OFFICE OF NATIONAL STEERING COMMITTEE 33
MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT
"ENVIRONMENTAL REMEDIATION OF DIOXIN CONTAMINATED HOTSPOTS IN VIETNAM" PROJECT

DIOXIN CONTAMINATION IN VIETNAM

EMISSIONS FROM INDUSTRIES AND LEVELS IN THE ENVIRONMENT

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Hanoi, December 2014

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ABBREVIATIONS

Abbreviations	In English
3T	Temperature, Time and Turbulance
BAT	Best available technology
BEP	Best environmental practice
BCF	Bioconcentration factor
dl-PCBs	dioxin-like polychlorinated biphenyls
DRCs	Dioxins and related compounds
HRGC	High resolution gas chromatography
HRMS	High resolution mass spectrometry
I-TEF	International Toxic equivalent factor
LD_{50}	Median lethal dose
$logK_{ow}$	log octanol/water partition coefficient
Nm^3	Normal cubic meter
PCBs	Polychlorinated biphenyls
PCDDs	Polychlorinated dibenzo-p-dioxins
PCDFs	Polychlorinated dibenzo furans
POPs	Persistent Organic Pollutants
ppb	Part per billion
ppt	Part per trillion
QCVN	Vietnam regulation
TCVN	Vietnam standard
TEF	Toxic equivalent factor
TEQ	Toxic equivalent quantity
TDI	Tolerable daily intake
UPOPs	Unintentionally Persistent Organic Pollutants

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Foreword

Dioxins are products of fire and the most toxic compounds of all toxic chemicals discovered and produced by human beings.

Over the past decades, dioxins and their impacts on the environment and human are always the topic attracting attention and research of scientists, especially those from developed. Every year, in the summer, the International Symposium on Halogenated Persistent Organic Pollutants is organized with the participation of approximately 1,000 delegates from many countries. The Madrid 34th International Symposium on Halogenated Persistent Organic Pollutants was held in Spain in September, 2014 and the 35th International Symposium on Halogenated Persistent Organic Pollutants will be organized in Brazil in August 2015.

As the consequences of the herbicides used by the US during the Vietnam War from 1961 to 1972, Vietnam has become the focal point for those who are interested in dioxin problems. At least 366 kg of dioxins (Stellman, Nature 2004) from herbicides, mostly from Agent Orange, was sprayed in the South of Vietnam.

With participation of some organizations and individuals from the USA, Japan and Canada, etc. there have been a number of researches on dioxins and their impacts on humans and the environment in Vietnam. Although it has been made clear to some items of concern, there remain a lot of questions on dioxin issues due to the complexity of dioxins and the research conditions in Vietnam.

Researches on dioxins from herbicides not only help us to overcome the consequences but also create fundamental basis to study, control and minimize the impacts by dioxins from other sources.

For some of the above reasons, the report on "Dioxin Contamination in Vietnam: Emissions from Industries and Levels in the Environment" has been compiled by Office of National Steering Committee 33/Project "Environmental Remediation of Dioxin Contaminated Hotspots in Vietnam". Basic information about dioxin properties; dioxin emissions from wastes and waste treatment, paper industry, cement, metallurgy and brick production, etc. and dioxin residues in the soil, water and air environments in some regions in Vietnam; and dioxins in heavily contaminated areas have been mentioned in the report.

However, due to restricted technical conditions and cost for additional researches, a comprehensive research program on dioxin contamination in the environment and dioxin impact on the human in Vietnam has yet been carried out. It is also because of this that there has yet been a controlling and exposure prevention system for dioxins and dioxin related compounds from herbicides or other sources. Nevertheless, this report provides scientists, environmental management staff and other stakeholders a general picture on dioxins and dioxin contamination in Vietnam. Then, a glimpse of things required to be done in the coming time will be visualized.

In spite of great effort from the edition team, mistakes may be inevitable. Office of National Steering Committee 33/Project "Environmental Remediation of Dioxin Contaminated Hotspots in Vietnam" wishes to fulfil these in the follow-up reports.

We would also like to send our sincere thanks to organizations and individuals for their interests and support during the development of the report./.

Assoc. Prof. Dr. Le Ke Son - National Project Director

Part 1

GENERAL INFORMATION

1.1. The Environmental remediation of dioxin contaminated hotspots in Vietnam

In Vietnam, the main source of dioxin emission into the environment is related to airbases, which were used by the US army during the war to store, load and wash aircraft. The chemical inert characteristics and persistence in the environment of these chemicals, nearly half a century after the end of the war, means that the environmental contamination of Agent Orange/dioxin at the airbases and in the surrounding areas of Da Nang, Bien Hoa and Phu Cat remains serious. The Government of Vietnam, together with international organisations, is making an effort to remediate dioxin contamination in the soil in these hotspots, using modern technologies such as active landfill and thermal desorption destruction.

Dioxins and dioxin related compounds are categorised by the Stockholm Convention as unintentional persistent organic pollutants (UPOPs) from industrial activities. These toxic chemicals are formed and emitted into the environment because of activities such as burning (of domestic, industrial and medical waste, and biomass such as wood and straws); metallurgy (siderurgy, zinc recycling and aluminium manufacturing); production and use of organic chlorinated compounds (pesticides and paper pulp whitening) and sewage treatment activities. The more developed industry becomes, the more dioxins are formed and emitted into the environment, leading to a more complicated situation which is harder to control.

The *"Environmental remediation of dioxin contaminated hotspots in Vietnam"* project was approved and implemented by the Vietnam Ministry of Natural Resources and Environment, in cooperation with the United Nations Development Programme (UNDP) and the Global Environmental Facility. The project was kicked off in July 2010 and will be completed by 2014. The objectives of the project are to "minimize disruption of ecosystems and health risks for people from environmental releases of dioxin (TCDD) contaminated hotspot". Compounds to be controlled and limited from emission while targeted for complete remediation include PCDDs (polychlorinated dibenzo-p-dioxins), PCDFs (polychlorinated dibenzo furan) and PCBs (dioxin-like polychlorinated biphenyl).

The project aims to achieve three key outcomes: (1) dioxin in core hotspot areas contained and remediated; (2) land use on and around hotspots eliminates risks and contributes to environmental recovery; and (3) national regulations and institutional capacities strengthened.

1.2. Key objectives of the survey on dioxin emission from industries

The survey mainly contributes to the third outcome of the project – to contribute to enhance national regulations and institutional capacities in controlling emissions and remediation of dioxin contamination. Vietnam is being contaminated with dioxins from different sources. However, the country does not have sufficient regulations and standards to cope with this. The biggest hindrance for completing and supplementing regulations on dioxin emission values for different industries is the lack of a database on dioxin emission.

The objectives of the survey project were to design the survey and supervise and conduct surveys on dioxin emission into the air and water environment from industrial units. On-site sampling and dioxin analysis was carried out by a highly qualified technical laboratory in Vietnam. After completion of the surveys, sampling, analysis and processing of the analysis data, dioxin emission levels from industrial units and the dioxin level in the environment was calculated. This information will be a reliable basis for the development of effective legal instruments to control the environment quality.

1.3. The report on "Dioxin Contamination in Vietnam: Emissions from Industries and Levels in the Environment"

This report was developed based on data collection and a comprehensive assessment of dioxins and related compounds (DRCs) contamination in the environment. Data sources used as references and for the development of this report include the national survey data on dioxin from the Ministry of Natural Resources and Environment, dioxin analysis data from the dioxin laboratory under the Vietnam Environment Administration, dioxin analysis data from the Vietnam-Russia Tropical Center, Ministry of Defence and dioxin survey and analysis data from other national and international researchers.

The report provides comprehensive and up-to-date information regarding the status and distribution of DRCs in the environment of Vietnam. The report not only reflects on the status of dioxin contamination in Vietnam, but is also an important basis to propose recommendations to complete national regulations on dioxin thresholds in the environment, with the long-term objective of controlling and mitigating the emission of dioxins and completely eliminating dioxins from the environment. In order to develop suitable regulations and standards on dioxin thresholds in the environment, which the Ministry of Natural Resources and Environment and other organisations are making an effort to develop, an assessment report like this is essential.

The report comprises five main parts as follows:

(1) **Introduction to dioxins and its related compounds:** This part provides an overall introduction to dioxins, furans and dioxin-like PCBs, including definitions, structures, physical features, bio-chemical features, the existence and transformation in the environment, the toxic impact of this compound on the environment, eco-system and people, and mechanisms for formation of dioxins.

(2) **Introduction of a dioxin analysis method:** This part introduces the principles in trace amount and ultra-trace of DRCs, using modern analysis and equipment.

(3) **The current regulations on dioxin concentration in the environment:** An overview of regulations and standards for dioxins in the environment in Vietnam is provided, as well as references and introductions to dioxin thresholds in the environment issued by other countries and organisations.

(4) **Dioxin contamination in the environment in Vietnam:** Residue concentrations of dioxins related compounds in different media such as industrial samples (flue gas, ash) and dioxin contamination **in Vietnam will be assessed and compared to** other studies in the world.

(5) **Conclusions and recommendations**: Based on the dioxin contamination assessment and available regulations on dioxin thresholds, a series of recommendations on developing and completing regulations, standards and rules on dioxin thresholds in the environment in Vietnam is provided.

Part 2

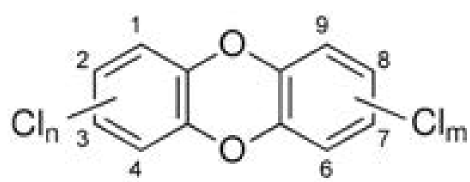
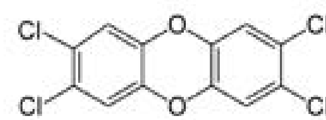
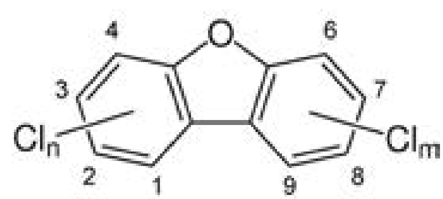
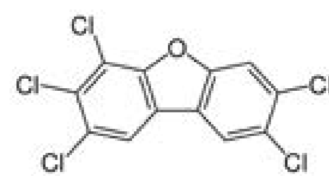
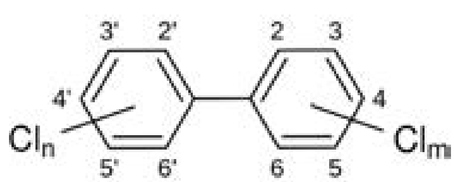
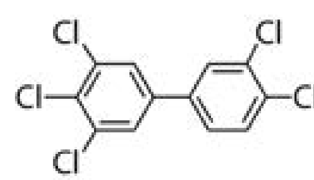
INTRODUCTION TO DIOXINS AND DIOXIN RELATED COMPOUNDS

2.1. Definition and composition of dioxins and related compounds

Dioxins, as they are commonly called, are chemical compounds of chlorinated dibenzo-*p*-dioxins (CDDs) and chlorinated dibenzofurans (CDFs). Meanwhile, the term "dioxins and related compounds (DRCs)" are chemical compounds of chlorinated dibenzo-*p*-dioxins (CDDs), chlorinated dibenzofurans (CDFs), and coplanar polychlorinated biphenyls (PCBs). Coplanar PCBs congeners mimic the chemical and physical properties of dioxins and have similar toxic effects. Figs 1.1 show the general structure of PCDDs, PCDFs and two toxic dioxin-like PCBs.

The general structures of DRCs are shown in the below Table 2.1:

Table 2.1. Chemical structures of dioxins and DRCs

No.	Group	General structures	Typical formula
1	**Dioxins**		 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)
2	**Furans**		 2,3,4,7,8-pentachlorodibenzofuran (2,3,4,7,8-PeCDF)
3	**PCBs**		 3,3',4,4',5-pentachlorobiphenyl (PCB 126)

Dioxins include 75 individual compounds, which are classified into eight groups subject to the number of chlorine atoms in the molecule ranging from 1 to 8. Furans include 135 individual compounds, which are classified into 8 groups similar to dioxins. PCBs include 209 congeners, which are classified into 10 groups with the number of chlorine atoms ranging from 1 to 10. Of which, only homogenous PCBs, that means PCBs do not have or only have one chlorine atom located at 2,2',6,6', will have the structures and toxication mechanism similar to dioxins.

The number of dioxins, furans, and PCBs in each sub-group classified according to the number of chlorine atoms is shown in Table 2.2:

Table 2.2. Homologues and congeners of PCDDs, PCDFs, and PCBs

No. Of chlorine atom substitution	Group	Number of compounds		
		PCBs	*Dioxins*	*Furans*
1	Monochloro-	3	2	4
2	Dichloro-	12	10	16
3	Trichloro-	24	14	28
4	Tetrachloro-	42	22	38
5	Pentachloro-	46	14	28
6	Hexachloro-	42	10	16
7	Heptachloro-	24	2	4
8	Octachloro-	12	1	1
9	Nonachloro-	3		
10	Decachloro-	1		
Total		**209**	**75**	**135**

2.2. Physical and biological properties of dioxins, the existence and transformation of dioxins and DRCs in the environment

Dioxins are the colorless solid or crystals in the pure state. Dioxins have high melting and boiling temperature and thus they are persistent in natural environment. For the most toxic substance in this group, which is 2,3,7,8-TCDD, some temperature values provided below show the thermal persistence of dioxins. The melting temperature is 305-306^{0}C, the boiling temperature 412.2^{0}C, and generation at the temperature range of 750-900^{0}C. Even at 1,200^{0}C, the dioxin decomposition process is still reversible. Dioxins are completely decomposed at 1,200-1,400^{0}C or higher. Dioxins have low evaporating pressure and Henry constant.

Dioxins are compounds with very low bias and logarit value for partition coefficient between two phases is n-octanol and water ($logK_{ow}$) which ranges from 6 to 9. In which, 2,3,7,8-TCDD has $logK_{ow}$ = 6.4. As dioxin's polarization is very low, they mostly do not melt in water. Dioxin's dissolubility reduces when their molecule mass increases.

