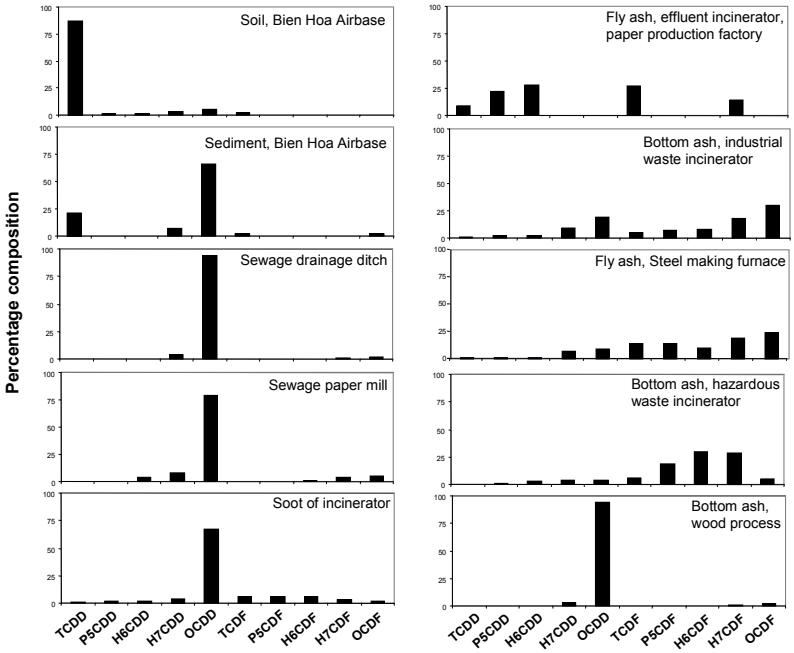

Fig. 2. Homolog profile PCDD/Fs in different samples samples from Agent Orange/Dioxin contaminated hotspots and industrial sources in Vietnam. Vertical bars represent the percentage of each homolog to total PCDD/Fs concentrations.

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