Dioxins better dissolve in organic solutions such as 1,2-dichlorobenzene, chlorobenzen, chloroform, and benzene, etc. and these especially well dissolve in lipid. The lipophilic and hydrophobic properties of dioxins are closely related to their persistence and distribution in organisms, the human body and the natural environment. Dioxins' partition coefficient in different media as compared to water is very high. For instance, the dioxin partition coefficient between soil/water is 23,000 and between biota/water is 11,000.

Furans have similar physical properties to dioxins. They are solid under normal temperature, the melting and boiling temperatures are high. The evaporating pressure and Henry Law's constant are low, the $logK_{ow}$ value is high and thus furans are not likely to dissolve in water and much better dissolve in lipid.

Some basic physical constants of dioxins and furans are shown in Table 2.3:

Table 2.3. Typical physico-chemical properties of dioxins and furans at 25⁰C

No.	Homologue group	Vapour pressure (mmHg)	$logK_{ow}$	Solubility ($mg.l^{-1}$)	Henry's constant ($L.atm.mol^{-1}$)
Dioxins					
1	Tetra-CDD	$8.1.10^{-7}$	64	$3.5.10^{-4}$	$1.35.10^{-3}$
2	Penta-CDD	$7.3.10^{-10}$	6.6	$1.2.10^{-4}$	$1.07.10^{-4}$
3	Hexa-CDD	$5.9.10^{-11}$	7.3	$4.4.10^{-6}$	$1.83.10^{-3}$
4	Hepta-CDD	$3.2.10^{-11}$	8.0	$2.4.10^{-6}$	$5.14.10^{-4}$
5	Octa-CDD	$8,3.10^{-13}$	8.2	$7.4.10^{-8}$	$2.76.10^{-4}$
Furans					
6	Tetra-CDF	$2.5.10^{-8}$	6.2	$4.2.10^{-4}$	$6.06.10^{-4}$
7	Penta-CDF	$2.7.10^{-9}$	6.4	$2.4.10^{-4}$	$2.04.10^{-4}$
8	Hexa-CDF	$2.8.10^{-10}$	7.0	$1.3.10^{-5}$	$5.87.10^{-4}$
9	Hepta-CDF	$9.9.10^{-11}$	7.9	$1.4.10^{-6}$	$5.76.10^{-4}$
10	Octa-CDF	$3.8.10^{-12}$	8.8	$1.4.10^{-6}$	$4.04.10^{-5}$

Pure PCBs exist in the form of clear crystal while commercial PCBs are compounds of different isomers which are in form of light or dark yellow liquid. It has high viscosity, and is heavier than water; the density is from 1.182 to 1.566 g/ml, low electrical conductivity, and high thermal conductivity. PCBs have relatively high flash point at about of 170-380⁰C. PCBs in general have low vapour pressure and Henry's constant, high $logK_{ow}$. PCBs are not likely to dissolve in water (below 1 ng/l), and better melt in organic solutions and lipid.

2.3. Toxicity of dioxins and related compounds

Dioxin is one of the most toxic compounds ever known. Of the DRCs group, 2,3,7,8-TCDD is the most toxic. It causes cancer in humans (soft tissue sarcoma, prostate cancer, respiratory cancers such as lung cancer, bronchus cancer, trachea cancer and throat or larynx cancer). In addition, it also causes a series of dangerous diseases such as skin hyperpigmentation, diabetes, multiple myeloma, malignant lymphomas, and disorders of the peripheral nervous system, which can lead to fatal cases. More worryingly, 2,3,7,8-TCDD also causes reproductive abnormalities in both men and women, causing birth defects or birth abnormalities. 2,3,7,8-TCDD is classified by the International Agency for Research on Cancer as group 1, meaning the group of substances that causes fatal cases of cancer in human beings. The dioxin toxicity is shown via the median lethal dose, LD_{50}, which means the amount of toxic substance per unit of body weight which would kill 50 percent of the members of a tested population. The value of LD_{50} depends on the toxicity of the substance, species features and the exposure pathways. In general, the lower LD_{50} is the more toxic it becomes. LD_{50} is normally studied on animals and transference factors are then used to estimate it for humans. The LD_{50} of 2,3,7,8-TCDD for some animals is shown in Table 2.4

Table 2.4. LD_{50} of 2,3,7,8-TCDD and other compounds in various species

No.	Species	LD_{50} (µg/kg)	No.	Species	LD_{50} (µg/kg)
1	Hamster	0.5 – 2.1	6	Dogs	30 - 300
2	Rats	22 - 100	7	Chicken	25 - 50
3	Mice	112 - 2570	8	Monkeys	70
4	Cat	115	9	Humans	60 - 70
5	Rabbits	10 - 275			

Dioxins and furans that contain from four chlorine atoms upward, replacing the locations of 2,3,7,8 of the dibenzo-p-dioxin molecule and PCBs containing four to seven chlorine atoms in which none or one chlorine atom replaces the locations of 2,2',6,6' of the biphenyl molecule (referred to as non-ortho PCBs and mono-ortho PCBs) will also have the same toxification mechanism as 2,3,7,8-TCDD but with less toxicity. The relativity of toxicity of DRCs is shown in a value called the Toxic Equivalent Factor (TEF). The TEF value of 2,3,7,8-TCDD is regulated as one. The TEF value for seven dioxin congeners, 10 furan congeners and 12 PCB congeners are uniplanar and are shown in Table 2.5 below, subject to international-TEF (I-TEF) and World Health Organization-TEF (WHO-TEF) standards.

Table 2.5. The equivalent toxicity factor of dioxins, furans and dl-PCBs

TT	Substance	I-TEF	WHO-TEF
	Dioxins		
1	2,3,7,8-TetraCDD	1	1
2	1,2,3,7,8-PentaCDD	1	1
3	1,2,3,4,7,8-HexaCDD	0.1	0.1
4	1,2,3,6,7,8-HexaCDD	0.1	0.1
5	1,2,3,7,8,9-HexaCDD	0.1	0.1
6	1,2,3,4,6,7,8-HeptaCDD	0.01	0.01
7	OctaCDD	0.001	0.0001
	Furans		
8	2,3,7,8-TetraCDF	0.1	0.1
9	1,2,3,7,8-PentaCDF	0.05	0.05
10	2,3,4,7,8-PentaCDF	0.5	0.5
11	1,2,3,4,7,8-HexaCDF	0.1	0.1
12	1,2,3,6,7,8-HexaCDF	0.1	0.1
13	1,2,3,7,8,9-HexaCDF	0.1	0.1

***Table 2.5. The equivalent toxicity factor of dioxins, furans and dl-PCBs** (cont.)*

TT	Substance	I-TEF	WHO-TEF
14	2,3,4,6,7,8-HexaCDF	0.1	0.1
15	1,2,3,4,6,7,8-HeptaCDF	0.01	0.01
16	1,2,3,4,7,8,9-HeptaCDF	0.01	0.01
17	OctaCDF	0.001	0.0001
dl-PCBs			
18	3,3',4,4'-TetraCB (PCB 77)	-	0.0001
19	3,4,4',5-TetraCB (PCB 81)	-	0.0001
20	3,3',4,4',5-PentaCB (PCB 126)	-	0.1
21	3,3',4,4',5,5'-HexaCB (PCB 169)	-	0.01
22	2,3,3',4,4'-PentaCB (PCB 105)	-	0.0001
23	2,3,4,4',5-PentaCB (PCB 114)	-	0.0005
24	2,3',4,4',5-PentaCB (PCB 118)	-	0.0001
25	2',3,4,4',5-PentaCB (PCB 123)	-	0.0001
26	2,3,3',4,4',5-HexaCB (PCB 156)	-	0.0005
27	2,3,3',4,4',5'-HexaCB (PCB 157)	-	0.0005
28	2,3',4,4',5,5'-HexaCB (PCB 167)	-	0.00001
29	2,3,3',4,4',5,5'-HexaCB (PCB 189)	-	0.0001

From the TEF value shown in the above table, when the toxicity of DRCs is studied, the Toxic Equivalent Quantity (TEQ) is considered for each compound. Normally, this will be shown in the concentration form of the substance and will be multiplied by respective TEF value. Hence, with some of the compounds the higher concentrations and TEF value there are, the higher the dioxin level is. After the content of each congener, the value of the total TEQs calculated will fully reflect the contamination level and becomes an important value to assess the toxicity of DRCs.

2.4. Mechanism for the formation of dioxins and industrial activities with the possibility to produce dioxins

2.4.1. Mechanism on dioxin formation

2.4.1.1. Formation of dioxins during combustion and thermal processes

Nowadays, combustion and thermal processes are considered as dioxin emitters and have attracted a lot of attention from scientists. Dioxins and furans are substances which are formed unintentionally as a by-product of some chemical reactions, mainly combustion processes with the presence of carbon, oxygen, hydrogen and chlorine. Parameters of the combustion process such as type of fuel used, waste to be destroyed, technology used, efficiency, contamination control mechanism and waste remediation technology after combustion are important criteria, which decide the amount of dioxin emission. Factors influencing the formation of dioxins during combustion and thermal processes are shown in Table 2.6.

Table 2.6. Factors influencing the formation of dioxins and furans during thermal processes

No.	Factors	Impacts
1	Technologies	The formation of dioxins/furans may occur in unfinished/incomplete combustion or due to weak control of the combustion process or pollution controlling equipment.
2	Temperatures	The formation of dioxins/furans in the combustion chamber or in the pollution controlling equipment is recognised within the temperature range of 200^{0}C to 650^{0}C. The range in which dioxins/furans form the most is 200^{0}C-450^{0}C, especially at a temperature of 300^{0}C.
3	Metals	Copper, iron, aluminium, chrome and manganese are catalysts for the formation of dioxins/furans.
4	Sulphur and nitrogen	Substances carrying/containing sulphur and nitrogen restrict the formation of dioxins/furans while possibly leading to the formation of other toxic by-products.
5	Chlorine	Chlorine in its organic, inorganic or elementary form. The existence of chlorine in fly ash or in elementary form in the gas phase plays an important role in accelerating the formation of dioxins/furans.

Dioxins/furans are formed during the combustion and thermal process through the following mechanisms:

- *Incomplete destruction of dioxin compounds.* If the incineration is not efficient and the technology and contamination control system weak, the required conditions for complete incineration are not ensured, including the burning temperature, duration and oxygen mixing (temperature, time and turbulence, the 3Ts), and the dioxins/furans which has not yet been destroyed will be emitted to the flue gas of the incinerators.
- *The formation of dioxins in the incinerator through chemical reactions between pre-cursor compounds.* The pre-cursor compounds with aromatic hydrocarbons and chlorine such as chlorobenzenes, chlorophenols and chlorobiphenyls. If the incineration is not complete due to the lack of 3T conditions, the precursors as mentioned will be formed as by products of the incineration process. Under such conditions, the existence of chlorine will lead to the reaction of the pre-cursors with chlorine to form dioxins and furans.
- *The formation of dioxins due to de novo synthesis.* Dioxins were formed by oxidation and transformation of macromolecular carbon structures (such as carbon, charcoal, and soot) into the aromatic compounds with chlorine and hydrogene. Factors affecting the formation of dioxin subject to this mechanism include: (1) a temperature of 250 - 400^{0}C. Yet at 1,000^{0}C, the de novo synthesis reaction may still take place; (2) carbon sources from fly ash in flue gas; (3) oxygene in the flue gas is the inevitable condition for the formation of dioxins/furans subject to this mechanism, the higher the oxygene content is, the easier it is to form dioxins/furans; (4) hydrogene and chlorine are mainly from inorganic compounds bind with solid particles of carbon but not from the gas form compounds such as HCl, Cl_2 in the flue gas; (5) ion Cu^{2+} is a strong catalyst for this process; and (6) the factors that prevent or restrain this process is the quick cooling of the flue gas and the appearance of some catalysts.

2.4.1.2. Formation of dioxins during industrial production/manufacturing process

Dioxins/furans can be formed during different industrial manufacturing processes, such as chemical, cement, metallurgy or recycling of metals, paper pulp and textile production. Below are some mechanisms whereby dioxins formation can happen.

- *Chemical production industry:* During the production and usage of chemicals, the formation of dioxins/furans takes place when one of the following conditions happens: (1) using chemicals with chlorine radicals or with the possibility for formation of chlorine radicals; (2) increase of temperature (>150^{0}C); (3) using an alkali environment (especially in cleaning); (4) using metal as an additive; (5) using ultraviolet (UV) irradiation. One typical example is the production of 2,4,5-T from original material of 1,2,4,5-tetrachlorobenzen, which if not produced under strict conditions will produce a by-product of 2,3,7,8-TCDD, a toxic compound part of the dioxin group.
- *Cement production industry:* In the cement production industry, apart from normal materials used for burning in the cement kilns such as oil and coke coal, other materials such as waste oil, tyres, organic liquid mixtures, plastic, and humus and saw dust will also be used. The burning of the above organic materials at a temperature of 200^{0}C-450^{0}C is not enough for a complete burning reaction together with suitable oxygen and the chlorination agents during the operation of the kiln; it will become significant dioxins discharge. With coal is used as fuel for the kiln, this can combine with aromatic karyoplast compounds such as benzene and phenol, thus forming chlorination loops when chlorine exists during the process. These chlorination structures can encourage the formation of dioxins on the surface of carbon particles.
- *Metallurgy industry:* Dioxins/furans can be formed during ore dressing and caking, as a process in steel recycling, lead melting, producing magnesium dioxide, production of titanium dioxide and metal recycling, as the existence of metal ions with multi atomicities play the role of an catalyst for the dioxin formation process.
- *Textile and garment industry:* the dioxins/furans formation in the textile and garment industry is relatively complicated. Most of dyes contain organic chemicals with relatively persistent functional groups, and chlorine is often applied at the final step of this production. The persistent and volatile organic hydrocarbons, mainly benzene, formed during the process react with chlorine on the metal surface at the temperature from 100 – 140^{0}C to release dioxins. Research results showed that the level of dioxins from the garment and textile industry is low; however, this source of dioxins should be putted into account because of the considerable number of the available garment and textile factories.
- *Paper and paper pulp industry:* Chlorophenols, which are used in the pulp and paper bleaching processes, are considered as dioxin precursors under certain conditions; dioxins can be formed and discharged into the environment.

2.4.2. Potential industrial activities for the formation and releases of DRC

2.4.2.1. Activities with combustion and thermal processes

Thermal processes especially combustion processes are considered as the main sources of dioxins/furans emission into the environment. Dioxins/furans are formed unintentionally during incomplete combustion of various subjects such as fuel, urban solid wastes, medical wastes, hazardous wastes, culvert sludge and biomass, as well as in activities using high temperature such as cement burning, metallurgy and metal recycling, etc. In addition, dioxins/furans are formed from an incomplete controlling combustion process and especially uncontrolled burning processes such as forest fires and house fires in residential areas, and spontaneous and smouldering burnings at dumpsites or landfills. Thermal or burning activities with a possibility to produce dioxins are listed in Table 2.7.

Table 2.7. Dioxin emission sources from combustion activities

No.	Production process	Characteristics
1	Urban waste burning	Outdated technologies that are not equipped with flue gas controlling equipment
2	Industrial waste burning	Outdated technologies that are not equipped with flue gas controlling equipment
3	Hazardous waste burning	Outdated technologies that are not equipped with flue gas controlling equipment
4	Sludge burning	Old incinerator, not equipped with flue gas controlling equipment, manual operating incinerator
5	Hospital waste burning	Old incinerator, not equipped with flue gas controlling equipment, manual operating incinerator
6	Burning of sacked wood	Wood that has been processed with chlorinated organic compounds
7	Cremators and animal cremators	Outdated technologies that are not equipped with flue gas controlling equipment
8	Dumpsite flue gas, biogas	Not controlling flue gas contamination
9	Coal burning	Burning of brown, lignite and peat coal
10	Production of coke coal	Using lignite and peat coal
11	Biomass burning	Uncontrolled; burning the remaining of forest, bush and straw, etc.
12	Fires from accidents	Uncontrolled; fire accidents at industrial parks, storehouses and residential houses, etc.
13	Smouldering burning in dumpsites	Uncontrolled process
14	PVC burning	Halogenated plastic
15	Iron burning in high kiln	Circulated ash and dirt
16	Preliminary melting of copper	Ion Cu^{2+} has a catalystic role in the formation of dioxins
17	Recycling of scraped metals	Burning of electrical wires, recollecting metal from ash
18	Cement kilns	Using halogenated hazardous waste as fuel
19	Production of substances such as lime, ceramics, glass, bricks and tiles, etc.	Small scale without flue gas and dust controlling system
20	Bitumen/tar melting	Tar melting and spraying processes conducted at high temperature without controlling flue gas
21	Power industry	Power plants using coal, oil, gas and biomass, etc.
22	Transportation	Lead-added fuel used for combustion engine.

2.4.2.2. Industrial production/manufacturing activities

Dioxins/furans can be formed as by-products of various industrial activities, especially production activities using high temperature and organic chlorinated chemicals. There are no clear boundaries in the classification of dioxin formation from thermal using category or production activities. These two activities both unintentionally produce dioxins/furans in complicated mechanisms. However, industrial activities normally relate to the formation or use of organic chlorinated compounds while thermal activities mainly relate to incomplete combustion of fuel and materials. Some industrial production/manufacturing activities with the possibility to produce dioxins are listed in Table 2.8.

Table 2.8. Dioxin emission sources from industrial activities

No.	Production process	Characteristics
1	Chemical production	Chlorinated organic compounds are synthesized for different purposes. These chlorinated organic compounds can be precursor substances of dioxins such as chlorinated benzene, chlorophenol, PCBs, herbicides (2,4-D and 2,4,5-T), chlorinated organic pesticides (DDT, DDE and HCHs); chlorinated lipids (dicloetylen, vinyl clorua and polyvinyl clorua).
2	Paper and paper pulp production	Chemicals used during paper pulp bleaching such as chlorophenols used during the heating stage can possibly form dioxins.
3	Garment and textile industry	Using organic solutions such as benzene, and especially dyes originated from organic chlorine.
4	Leather industry	Using chlorinated organic solutions and compounds during material processing, leather bating, and colouring agents/pigments during the finishing process.
5	Wood industry	Chemicals used during steeping, soaking and treating of wood materials and paint solutions, etc.
6	Production industry from mineral materials	High temperature and fuel burned during cement, pottery, ceramics, brick, tile and glass production processes.
7	Metallurgy	High temperature, input materials, metal ions as catalysts for the formation of dioxins in metallurgy and recycling of metals and alloys such as steel, copper, aluminium, lead and zinc, etc.

2.5. Analytical methods for determination of DRC

2.5.1. Sampling methods

2.5.1.1. Industrial emission sampling

As dioxins are formed mainly from the combustion process and related to some special industries such as waste incineration, metallurgy and cement production, flue gas is the subject of interest. Dioxins exist in flue gas in both phases namely the particle phase and gas phase and thus, in order to collect representative samples, both phases should be collected and analysed. There are several methods of industrial flue gas sampling such as Method 23 introduced by the US Environment Protection Agency (US EPA) which is currently adopted in the USA, Canada and many other countries in the world; Method EN 13284:2001 introduced by the European Union (EU) and mainly adopted in Europe, and Method JIS K0311:2008 introduced by Japan and mainly adopted in Japan. Of the above methods, Method 23 is becoming the standard method of many countries.

The solid waste collected and analysed includes bottom slagged ash after each combustion batch, fly ash samples, input material samples, sludge samples, and soil and sediment samples collected in the production and manufacturing areas. Water samples are mainly collected from wastewater from scrubber towers.

2.5.1.2. Environmental sampling

For soil and sediment samples, the sampling procedures adhere to Vietnam standards. The soil sampling procedure adheres to Vietnam standard TCVN 7538-2:2005 on soil quality and sampling. The sediment sampling procedure adheres to TCVN 6663-13:2000 on water quality and sampling, in particular part 13 on guidance on sludge, sludge from wastewater and related sludge sampling, and TCVN 6663-15:2004 on guidance on preservation and processing of sludge and sediment samples.

2.5.2. Analysis methods

The ultra-trace analysis (at part per billion (ppb) and even at part per trillion (ppt)) of DRCs for complicated base samples is a difficult and costly job which requires standardised methods, modern equipment, specialised chemicals, purified solutions and also the capacity of laboratories. US EPA has announced standard methods for DRCs analysis, including Method 1613 (for dioxins and furans) and Method 1668 (for dl-PCBs).

The DRCs criteria are analysed using high definition chromatography and low definition mass spectrum, which are quantified and qualified using an isotope dilution method and internal standard method. This is the most preeminent method at the moment regarding the sensitivity, accuracy and speed of analysis at the same time of dozens of compounds with similar chemical features. This method uses standard isotopic mass substances ($^{13}C_{12}$-PCDD/PCDF/dl-PCBs). These are substances with similar characteristics to the analysed substances, yet are not available in nature. When they are added to the samples throughout the sampling, sample processing as well as injecting samples into the analysis equipment, they will control the sample loss at each phase of the procedure, ensuring that the analysis results are correct.

For trace amount analysis in complicated sample backgrounds, techniques such as analysis extraction and separation from the sample background, extraction solution cleaning and sample enriching during analysis play a vital role. If these techniques are adopted well, the analysis effect will be improved through criteria such as complete extraction and selection of analysed substances from the sample base, reduction of the basic signals and lowering of the detection limit. US EPA has introduced the standard method set for sample preparation (3500 Series Methods) and cleansing of extraction solution (3600 Series Methods) to analyse organic criteria using the spectrum method. The methods normally used for DRCs extraction from the solid sample base are soxhlet extraction, automatic soxhlet extraction, supercritical liquid extraction or accelerated solvent extraction. For the sample base they are liquid extraction and solid phase extraction. Then the solution is continuously purified in the uncased column system or solid phase extraction column containing specialised absorbance, such as multilayer silica gel, alumina column, and activated carbon or cleansed via a solid phase extraction column and then cleaned up using suitable solutions. Sample enrichment and condensing techniques, such as vacuum rotating condensing and a solution removing condensing using light nitrogen flow, is also used during the analysis process.

Part 3
REGULATIONS AND STANDARDS ON DIOXIN THRESHOLD LEVELS IN INDUSTRIES AND IN THE ENVIRONMENT

3.1. Regulations and standards on dioxins in Vietnam

The national technical regulation system on environment includes regulations on the ambient environment quality and waste standards (the emission thresholds into different parts of the environment such as air, surface water, and groundwater, seawater at shore, soil, sediment, bio-organisms and solid waste). Together with regulations on thresholds of substance concentrations, there are standards for accompanying measuring methods.

Some national standards (TCVN) on dioxins issued by the Ministry of Science and Technology include TCVN 8183:2009 on dioxin thresholds in soil and sediment; TCVN 7556-1:2005 on health care solid waste incinerators, the determination of the mass concentration of PCDDs/PCDFs and sampling; TCVN 7556-2:2005 on health care solid waste incinerators, the determination of the mass concentration of PCDDs/PCDFs and extraction and clean-up; and TCVN 7556-3:2005 on health care solid waste incinerators, the determination of the mass concentration of PCDDs/PCDFs, and identification and quantification. Sampling methods and dioxin analysis methods in other sample parts of the environment mainly use the standardised methods introduced by organisations such as US EPA.

Some national technical regulations (QCVN) on dioxins issued by the Ministry of Natural Resources and Environment are:

QCVN 07:2009/BTNMT: National Technical Regulation on Hazardous Waste Thresholds, issued together with Circular No. 25/2009/TT-BTNMT, with effect from January 2010.

QCVN 41:2011/BTNMT: National Technical Regulation on Co-processing of Hazardous Waste in Cement Kilns, issued together with Circular No. 44/2011/TT-BTNMT, with effect from March 2012.

QCVN 45:2012/BTNMT: National Technical Regulation on Allowed Limits of Dioxins in Soils, issued together with Circular No. 13/2012/TT-BTNMT, with effect from December 2012.

QCVN 02:2012/BTNMT: National Technical Regulation on Solid Medical Waste Incinerators, issued together with Circular No. 27/2012/TT-BTNMT, with effect from March 2013.

QCVN 30:2012/BTNMT: National Technical Regulation on Industrial Waste Incinerators, issued together with Circular No. 27/2012/TT-BTNMT, with effect from March 2013.

QCVN 51:2013/BTNMT: National Technical Regulation on Emissions from the Steel Industry, issued together with Circular No. 32/2013/TT-BTNMT, with effect from January 2014.

DRC thresholds for some of the subjects pursuant to Vietnamese regulations (QCVN) are shown in Table 3.9.

Table 3.9. DRC thresholds for some sections of the environmental media pursuant to QCVN

QCVN 07:2009/BTNMT: Thresholds for hazardous wastes			
No.	**Parameters**	**Baseline absolute content (ppm)**	**Extraction concentration (mg/l)**
1	PCB	5	
2	2,3,7,8-TCDD	0.1	0.005
3	1,2,3,7,8-PeCDD	0.2	0.01
4	1,2,3,4,7,8-HxCDD	1	0.05
5	1,2,3,6,7,8-HxCDD	1	0.05
6	Total dioxin (tetra, penta, hexa)	0.1	0.005
7	TCDF	1	0.05
8	1,2,3,7,8-PeCDF	2	0.1
9	2,3,4,7,8-PeCDF	0.2	0.01

Table 3.9. DRC thresholds for some sections of the environmental media pursuant to QCVN *(cont.)*

10	1,2,3,4,7,8-HxCDF	1	0.05
11	1,2,3,6,7,8-HxCDF	1	0.05
12	Total furans (tetra, penta, hexa)	0.2	0.01

QCVN 41:2011/BTNMT: National Technical Regulation on Co-processing of Hazardous Waste in Cement Kilns

No.	Parameters	Maximum allowable concentration (ngTEQ/Nm^3)
1	Total dioxins/furans	0.6

QCVN 45:2012/BTNMT: National Technical Regulation on Allowed Limits of Dioxins in Soils

No.	Land types	Maximum acceptable level of dioxin (ng/kg TEQ subject to dry weight)
1	Annual crop	40
2	Forestry land, land for perennial plants	100
3	Rural land	120
4	Urban land	300
5	Land for recreation purpose	600
6	Land for commercial purpose	1200
7	Land for industrial purpose	1200

QCVN 02:2012/BTNMT: National Technical Regulation on Solid Medical Waste Incinerators

No.	Subjects	Total PCDD/PCDF (ng TEQ/Nm^3)
1	Flue gas from medical waste incinerators at medical waste treatment plants as planned (not located at the healthcare complex precinct)	2.3
2	Flue gas from medical waste incinerators at healthcare complex precinct	2.3

QCVN 30:2012/BTNMT: National Technical Regulation on Industrial Waste Incinerators

No.	Subjects	Total PCDD/PCDF (ng TEQ/Nm^3)	
		A	B
1	Incinerator capacity < 300 kg/h	2.3	1.2
2	Incinerator capacity > 300 kg/h	1.2	0.6

A: Industrial waste incinerator until 31/12/2014; B: Industrial waste incinerator until 01/01/2015.

QCVN 51:2013/BTNMT: National Technical Regulation on Emissions from the Steel Industry

No.	Parameters	C value (ngTEQ/Nm^3)	
		B1	B2
1	Total dioxins/furans	0.6	0.1

B1: Production units commencing operations from 01/01/2015; B2: newly invested units

There are no regulations on dioxin/furan content in the ambient air, water, and biological media (tolerable daily intake (TDI) regulations), and no dioxin/furan regulations on products or waste from typical industries which have the potential for dioxin/furan emissions. The development and completion of the above mentioned regulations are essential in the context of the current growth of dioxin/furan emissions.

3.2. Related regulations on dioxins

Currently, Vietnam does not have sufficient national regulations on the maximum concentration of total PCDDs/PCDFs in wastes of various types from industries with the possibility to produce dioxins, as well as in water and ambient air. This is one of the significant obstacles in controlling, limiting and eliminating dioxins from industrial production activities in particular and the environment in general.

The development of regulations on dioxins in industries in Vietnam is a difficult assignment. First of all, the formation of dioxins in industrial activities is not intentional and it occurs subject to very complicated mechanisms. Industrial activities are getting more and more developed, while the discharges from these industries have also increased, requiring advanced treatment technologies. For medium- and small-scale production units, investment in a discharge source treatment system and operating this effectively is not simple. Moreover, the capacity for dioxin monitoring and analysis in Vietnam remains relatively weak.

Due to the high hazardous risks of DRCs to the environment and human beings, many industrial developed countries have developed regulations on dioxin emission in potential industrial sectors as well as in environmental media. The UN Environment Programme has also developed a toolkit to support countries in identifying and quantifying dioxin/furan emissions in different operations by providing methodologies and emission factors. These are highly valuable references in combination with site surveys, which help Vietnam to develop dioxin regulations which both ensure scientific methodologies and suitability of the country's specific context and conditions.

3.2.1. International regulations

Currently, international regulations on dioxins mainly focus on contact thresholds and intake by human beings. The World Health Organization (WHO) regulates the TDI of dioxins at 1-4 pg WHO-TEQ/kg of the body weight/day. The Expert Committee on Food Additives regulates the tolerable daily, weekly and monthly intake of dioxins at 2.3 pg TEQ/kg of the body weight/day, 16.1 pg TEQ/kg of the body weight/week and 70 pg TEQ/kg of the body weight/month respectively. Although these dioxin threshold values do not reflect dioxin emission regulations directly in industrial activities, they are still mentioned in this report to ensure the systematic characteristics of regulations as well as to stress the most important objective of strict regulations on dioxins – namely to protect human health.

3.2.2. Regulations in the USA

Regulations in the USA on dioxins include dioxin emission in the air and water. Laws related to these include the law on clean air, the law on clean water, the law on safe drinking water and the law on resource preservation and recovery.

In general, dioxin emission into the air is regulated by the Clean Air Act and the Resource Conservation and Recovery Act. The emission limitation is included in Article 40, Section 60 of the Federal Act, including regulations on waste incinerators. These regulations were promulgated and took effect in 1990, and apply to all units in operation, as well as newly developed units. The limits introduced are total of both dioxins and furans.

The permitted dioxin level in water is mentioned in the Safe Drinking Water Act, promulgated in 1994. The maximum contaminated value as setup is 3.10-8 mg/l. This value is not a strict legal value but rather considered as a voluntary medical objective. For sludge water treatment activity, the dioxin threshold is 0.0003 mg TEQ/kg for dry sludge applied to soil.

3.2.3. Regulations in Canada

Dioxin and furan contamination in soil, water, and sediment and bio tissue is regulated in Canadian standards on dioxins and furans. The regulations focus on six areas including waste incinerators (urban waste, hazardous waste and medical waste), the paper and paper pulp production industry (steam boiler), wood burnt for domestic use, iron ore caking, electric arc furnaces, and burning of waste in pyramid incinerators. These fields are considered as the main emission sources, accounting for 80 per cent of the emission amount into the environment.

Regulations on dioxin and furan emission thresholds have been developed by Canada since 2001 focusing on two areas, paper and paper pulp, and waste burning, on the basis that prevention is the main measure to restrict contaminants from being emitted into the environment. The remaining areas were developed later.

3.2.3.1. Regulations on boilers in the paper and paper pulp production industry

According to statistics from the Canadian Environment Protection Agency, dioxin and furan emissions from this area into the air account for around 8.6 g TEQ/year, representing 4.3 per cent of the total emission amount. Emission limitations are regulated subject to two timelines:

- For boilers installed after the standard came into effect, the dioxin and furan threshold is less than 100 pg/m^3 TEQ.
- For current boilers in operation since 2006 and before that, the dioxin and furan threshold is less than 500 pg/m^3 TEQ.

Each boiler subject to this standard will be examined twice per year to identify the dioxin and furan emission level. The data will be archived and compared on an annual basis. The examinations and reports will be carried out by using methods and procedures regulated by relevant authorities.

3.2.3.2. Regulations on waste incinerators

Annually, dioxins and furans emitted into the environment not coming from waste incineration is around 44.9 g TEQ/year, making up 22.5 per cent of the total emission amount in Canada. For any newly developed or expansion units, these are to apply the best environmental protection and controlling techniques. For example, the maximum allowable concentration in flue gas for waste transformation programmes is 80 pg I-TEQ/m^3.

A regulation on the dioxin/furan threshold in hazardous waste is 80 pg I-TEQ/m^3, of which the particular requirement for sludge incinerators is 100 pg I-TEQ/m^3. These regulations took effect in 2005 for sludge incinerators and in 2006 for urban, medical and hazardous waste incinerators.

3.2.4. Regulations in the EU

3.2.4.1. Regulations on dioxins in the environment

There are various regulations in the EU on dioxin thresholds in the soil and surface environment. Sweden is one of the countries with the strictest regulations, with dioxin thresholds in residential land, agriculture land, land for dairy cattle and playgrounds for children at 10 ng I-TEQ/kg dm and a dioxin threshold for industrial zones at 250 ng I-TEQ/kg dm. For residential areas, Germany and the Netherlands regulate the limit at 1,000 ng I-TEQ/kg dm, while Finland’s regulation is 500ng I-TEQ/kg dm. In terms of agricultural land, the regulation in the Netherlands on dioxin concentration is 1,000 ng I-TEQ/kg dm, for Finland it is 500 ng I-TEQ/kg dm and Germany has a regulation threshold of 40 ng I-TEQ/kg dm. In the Netherlands, where dairy cattle is a developed branch of agriculture, regulations on dioxins in land used for cattle raising are very strict at 10 ng I-TEQ/kg dm. In Austria, the dioxin threshold in fertilizers and breeding additives is 50 ng I-TEQ/kg dm. Many other countries, as well as the EU in general, do not have specific regulations and guidance on this limitation.

3.2.4.2. Regulations on dioxin emission from solid waste incineration

Regarding solid waste incineration, the EU provides the following instructions: 89/429/EEC, 89/369/EEC and 94/67/EEC regulating dioxin/furan emission concentration thresholds. Of these, instruction 94/67/EEC regulates the limit of emission into the air environment from hazardous waste incinerators at 0.1 ng I-TEQ/m^3. For emissions from urban solid waste incinerators, the instruction does not provide a specific limit for emission. All EU members, except for Greece, have their own regulations on dioxin/furan emissions into the air environment from urban solid waste incinerators (both facilities under operation and newly developed ones). Of these, the value of 0.1 ng I-TEQ/m^3 has been selected by most countries as the emission threshold. Air volume is measured under the conditions of 11 percent O2, 0°C, and 101.3 kPa. For water environment, countries in the EU do not regulate dioxin/furan emission limit values, as many researches stipulate that solid waste combustion does not have significant impacts on the water environment.

3.2.4.3. Regulations on dioxin emission from industries

For the air environment, the EU does not apply any specific instructions or regulations. Each EU member country has its own regulations on dioxin/furan emission thresholds for six types of industries that include metal manufacturing and processing, iron and iron ore caking, combustion processing, paper and paper pulp production, coke production, and the cement and lime industry.

Regarding the specific values of dioxin emission, most countries adopt the value of 0.1 ng I-TEQ/m^3 for industries. Other regulations include an emission limitation value by the UK for metal manufacturing and processing, and paper and paper pulp production, which is 1 ng I-TEQ/m^3. France has a threshold for metal manufacturing and processing of 1 ng I-TEQ/m^3 and Belgium and Holland have dioxin/furan emission limits into the air environment ranging from 0.4 to 0.5 ng I-TEQ/m^3 for the steel and metal manufacturing industry.

Table 3.10. The EU's dioxin/furan emission thresholds from the industry into the air environment (ng I-TEQ/m^3)

No	Country	Metal manufacturing and processing	Iron and iron ore caking	Emission from combustion processes	Paper production industry	Coke production	Cement and lime production
1	Austria	0.1	0.4	0.1	-	-	-
2	Belgium	0.5	0.5	0.1	-	-	-
3	France	1.0	-	-	1.0	-	-
4	Germany	0.1	0.1	0.1	0.1	0.1	0.1
5	Luxembourg	0.1	0.1	0.1	0.1	0.1	0.1
6	Holland	-	0.4	-	-	-	-
7	Britain	1.0	-	0.1	1.0	0.1	0.1

Note: Measured at 16 percent O_2, dry air, 0°C, 101.3 kPa.

The EU does not regulate dioxin limit in wastewater sludge. Only three countries in the EU provide this regulation. Austria and Germany regulate the dioxin threshold in wastewater sludge to be used for compost organic fertiliser at 100 ng I-TEQ/kg dm. The threshold adopted by Holland is 190 ng I-TEQ/kg dm.

3.2.5. Regulations in Japan

The ratification of the 1999 act related to special measures to minimise dioxins has fulfilled the need of the public regarding the current dioxin contamination status in Japan. This act regulates that "businesses are responsible for taking necessary measures to prevent environmental pollution due to dioxin emission from their business operation activities, as well as measures to eliminate dioxins; businesses are also to cooperate with the government and local authorities in prevention of environmental pollution and dioxin eradication". The articles regulate the TDI of dioxins, regulating the environmental quality standards of air, water and soil and providing strict standards for adjusting gas emissions into the air and water.

The law on dioxins regulates that the annual average concentration of dioxins in the air should not exceed 0.6 pg TEQ/m^3; in water should not exceed 1 pg TEQ/m^3 and in soil not exceed 1,000 pg TEQ/g.

Specific regulations regarding dioxin emission thresholds in industrial activities are shown in Table 3.11.

Table 3.11. Standards in Japan on dioxin/furan emission from industries into the environment

No.	Impact/areas	Law/ guidelines	Time of effectiveness	Contents/thresholds
1	Waste incinerator	The dioxin law and emission standards	01/2001- 11/2002 12/2002	New production unit: 0.1–5 ng TEQ/Nm^3 Production unit under operation: 80 ng TEQ/Nm^3 New production unit: 0.1–5 ng TEQ/Nm^3 Production unit under operation: 1-10 ng TEQ/Nm^3
2	Steel manufacturing and electrical furnace	The dioxin law and emission standards	01/2001- 11/2002 12/2002	New production unit: 0.5 ng TEQ/Nm^3 Production unit under operation: 20 ng TEQ/Nm^3 New production unit: 0.5 ng TEQ/Nm^3 Production unit under operation: 5 ng TEQ/Nm^3
3	Caking facilities of the steel industry	The dioxin law and emission standards	01/2001- 11/2002 12/2002	New production unit: 0.1 ng TEQ/Nm^3 Production unit under operation: 2 ng TEQ/Nm^3 New production unit: 0.1 ng TEQ/Nm^3 Production unit under operation: 1 ng TEQ/Nm^3
4	Zinc recollection stage	The dioxin law and emission standards	01/2001- 11/2002 12/2002	New production unit: 1 ng TEQ/Nm^3 Production unit under operation: 40 ng TEQ/Nm^3 New production unit: 1 ng TEQ/Nm^3 Production unit under operation: 10 ng TEQ/Nm^3
5	Aluminium and alloy manufacturing unit	The dioxin law and emission standards	01/2001- 11/2002 12/2002	New production unit: 1 ng TEQ/Nm^3 Production unit under operation: 20 ng TEQ/Nm^3 New production unit: 1 ng TEQ/ Nm^3 Production unit under operation: 5 ng TEQ/Nm^3

***Table 3.11. Standards in Japan on dioxin/furan emission from industries into the environment** (cont.)*

No.	Impact/areas	Law/ guidelines	Time of effectiveness	Contents/thresholds
6	Cleansing and decomposition of PCB wastes	The dioxin law and emission standards	01/2001	New production unit: 10 pg TEQ/l Production unit under operation: 10 pg TEQ/l
7	Cleansing of flue gas and wet dust	The dioxin law and emission standards	01/2001- 11/2003 01/2003	New production unit: 10 pg TEQ/l Production unit under operation: 20 pg TEQ/l New production unit: 10 pg TEQ/l Production unit under operation: 10 pg TEQ/l
8	Landfill for incinerator waste	The dioxin law and emission standards	01/2001- 11/2003 01/2003	New production unit: 10 pg TEQ/l Production unit under operation: 50 pg TEQ/l New production unit: 10 pg TEQ/l Production unit under operation: 10 pg TEQ/l
9	Waste water treatment plants for the above	The dioxin law and emission standards	01/2001	New production unit: 10 pg TEQ/l Production unit under operation: 10 pg TEQ/l

3.2.6. Regulations in Korea

In Korea, burning is a regularly used measure to treat medical waste and waste containing hazardous materials and contagious bacteria. The combustion method has a number of advantages, such as reducing waste volume and completely solving problems with contagious bacteria and germs. On the other hand, thermal recollection or electricity can be generated from the combustion process. However, the combustion measure can spread hazardous material into the surrounding environment, has a high cost of operation and maintenance, and there is a need to study the complete treatment of ash and flue gas.

The conditions for incinerator operations are that the temperature at the secondary combustion chamber must be higher than 850°C and the time for smoke retaining at least two seconds. All medical incinerators shall be in compliance with emission standards for industrial activities to minimise arising contaminants in the environment. Table 3.12 shows the dioxin emission standards for solid wastes as developed by Korea's Ministry of Environment. Pursuant to the amendments of the Law on Waste Management, since 2001 medical waste incinerators have measured dioxins at least one time per year. The measurement should be archived as operation data of the incinerators.

Table 3.12. Standards in Korea on dioxin emission for medical incinerators

No	Subjects	Capacity	Emission standards (ng-TEQ/Nm³)		Frequency of examinations
			New facility	Under operation	
1	Medical waste incinerator	4 ton/h	0.1	20[a] or 1[b]	At least twice/year
		2-4 ton/h	1	40[a] or 5[b]	At least twice/year
		0.2 - 2 ton/h	5	40[a] or 10[b]	At least twice/year
		25 - 200 kg/h	5[a]	10[b]	At least twice/year
		< 25 kg/h	-[c]	-[c]	
2	Urban solid waste incinerator	2 ton/h	0.1	0.1 commencing on 1/7/2003 0.5 latest until 30/6/2003	At least twice/year

Note: a: untill 31/12/2005; b: commencing on 1/1/2006; c: incinerators not to be used anymore.

3.2.7. General comments on country regulations on dioxins

In reviewing standards introduced by a number of countries and international organisations, it is clear that there has been a great effort to develop standards and policies to supervise and manage the generation of dioxins, which has led to mitigation measures to prevent dioxin/furan emission into the environment.

a) The development of standards, regulations and guidance has been carried out in a relatively sufficient and systematic manner by a number of countries for many years.

Austria was the first country in the EU to introduce regulations on the ban of PCBs and threshold values for dioxins in compounds, starting in 1989. Other countries started issuing regulations related to dioxins between 1990 and 1998. Canada started to develop regulations on emission thresholds and emission limits for the paper and paper pulp and waste incineration industries in 2001. The USA started issuing laws on dioxins in 1990. Japan issued the regulation on TDI of dioxins in 1998. Other related regulations were issued later, and by 2003 Japan had finalised the law on dioxins and its environment standards. The World Health Organisation regulates a TDI of 1-4 pg WHO-TEQ/kg body weight/day, and this came into effect in 1998. By 2001, the joint FAO/WHO Expert Committee on Food Additives issued its own regulations on dioxins.

b) Issues related to dioxins have attracted the attention of countries at different levels

The field that has attracted the most attention from countries is waste incinerators. In addition, many countries have promulgated specific regulations on TDI of dioxins.

Canada has focused on six areas that have been assessed as the emitting source of up to 80 per cent of dioxins into the environment: waste incinerators (urban waste, hazardous waste, sludge and medical waste), paper and paper pulp production industry (boiler), wood burning for domestic use, iron ore caking, steel manufacturing from electric arc furnaces and waste combustion in pyramid incinerators.

The USA's regulations on dioxins include thresholds on dioxin emission into the air and water. The USA focuses in particular on dioxin emissions from waste incinerators and the paper and paper pulp industry. On water, the USA regulates the dioxin threshold and the maximum level of dioxins permitted in drinking water and public tap water. Some states in the USA even regulate the level of dioxins permitted in groundwater and soil.

Countries in the EU have promulgated regulations on dioxin emission thresholds from solid waste incineration in six industrial categories: metal manufacturing and processing, iron and iron ore caking, combustion processing, paper and paper pulp production, coke production and the cement and lime industry.

They have also issued regulations on dioxin emission into the water and aquaculture environment, regulations on the use of chemicals, the Sevoso instruction on dangerous substances, regulations on dioxins in sludge as well as a dioxin limitation in soil and the environment.

The law on dioxins and the environment quality standard in Japan focuses on regulating dioxin emission thresholds into the air from waste incineration and metallurgy, in particular caking, steel kilns and electric arc furnaces. For the water environment, Japan has regulations on dioxin emission for areas and stages such as PCB cleansing and decomposition facilities, the flue gas cleansing stage, landfill for waste incinerators, wastewater treatment plants and wastewater leaking from landfill facilities.

c) Specific values adopted in dioxin emission standards and regulations for environmental media are various in different countries.

Values for the same targeted environmental media among the countries can be different at several times or dozen times. Some countries have yet issued specific values or the thresholds adopted remain as recommendations and not legally mandatory.

Part 4
DIOXIN EMISSION FROM INDUSTRY IN VIETNAM

4.1. Status of dioxin emission from industry in Vietnam

The dioxin contamination in the environment, such as in soil, sediment and water samples, and in human biological specimens such as blood samples and breast milk samples, collected from dioxin hotspots such as Da Nang, Bien Hoa and Phu Cat has been studied over the past years. The database on dioxin contamination in these hotspots is relatively sufficient and detailed. However, the database on dioxin concentration from industrial samples in Vietnam is very limited. Vietnam is on its way to industrialisation and it is estimated that by 2020 the country will have become industrialised. The development of industries is the key objective of economic development strategies. However, industrial activities, especially small-scale activities and spontaneous activities which are difficult to control entail serious risks regarding dioxin emission into the environment. The development of a dioxin emission profile from high-risk industries is essential – firstly to facilitate the completion of the institutional, legal foundation of the country, as well as to provide instruments to manage, control and limit dioxin emission from industrial activities.

Data on DRC concentration shown below mainly focuses on industrial samples such as flue gas samples from incinerators, wastewater samples from gas cleansing activities, solid samples such as fly ash, bottom slagged ash, dust and soil samples collected from industrial parks. Samples have been collected from enterprises units belonging to the high-risk category for dioxin emission, such as waste incineration, cement production, metallurgy, paper production and thermal power, in projects related to control, mitigation and elimination of dioxins. These projects have been implemented by the Ministry of Natural Resources and Environment and the Ministry of National Defence, in cooperation with other international organisations such as the UN Development Programme, UN Industrial Development Organization and the Global Environment Facility. The analysis data has been provided by two laboratories: the dioxin laboratory of the Center for Environment Monitoring, Vietnam Environment Administration, and the dioxin laboratory of the Environmental Chemistry Division, Vietnam-Russia Tropical Center, Ministry of Defence.

Dioxin contamination is expressed based on total TEQ concentrations and the congener specific profile to provide overall evaluations on the emission of DRCs and to characterize the sources of emission.

For dioxin concentrations in flue gas samples, reported values are the ones that were measured at the actual oxygen concentration at the sampling locations. The average oxygen concentration at waste incinerators ranges from 8-12 per cent, while at steel and blast electric arc and air furnaces it ranges from 8-20 per cent, at zinc furnaces 14-16 per cent, cement 8-12 per cent, and thermal power 3-6 per cent. For emission standards, the TEQ concentration in flue gas varies. For example, standards introduced by EU countries normally regulate the TEQ standard value in flue gas with oxygen content for reference at 16 per cent, while the oxygen value for reference in the Vietnam standard for blast furnaces is 7 per cent and for industrial waste incinerators it ranges from 6-15 per cent. In this report, TEQ values in flue gas samples will be presented at actual condition at the sampling locations, and are not corrected to the reference value of oxygen concentration as indicated in regulations or standards. The dioxin concentrations can be corrected using the following formula:

$$C_{A(\text{đkc})} = C_{A(\text{đo})}\left(\frac{20{,}9\% - \%O_{2(\text{đkc})}}{20{,}9\% - \%O_{2(\text{đo})}}\right)$$

Where:

$C_{A(\text{đkc})}$: the concentration of the substance to be analysed at the reference value of O_2 concentration, ng/Nm^3

$C_{A(\text{đo})}$: the concentration of the substance to be analysed at the measured value of O_2 concentration, ng/Nm^3

% $O_{2(\text{đkc})}$: reference oxygen concentration

% $O_{2\,(\text{đo})}$: measured oxygen concentration

For instance, in one incinerator when analysing the concentration of PCDD/Fs in flue gas at the value of 0.6 ng TEQ/Nm^3 at the condition with oxygen with exceeding concentration of 18 percent. When correcting this dioxin concentration value to the condition at the reference oxygen concentration of seven per cent, the equivalent dioxin concentration at the standard condition (with oxygen content of 7 percent) is:

$$C_{7\%\ oxygene} = 0.6 \times (20.9\ \% - 7\ \%)/(20.9\ \% - 18\ \%) = 2.875\ \text{ng TEQ/Nm}^3$$

The regulation on dioxin threshold in flue gas from incinerators as specified by QCVN: 30/2012/BTNMT for industrial waste incinerators is 0.6 ng TEQ/Nm^3. Thus, the dioxin levels from this incinerator exceeded the Vietnamese regulation threshold 4.79 fold.

4.1.1. DRC concentration from waste treatment activities

Combustion activity is considered as the main dioxin emission source. Outdated incineration technology (temperature in the combustion chamber), the lack of an air pollution control device (APCD) and improper classification of waste are the major causes for the elevated emissions of dioxins from waste incinerators. Studies on dioxins from waste incineration usually classify dioxin emission levels according to the type of waste, such as municipal waste, industrial waste, medical waste and biomass. They can also be classified according to controlled combustion activity (using incinerators) and uncontrolled combustion activity (open waste and biomass burning). In this section, the report mainly focuses on data regarding DRC concentrations from industrial waste incinerators and waste treatment facilities.

4.1.1.1. DRC concentrations in flue gas from waste treatment facilities

Within the activities of developing U-POP monitoring technical guidelines in industry conducted by units under the Ministry of Natural Resources and Environment, two waste incinerators in the north were selected for a survey on dioxin/furan concentration in incinerators flue gas. In another study carried out by the Vietnam-Russia Tropical Center, some incinerators and hazardous waste treatment facilities in Hanoi, Nam Dinh, Hai Duong, Thanh Hoa and Ho Chi Minh City were surveyed, sampled and analysed for 29 parameters of DRCs, including dioxins, furans and dioxin-like PCBs.

DRC concentration in flue gas from waste incinerators depends on three main factors: (1) types of waste and incinerator capacity; (2) temperature of the primary and secondary combustion chamber and (3) flue gas treatment technology (APCD). Most of the incinerators surveyed have small and medium capacities (around 300 kg/h), and a few have a large capacity (such as incinerators at one domestic, medical and industrial waste treatment facility in Ho Chi Minh City with a capacity of approximately 1 ton/h). An important factor is the flue gas treatment technology of the incinerator. In order to reduce dioxin emissions into the environment, flue gas is first required to be put out, separated from dust and cooled down with water. Then it will be treated using a lime solution or absorbed using activated carbon. In some of the incinerators with ordinary technology, flue gas is only treated by cooling. Quality of the dust filtration system could play an important role for the extent of dioxin emission in flue gas.

Results of dioxin concentrations (reported as total TEQs, in average and range values) in flue gas collected from chimneys at waste treatment facilities with incinerators, together with some characteristics of the incinerators, are shown in Table 4.13.

Table 4.13. TEQ concentrations in flue gas (pg/Nm^3) of some incinerators

No.	Type of incinerator (number of samples)	TEQ (pg/Nm^3)		Characteristics of incinerator
		I-TEQ	WHO-TEQ	
Hanoi				
1	Industrial waste incinerator (n=3)		7870 (5100 - 9800)	- Capacity: 200 kg/h - Primary chamber temperature: 800-850^{0}C; Secondary chamber temperature: 950-1,200^{0}C - Wet type flue gas treatment system in combination with activated carbon absorption
2	Industrial and medical waste incinerator (n=4)	134 (16.4 - 463)	127 (14.1 - 442)	- Capacity: 200 kg/h -Treating flue gas using lime and activated carbon
Hai Duong				
3	Industrial waste incinerator (n=2)		24870 (2930 - 46800)	- Capacity: 1,000 kg/h - Primary temperature: 700-1000^{0}C; Secondary temperature: 1000-1200^{0}C
4	Hospital waste incinerator (n=1)	32.3	28.6	- Capacity: 400 kg/h - Primary temperature: 800-850^{0}C - Secondary temperature: 1100^{0}C
Thanh Hoa				
5	Urban waste incinerator (n=2)	17.8 (15.6 – 20.1)	17.2 (15.1 – 19.3)	- Capacity : 350 - 600 kg/h
Ho Chi Minh City				
6	Industrial and domestic waste incinerator (n=3)	1360 (300 - 3000)	1340 (280 - 2980)	- Capacity: 300 kg/h - Primary temperature: 700-900^{0}C; Secondary temperature: 1,050-1,100^{0}C - Putting out dust and cooling down flue gas with water
7	Hazardous waste treatment station (n=3)	76.4 (51.3 - 110)	71.8 (48.2 - 103)	- Capacity: 21 ton/day - Primary chamber temperature: 800-850^{0}C; Secondary chamber temperature: 950-1,200^{0}C - Waste combustion: domestic, industrial and medical wastes - Separate dust and treat flue gas using lime solution

The TEQ concentrations in flue gas samples from incinerators varied substantially, from 14.1 to 46,800 pg WHO-TEQ/Nm^3. Differences in combustion technologies (in which temperatures in primary and secondary combustion chambers during operation is the most important factor), flue gas treatment systems (with the possibility of wet treatment in combination with activated charcoal absorption or with only water treatment) and especially the complicated sources of burned wastes, are the most important causes for such large variations of dioxin concentrations encountered in the flue gas samples. Flue gas samples collected at one industrial waste incinerator in Hai Duong have the highest concentrations of DRCs, as compared to samples collected at the same time of the survey, reaching up to 46,800 pg TEQ/Nm^3. The TEQ concentrations of some flue gas samples from the incinerators surveyed, in comparison to the Vietnamese regulation threshold for industrial waste incinerator (QCVN 30:2012/BTNMT), are shown in Figure 4.1.

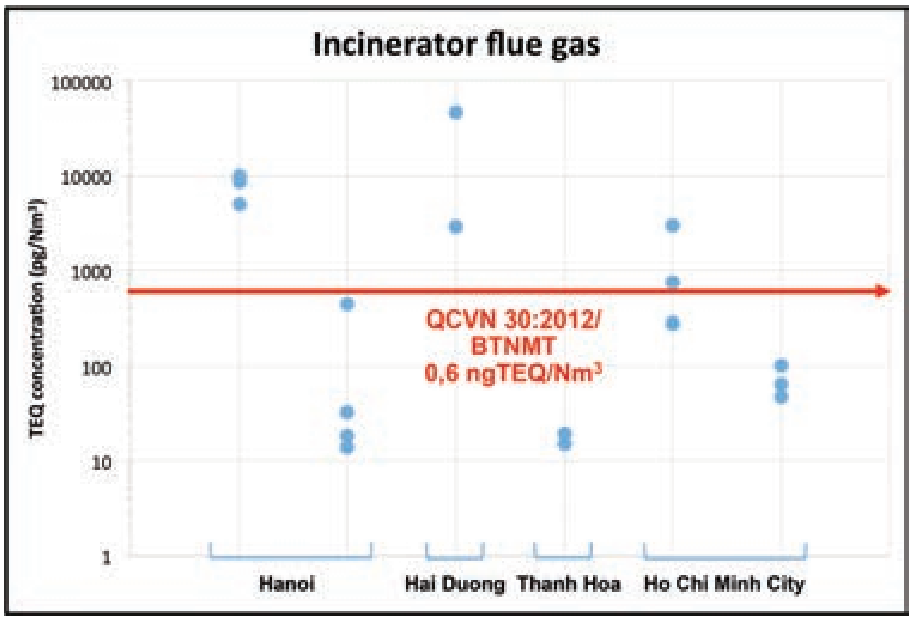


Figure 4.1. Dioxin concentrations in flue gas from waste incinerators

There are seven out of 18 flue gas samples from industrial waste incinerators and waste treatment activities with dioxins levels exceeding the threshold of 0.6 ng TEQ/Nm^3. In particular, many samples have a concentration thousand times higher than the acceptable limits. Significantly high TEQ concentrations in some flue gas samples from industrial waste incinerators indicate that this is the main emission source of dioxins and DRCs such as furans and dioxin-like PCBs into the environment. To minimise the formation and emission of DRCs in this activity, first it essential to strictly manage and classify burned waste, cease operations of outdated incinerators, upgrade technologies of incinerators under operations and will be in operations, especially to ensure combustion chamber temperature and flue gas treatment technologies (APCD), and periodically monitor to assess dioxin contamination in flue gas.

As for the PCDD/F congener-specific profile, OCDD is the predominant congener in most of the samples. The highest concentration of this congener in the sample is 7,670 pg/Nm^3. 2,3,7,8-TCDD, the most toxic substance in the DRC category, accounts for a relatively small proportion. In particular, the ratio of TCDD/TEQ in flue gas samples in Hanoi, Nam Dinh, Hai Duong and Ho Chi Minh City is low in general, ranging from 4.1 to 25.3 percent. However, two flue gas samples collected from a municipal waste incinerator in Thanh Hoa contained a higher proportion of TCDD/TEQ as compared to other samples collected from other provinces and cities (55.3 and 62.8 percent, respectively), while their total TEQ concentrations were relatively low (15.1 and 19.3 pg/Nm^3). As for furans compounds, 1,2,3,4,6,7,8-HpCDF is the most dominant congener. The highest concentration in the flue gas sample was 15,290 pg/Nm^3. In general, furan concentrations are higher than those of dioxins. Of all samples with all dl-PCBs detected, the three main congeners with the highest concentrations are PCB-118, PCB-105 and PCB-77; congeners such as PCB-123, PCB-189 have low concentrations orare not detected in many samples. In general, the congener-specific patterns in waste incinerators in Vietnam were similar to those observed for typical waste incineration reported by other investigations in the world.

4.1.1.2. DRC concentrations in wastewater from waste treatment activities

Current industrial waste incinerators in Vietnam usually use the wet treatment technology for flue gas. Flue gas from the secondary combustion chamber will be diverted to the scrubber tower, in fact completing the thermal transmission. Water is used to quickly cool down the flue gas flow, one of the factors reducing the formation of dioxins. After thermal transmission and dust filtration, the flue gas flow will be absorbed using a lime solution to cleanse contaminants especially acidic gas before being released into the environment. The water and lime solution will then be cooled down and the water will be then discharged or circulated. Depending on the incinerator technology and flue gas treatment technology, a considerable amount of dioxins might be discharged into the environment if these substances accumulate in the particulate phase.

To provide an overall assessment of DRC emission in wastewater from waste treatment activities, apart from wastewater samples from the scrubber towers of the industrial waste incinerators, water samples from some waste water treatment facilities were also collected. Provinces and cities including Hanoi, Hai Duong, Thanh Hoa and Ho Chi Minh City were surveyed. In particular, wastewater samples are collected from an environmental treatment company with an industrial waste incinerator and medical waste in Tay Mo Commune, Tu Liem District and one industrial waste incinerator at Nam Son Commune, Soc Son District, Hanoi; two waste treatment companies in Hai Duong City and Thanh Ha District, Hai Duong Province; one urban waste incinerator in Nga Son District, Thanh Hoa and 3 waste and waste water treatment facilities in Ho Chi Minh City. Wastewater samples are analysed with 29 parameters of DRCs and TEQ concentrations (in average and range values) are shown in Table 4.14.

Table 4.14. TEQ concentrations in wastewater (pg/L) from some waste treatment facilities in Ha Noi, Hai Duong, Thanh Hoa and Ho Chi Minh City

No	Facility (no. of samples)	TEQ (pg/L)		Some technology features of the incinerators
		I-TEQ	WHO-TEQ	
Hanoi				
1	Waste incinerator 1 (n=1)	-	228	Water at the scrubber tower for flue gas
2	Waste incinerator 2 (n=4)	-	12.9 (1.05 – 48.2)	Wastewater
Hai Duong				
3	Environment company 1 (n=2)	-	186 (36.5 - 335)	Wastewater at dust filtering cyclone of the post treatment flue gas and wastewater treatment system for discharging into the environment
4	Environment company 2 (n=2)	-	1290 (23.6 - 2560)	Wastewater of cooling system in the heat relieving oven before treatment and wastewater in the tank after primary treatment using sedimentation and filtration

Table 4.14. TEQ concentrations in wastewater (pg/L) from some waste treatment facilities in Ha Noi, Hai Duong, Thanh Hoa and Ho Chi Minh City *(cont.)*

No	Facility (no. of samples)	TEQ (pg/L)		Some technology features of the incinerators
		I-TEQ	WHO-TEQ	
Thanh Hoa				
5	Waste incinerator (n=1)	-	0.84	Wastewater
Ho Chi Minh City				
6	Industrial waste treatment station 1 (n=1)	-	1.03	Water in heat relieving basin, used for cooling down flue gas, which is then circulated
7	Industrial waste treatment station 2 (n=2)	-	50.9 (8.51 – 95.7)	Water used for cooling down flue gas, collected at two locations of pre and post treatment
8	Environment company (n=2)	-	24700 (2240 - 50080)	Waste water of the dust breaking up process. This water is then diverted into basins for circulation and it is untreated. In the water sample collected, there is a certain sediment amount

Dioxin concentrations of wastewater samples collected at incinerators and waste treatment facilities varied substantially, from 0.84 to 50,080 pg WHO-TEQ/L. This result suggests that controlling of the formation and emission of DRCs in this activity is complicated. The DRCs formed depends on the incineration technology and flue gas treatment technology but also on the changes of each incineration batch, especially the input materials used for combustion. The dioxins with the highest concentrations in most of the samples were 1,2,3,4,6,7,8-HpCDD and OCDD, while 2,3,7,8-TCDD accounts for a small content. Furans with number of chlorine atoms of seven and eight have a relatively higher proportion as compared to other congeners. Congeners such as PCB-77, PCB-105 and PCB-156 have relative high contents in samples while PCB-81 and PCB-123 have the lowest contents of all.

The surveyed TEQs in wastewater of industrial waste treatment activities in comparison with the maximum acceptable thresholds stipulated by Japan's standards on industrial wastewater are shown in Figure 4.2.

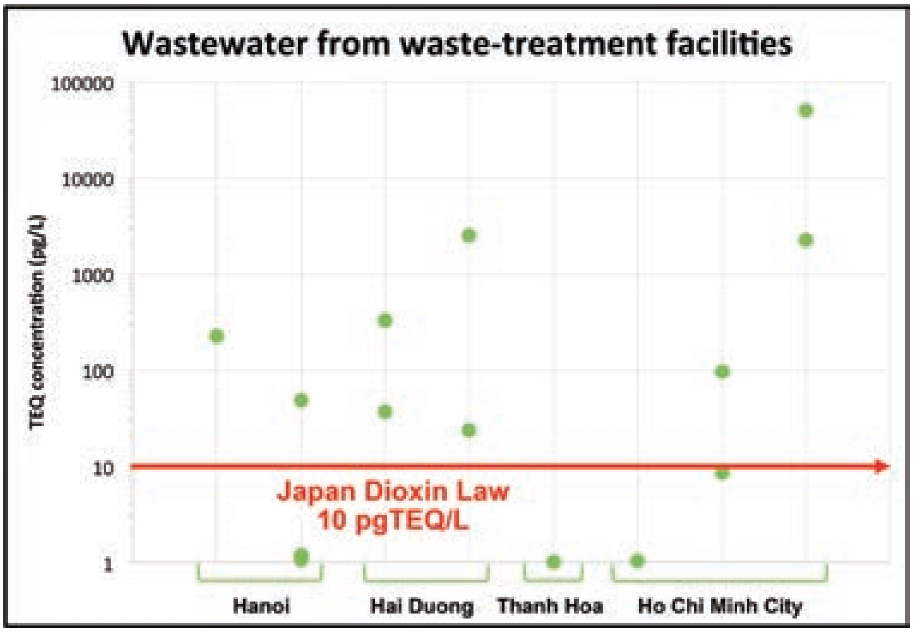


Figure 4.2. Dioxin concentrations in wastewater from waste incinerators

The standard guideline values of DRCs in wastewater in Japan are 10 pg TEQ/l. There are nine out of 15 samples analysed with dioxin concentrations exceeding this value. Particularly, the dioxin concentration in a wastewater sample collected at an industrial waste incinerator in Ho Chi Minh City was 50,075 pg TEQ/l, which is 5,000 times higher than the Japanese standard value. Hence, wastewater in industrial waste treatment facilities is a source of dioxin contamination. There needs to be an investment in and maintenance of wastewater treatment technologies to ensure the standard, as well as development of a periodical monitoring programme for wastewater quality before being discharged into surface water. Direct discharge into the water course without treatment will bring about risk of dioxin contamination in various environmental units, such as soil, water, sediment and bio-organisms.

For incinerators with a wet treatment type for flue gas, water samples collected from the scrubber tower is a specialised type of sample. The injection of water flow into a high temperature flue gas flow aims to quickly cool down flue gas. This is an important factor to reduce the formation of dioxins. However, dioxins which already exist in flue gas can dissolve into this water flow. Even if the content of dioxins dissolving is very small, if the washing water is not treated but directly discharged into the environment, the risk of environmental contamination with dioxin is inevitable. Currently, Vietnam does not have specific regulations on the maximum acceptable limits of dioxins in wastewater. When comparing the dioxin levels in wastewater in incinerators as stated above (around 200 to 1,000 pg TEQ/l) with some of the Japanese standards on dioxins in flue gas clean-up and collection of wet dust (activities at 10 to 50 pg TEQ/l), the dioxin concentrations in wastewater from these incinerators is very high. This is because dioxins distributed in the flue gas are mainly in the form of particulate phase (dust, fly ash etc.). Water is contaminated by dioxins during the washing and cooling process. Attention should therefore be paid to two factors: dust filtration in flue gas and wastewater treatment technology for the scrubber tower.

4.1.1.3. DRC concentrations in solid waste from industrial waste incinerators

The solid waste sample collected for analysis is bottom ash after each batch. Before getting into the scrubber tower, flue gas will be diverted into the filtration system and ash will be retained at this filtration device. Non-burned particulates will be in the slag layer at the bottom of the incinerators. Normally, this slag layer will be taken out of the incinerators after each batch and will then be treated using a containment method or used for infrastructure construction, such as making bricks. The TEQ concentration (average and in range values) in bottom slagged ash and fly ash at four facilities with waste incinerators in Hanoi, Hai Duong and Thanh Hoa are shown in Table 4.15.

Table 4.15. Dioxin levels in bottom ash (pg/g) from incinerators in Hanoi, Hai Duong and Thanh Hoa

No	Facility (no. of samples)	TEQ (pg/L)		Characteristics of incinerators
		I-TEQ	WHO-TEQ	
Hanoi				
1	Industrial and medical waste incinerator (n=5)	-	698 (24.3 – 1700)	Ash collected at the slag discharge point and fly ash from dust filtering cyclone. Material used for burning is medical waste which contains a lot of glass
2	Industrial waste incinerator (n=1)	-	121	Ash from incinerator collected at slag discharge point after one batch
Hai Duong				
3	Industrial waste incinerator (n=4)	-	30.6 (21.0 -40.9)	Ash from incinerator collected at slag discharge point after one batch
Thanh Hoa				
4	Industrial and urban waste incinerator (n=1)	-	8.73	Ash from incinerator collected at slag discharge point after one batch

Currently there are no standards for acceptable limits of dioxins for ash samples. The results show that the TEQ concentration in ash samples collected from surveyed facilities varied largely (from 8.73 to 1,700 pg TEQ/g). Currently, there are no specific regulations on the maximum content of DRCs in ash samples. The US standard on acceptable TEQ concentration in industrial sewage sludge of 300 pg TEQ/g can be referred to in order to evaluate the extent of contamination in ash. The comparison is shown in Figure 4.3.

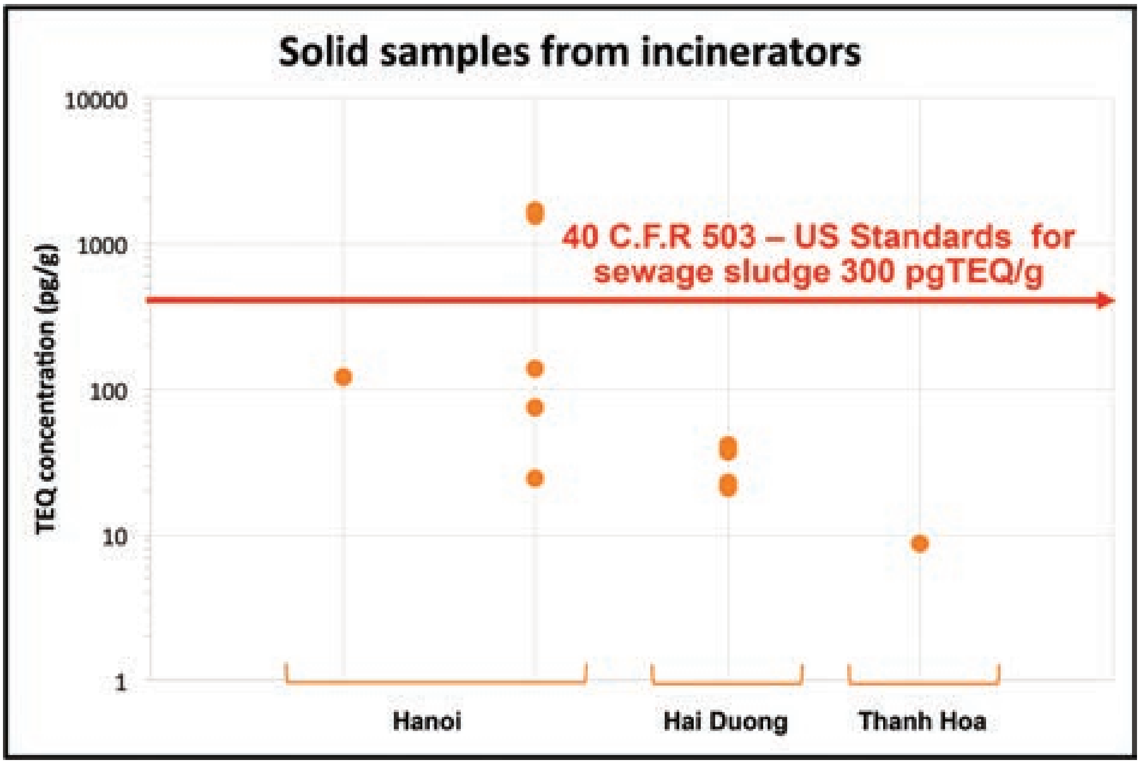


Figure 4.3. Dioxin concentrations in solid samples (ash, dust) from waste incinerators

There are two out of 11 bottom ash samples from waste incinerators with a TEQ concentration exceeding the threshold of 300 pg TEQ/g. These two samples are residual ash collected from the dust filtering cyclone of an industrial and medical waste incinerator in the Tu Liem district, Hanoi with levels of 1,550 and 1,700 pg/g respectively, five times higher than the US standard. The proportion of TCDD/TEQ in ash samples in Hanoi is low, from 4.2 to 7.9 percent; the main dioxin/furan congeners are OCDD; 1,2,3,4,6,7,8-HpCDD; OCDF and 1,2,3,4,6,7,8-HpCDF; the dl-PCB congeners are mainly PCB 77, PCB 118 and PCB 126. Samples collected in Hai Duong have relatively low TEQ concentration, ranging from 21 to 40.9 pg/g; the main congeners are 1,2,3,7,8,9-HxCDD and 1,2,3,6,7,8-HxCDF. Samples with lowest TEQ concentration (8.7 pg/g) were collected at one urban waste incinerator in Nga Son, Thanh Hoa. The proportion of TCDD/TEQ of this sample was 8.6 percent and the congeners with the highest concentration are OCDD; 2,3,7,8-TCDF; 1,2,3,7,8-PeCDF; 2,3,4,7,8-PeCDF; PCB 77; PCB 126 and PCB 118.

4.1.2. DRC concentrations from cement production activities

4.1.2.1. DRC concentrations in flue gas from cement production activities

Surveys were conducted in 2012 and 2013 of three cement plants in Thai Nguyen and Hai Duong using rotation kilns, the current popular technology in Vietnam. The dioxin concentrations in the flue gas samples collected from the chimneys of the cement plants, as well as some characteristics of the technology of the cement plants, are shown in Table 4.16

Table 4.16. Dioxin levels in flue gas from cement kilns (pg/Nm³) collected in Thai Nguyen and Hai Duong provinces

<table>
<tr><th rowspan="2">No</th><th rowspan="2">Facility
(no. of samples)</th><th colspan="2">TEQ (pg/Nm³)</th><th rowspan="2">Some technology features of the cement kiln</th></tr>
<tr><th>I-TEQ</th><th>WHO-TEQ</th></tr>
<tr><td colspan="5">Thai Nguyen</td></tr>
<tr><td rowspan="2">1</td><td>Cement plant 1
(2012)
(n=2)</td><td>-</td><td>402
(173 – 630)</td><td rowspan="2">- French rotating kiln technology, clinker capacity of 4,000 ton/day, output of 1.51 mil ton/year. Temperature for clinker burning of 1,400 – 1,500°C
- Good dust separation and filtration</td></tr>
<tr><td>Cement plant 1
(2013)
(n=2)</td><td>5.46
(4.38 – 6.54)</td><td>5.16
(4.21 – 6.12)</td></tr>
<tr><td>2</td><td>Cement plant 2
(n=2)</td><td>130
(65.8 – 188)</td><td>120
(61.0 – 177)</td><td>- Chinese rotating kiln technology, in operation since 2010, output of 1 mil ton/year/2 assemblies
- Old technology for dust separation and filtration</td></tr>
<tr><td colspan="5">Hai Duong</td></tr>
<tr><td>3</td><td>Cement plant
(n=3)</td><td>-</td><td>254
(57 – 450)</td><td>- Denmark rotating kiln technology, output of 3.5 mil ton/year/3 assemblies</td></tr>
</table>

The results of analysis show that the concentration of PCDD/FCDFs in flue gas samples from cement plants ranges from 4.21 to 630 pg TEQ/Nm³. This concentration is relatively low and also varied a lot. Plants with old technology for the dust filtration system have dioxin concentrations in chimney flue gas of cement kilns higher than those with good dust filtration systems.

TEQ concentrations in flue gas samples from cement plants are compared with Vietnamese regulation QCVN 41:2011/BTNMT for dioxin thresholds in hazardous waste treatment activities in cement kilns, which has a threshold value of 0.6 ng TEQ/Nm³. The comparison is shown in Figure 4.4 below.

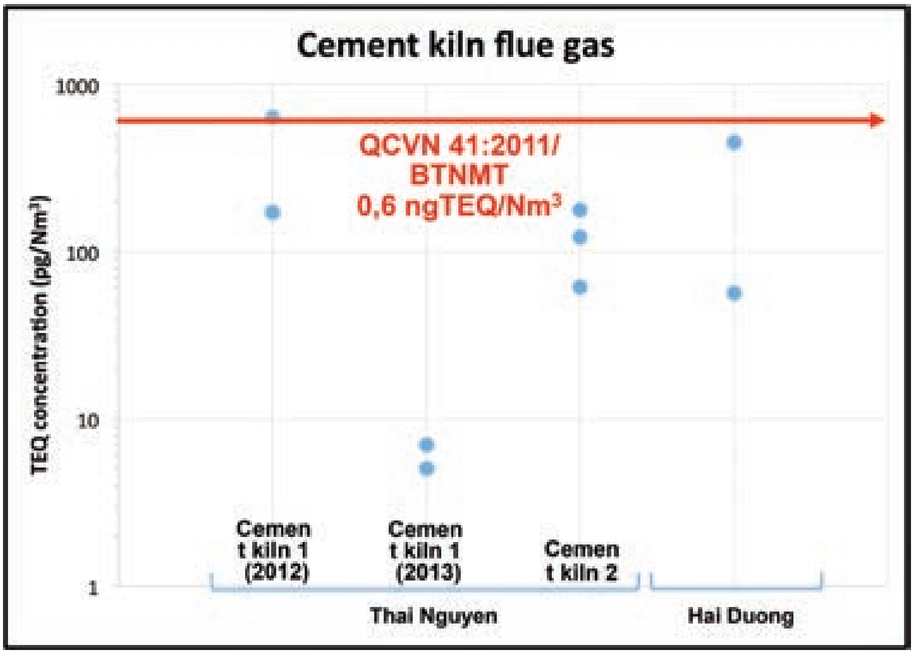


Figure 4.4. . Dioxin concentrations in flue gas from cement kiln

Only one flue gas sample had a TEQ concentration exceeding the threshold (sample collected at a cement plant in Thai Nguyen in 2012 with a level of 630 pg/Nm^3), while at this plant in the 2013 survey, the dioxin level was very low (4.21 and 6.12 pg/Nm^3). The high level of dioxins in the above sample can be explained by the fact that the time of sampling was during the recommencement of the plant, and the material drying process at low temperature is one of the conditions for the formation of dioxins. Plants with the same rotating kiln technology, yet with significantly different TEQ concentration in flue gas samples means there are differences between the flue gas treatment technologies. Dioxin emissions in flue gas from cement production plants are generally at a low range as compared to waste incineration and metallurgy. This is an industry with high capacity and thus, although the emission factor is low (from 0.05 µg/ton to 0.6 µg/ton), total emission quantity may be high. Flue gas samples from cement kilns were collected from cement plants with typical technologies in Vietnam. The level of DRCs in these samples is an important database which can be used for assessing and providing information about the status of dioxin emissions from cement production in Vietnam.

The proportion of TCDD/TEQ in flue gas samples from cement kilns is generally not high, ranging from 6.1 to 21 percent. Congeners of dioxins with high concentration in most of the samples are OCDD and 1,2,3,4,6,7,8-HpCDD. The most toxic congener 2,3,7,8-TCDD was discovered in many samples but at a low level. For furans, the congener 1,2,3,4,6,7,8-HpCDF was found at relatively high level in the samples. For dl-PCBs, congeners mainly found were PCB-105, PCB-118, PCB-123, PCB-167 and PCB-189 In general, the concentration of dl-PCBs in flue gas samples from cement plants is relatively low as compared to other industrial activities.

4.1.2.2. DRC concentrations in wastewater from cement plants

Wastewater is one of the subjects which require attention during the industrial production as after going through the treatment process of the plants; wastewater is discharged into the environment. In cement plants, water is mainly used during washing of input materials, thermal transmission and cleansing of flue gas. Dioxins/furans/dl-PCBs in wastewater samples from two cement plants in Thai Nguyen were analysed. Dioxin residue levels in the wastewater samples collected in cement production plants are shown in Table 4.17.

Table 4.17. TEQ concentration in wastewater (pg/L) from some cement plants in Thai Nguyen province

No	Facility (no. of samples)	TEQ (pg/L)		Sample/sampling site characteristics
		I-TEQ	WHO-TEQ	
1	Cement production plant 1 (n=2)	-	1.10 (0.67 – 1.54)	Water sample collected at the tank for thermal transmission of the entire system. The sampling point is the input water after being preliminarily treated by sedimentation and filtering. Wastewater sample collected from the tank after thermal transmission with the entire system and untreated. This amount of water after treatment will be circulated.
2	Cement production plant 2 (n=2)	-	1.29 (0.96 – 1.63)	Wastewater sample collected from the tank after going through all the phases of the assembly for thermal transmission and untreated. This water will then be treated using sedimentation, filtering and bio-organisms.

Wastewater from cement production plants are generally not heavily contaminated by dioxins and DRCs. The concentrations of these substances in wastewater are very low. The TEQ concentrations in wastewater samples from cement plants ranged from 0.67 pg TEQ/L to 1.63 pg TEQ/L. These levels were much lower than the Japanese standard level of 10 pg TEQ/L.

Congener 2,3,7,8-TCDD; 1,2,3,4,6,7,8-HpCDD; OCDD; 2,3,4,6,7,8-HxCDF; 1,2,3,4,6,7,8-HpCDF and OCDF are found in all samples. Dioxin-like PCBs mainly found are PCB-118, PCB-105 and PCB-156. Many congeners of dioxins/furans and some of dioxin-like PCBs were not detected in the analysed samples.

4.1.2.3. Dioxin/furan concentrations in solid waste from cement plants

Flue gas from cement plants contains a large amount of dust due to grinding and mixing of solid materials under relatively high temperature (200-450^{0}C). Dust from flue gas will be diverted through an electrostatic filtering system and retained. The fly ash samples will be collected at this filtering system for dioxin/furan analysis. Dioxin concentrations in fly ash samples from three cement kilns are shown in Table 4.18.

Table 4.18. Dioxin residue concentrations in solid waste (pg/g) of some cement plants in Thai Nguyen, Hai Duong and Kien Giang provinces

No	Facility (no. of samples)	TEQ (pg/g)		Some technology features
		I-TEQ	WHO-TEQ	
Thai Nguyen				
1	Cement plant (n=2)	-	1.54 (0.88 – 2.21)	Fly ash samples collected from electrostatic filtering system
Hai Duong				
2	Cement plant (n=2)	-	1.74 (1.58 – 1.90)	Fly ash sample collected from electrostatic filtering system
Kien Giang				
3	Cement plant (n=2)	-	7.57 (0.80 – 19.5)	Fly ash sample collected from electrostatic filtering system, slagged ash sample collected from kiln's bottom and product clinker sample

The results show that the dioxin/furan levels in fly ash samples is not high (from 0.80 to 19.5 pg WHO-TEQ/g). Currently, there are not regulations on the maximum acceptable levels of DRCs in fly ash samples from cement kilns. The standard guidelines values for industrial sewage sludge of 300 pg TEQ/g can be used. Fly ash from cement kilns surveyed were well below the above guideline values.

4.1.3. DRC concentrations from metallurgy activities

4.1.3.1. DRCs concentrations in flue gas from metallurgy activities

Metallurgy activities in general and steel manufacturing in particular all use high temperatures, which requires burning of different fuels and materials to provide heat and the availability of metal ions as additives for the formation of dioxins. Flue gas from the steel furnace is diverted through a dust filtering system before being discharged into the environment. These are the flue gas samples collected for the dioxin/furan analysis. Another metallurgy activity also surveyed in terms of dioxin emission was zinc production. The results of dioxin residue concentrations in flue gas samples collected from three metallurgy plants in Thai Nguyen in surveys in 2012 and 2013 are shown in Table 4.19.

Table 4.19. Dioxin concentrations in flue gas (pg/Nm³) of some metallurgy plants in Thai Nguyen Province

No	Facility (no. of samples)	TEQ (pg/Nm³)		Some technology features of the metallurgy plants
		I-TEQ	WHO-TEQ	
1	Steel manufacturing plant (2012) (n=3)		40.0 (16.3 – 46.0)	Technology: EAF furnace Capacity: 180000 ton/year Dust filtering, flue gas cooling using water and water circulation
	Steel manufacturing plant (2013) (n=3)	24.2 (14.2 – 31.6)	23.3 (13.7 – 29.7)	
2	Zinc electrolysis plant (n=2)	9.57 (8.76 – 10.3)	8.95 (8.06 – 9.85)	Technology: EAF furnace. Capacity: 350 ton/year.
3	Zinc production plant (n=2)	3840 (2730 – 4950)	3310 (2420 – 4200)	Technology: China. Capacity: 10000 ton/year

The result shows that TEQ concentrations in flue gas samples collected from the metallurgy industry (steel manufacturing) is relatively low (13.7 to 46.0 pg TEQ/Nm³). Flue gas samples from the plant using electric arc furnace technology has dioxin/furan emissions lower than that of steel manufacturing plants using a blast oxygen furnace. This could be due to differences in operating conditions and input materials of the two plants. The congener-specific pattern showed that furan concentrations were higher than those of dioxins. Tetra, penta and hexa-CDF are the predominant congeners. In some samples, congeners of TCDD are detected. In general, most of the samples have low TCDD/TEQ proportion, ranging from 3.7 to 25.3 percent; except for one sample with this ratio up to 81.5 percent. PCB-118 and PCB-123 are the predominant congeners. Congeners PCB-156, PCB-157, PCB-167 and PCB-189 have a very low level in the samples. The typical profile of dioxin/furan/dl-PCBs congeners are generally similar to those reported in other studies on dioxin contamination in industrial samples.

The results of dioxin/furan emissions from non-ferrous metallurgy show a substantial difference among two zinc production plants. The flue gas sample collected from the zinc electrolysis plant had low TEQ concentrations of below 10 pg TEQ/Nm^3, while the flue gas sample collected at the zinc production plant with high production capacity showed elevated PCDD/PCDF levels (up to 4,200 pg WHO-TEQ/Nm^3), apparently higher than those observed in some industrialized countries. In the two flue gas samples collected at the zinc production plant, typical congeners of dioxins/furans are TCDD; 1,2,3,7,8-PeCDD; TCDF; 1,2,3,7,8-PeCDF; 2,3,4,7,8-PeCDF and 1,2,3,4,6,7,8-HpPDF.

The dioxin levels of some of the flue gas samples from metallurgy plants in Thai Nguyen in comparison with the maximum acceptable limit stipulated in Vietnamese regulation QCVN 51:2013/BTNMT is shown in Figure 4.5.

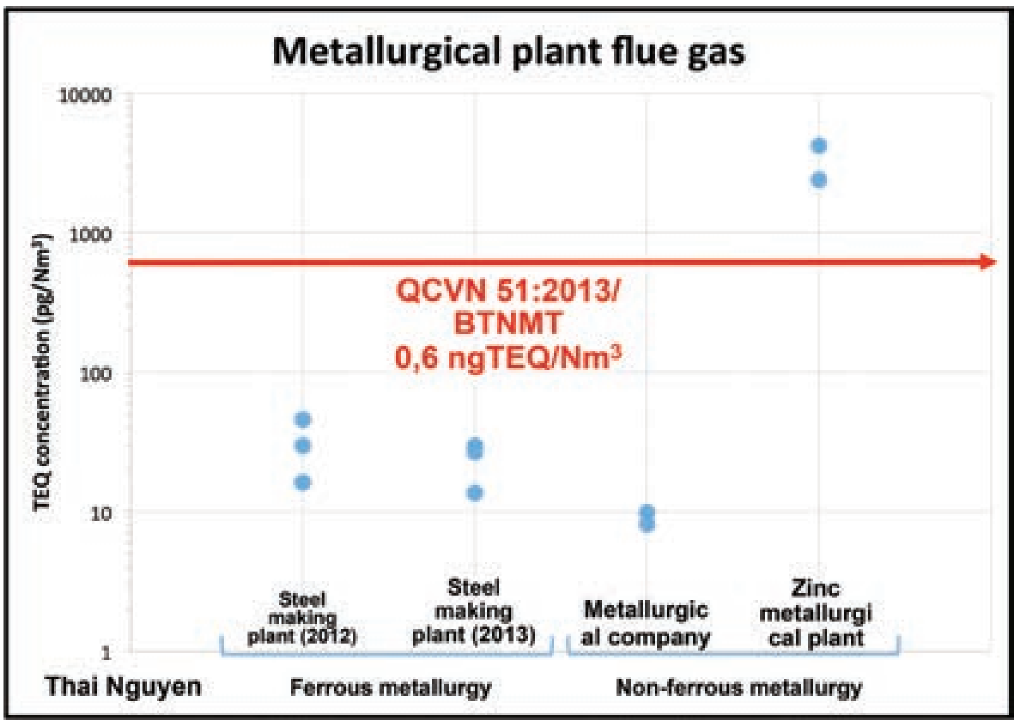


Figure 4.5. Dioxin concentrations in flue gas from metallurgical plants

In general, the value of TEQ in flue gas samples from the steel manufacturing industry in Vietnam is relatively low, ranging within the typical value of the steel manufacturing industry observed in industrialized countries. Flue gas samples from the steel manufacturing industry were generally lower than the Vietnamese regulation threshold value of 0.6 ng/Nm^3, while those in zinc production well exceeded the regulation level. This fact suggests potential emissions from zinc production and justifies the need for further comprehensive investigations of non-ferrous metallurgy in Vietnam.

4.1.3.2. DRC concentrations in wastewater from metallurgy plants

Wastewater samples collected from four metallurgy plants in Thai Nguyen were analysed for dioxins/furans/dl-PCBs. Of the surveyed facilities, there were two metallurgy plants (a steel manufacturing plant and a ferroalloy works plant) and two zinc production plants. TEQ concentrations (average and in range values) are shown in Table 4.20.

Table 4.20. Dioxin residue concentrations in wastewater (pg/L) from some metallurgy plants in Thai Nguyen Province

No	Facility (no. of samples)	TEQ (pg/L)		Some technology features
		I-TEQ	WHO-TEQ	
1	Steel manufacturing plant (n=2)	-	2.50 (2.44 – 2.55)	Water used for heat exchange tower, in circulation
2	Steel making plant (n=3)	-	0.78 (0.51 – 1.04)	Water used for heat exchange tower
3	Zinc electrolysis plant (n=2)	-	1.63 (1.16 – 2.10)	Water used for heat exchange tower
4	Zinc production plant (n=1)	-	1.78	Water used for heat exchange tower

Dioxin concentrations in wastewater samples from the steel manufacturing plant show a relatively low value, at only around 2 pg TEQ/L (water samples used for heat exchange collected at the electric arc and refining furnace have a concentration of 2.44 pg/L; water samples used for heat exchange collected at the casting machine has a concentration of 2.55 pg/L). In both these samples, almost dioxin congeners have chlorine atoms from four to six are below the detection limit of the analysis method. The congeners with highest concentrations are OCDD, TCDF and PCB-118. The remaining samples even have lower TEQ concentrations, ranging from 0.51 to 1.78 pg/L. Congeners mainly found are OCDD, TCDD, TCDF, especially one sample collected at the ferroalloy works plant having TCDD level of 0.59 pg/L, accounting for 42.1 percent of the TEQ value; two samples (one at the zinc production plant and another at the metallurgy and mining company) are not found with any dioxin/furan congeners. The main dl-PCBs were PCB-118, PCB-105, PCB-156 and PCB-77.

Hence, the DRC amount in wastewater samples from the steel manufacturing plant is not significant. If this is compared to the dioxin thresholds of wastewater in Japan of some other industries, which is 10 pg TEQ/L, the surveyed samples do not exceed that threshold. However, the existence of one sample with a relatively high TEF level of 0.1, as well as the availability of many other congeners of DRCs, the long-term risk of this emission source should not be neglected.

4.1.3.3. DRC concentration in solid samples from metallurgy plants

The input materials for a steel manufacturing plant are normally ferrous ore or scrap, scorifier (normally limestone) and air flow. The solid material inflow is from the top of the furnace while the airflow is injected from the bottom of the furnace and thus the amount of the dust created in the furnace is very large. Bottom ash is mainly composed of aluminium oxide and silicone dioxide, and is normally used as input materials for cement production. Dust in the flue gas is retained in the filtering system of the furnace, which is the main accumulating environment (if any) of dioxins and furans, and thus fly ash samples are collected from the furnace for dioxin/furan analysis. The analysis results of the DRC concentration in the solid waste samples of the metallurgy are shown in Table 4.21.

Table 4.21. Dioxin concentrations in industrial solid samples (pg/g) from some metallurgy plants in Thai Nguyen province

No	Facility (no. of samples)	TEQ (pg/g)		Some technology features
		I-TEQ	WHO-TEQ	
1	Steel manufacturing plant1 (n=2)	-	933 (839 – 1030)	Fly ash collected at the dust filtering system of the steel manufacturing furnace's chimney
2	Steel manufacturing plant2 (n=2)	-	0.39 (0.19 – 0.60)	Fly ash collected at the dust filtering system of the steel manufacturing furnace's chimney
3	Ferroalloy works plant (n=3)	-	3.67 (0.58 – 8.58)	Fly ash and slagged ash
4	The metallurgy and mining company (n=1)	-	5.51	Bottom slagged ash
5	Zinc production plant (2012) (n=2)	-	626 (8.94 – 1240)	Fly ash collected at the dust filtering system of the zinc production furnace's chimney
	Zinc production plant (2012) (n=2)	-	2500 (1200 – 3800)	Residual ash in wastewater collected at the beginning and end of the water ditch

The TEQ concentration in solid samples collected from steel manufacturing furnaces varies largely, ranging from 0.19 pg/g - 3,800 pg/g TEQ. The difference in dioxin/furan emissions in ash samples at steel manufacturing plants mainly depends on the technology. It should be noted that TEQ concentrations in dioxin highly contaminated dust samples from metallurgy is similar to those of soil samples collected from AO/ dioxin hotspots in Vietnam. Dioxin/furan congeners have the highest level in the samples are 1,2,3,7,8-PeCDD (with the highest sample reaching up to 215 pg/g) and 2,4,4,7,8-PeCDF (with the highest sample reaching up to 515 pg/g). Dioxin/furan congeners with chlorine atoms of seven and eight are in generally low concentration or were not even detected in many samples. Typical dl-PCBs congeners are PCB-118 and PCB-105. Congeners such as PCB-123, PCB-156, PCB-157, PCB-167 and PCB-189 are found in samples at low concentration.

Currently, there are not specific regulations on the maximum level of DRCs for solid waste from metallurgy plants. The TEQ concentration in solid waste samples of metallurgy plants compared to the US standard on TEQ thresholds in industrial sewage sludge is shown in Figure 4.6.

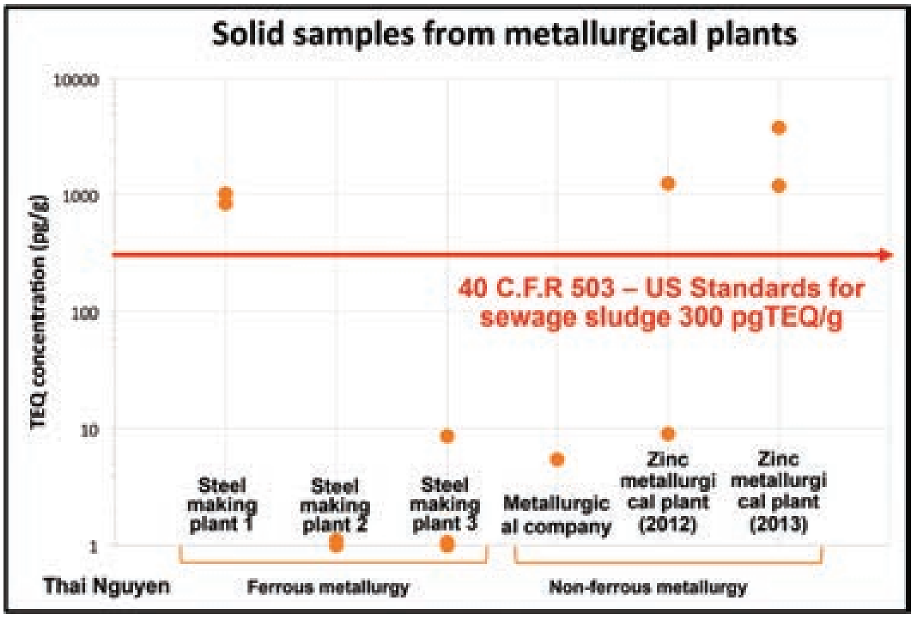


Figure 4.6. Dioxin concentrations in solid samples (ash, dust) from metallurgical plants

Five out of 12 solid samples have a TEQ concentration exceeding the threshold of 300 pg/g. The dioxin/furan level in fly ash collected from steel manufacturing plants using EAF technology have a TEQ of over 1,000 pg/g and ash and sediment ash from zinc production plants have a concentration of over 1,000 pg/g and nearly 4,000 pg/g respectively. In contrast, solid samples collected at steel manufacturing plants using air furnace technology and the other colour metallurgy plant have values below 10 pg/g with samples having almost no dioxin/furan congeners. Hence, to minimize the formation and emission of dioxins from metallurgy, it is necessary to pay attention to various phases of the production process, from the quality of the ore material powder to suitable technologies to be selected and especially the management and treatment of emission sources such as flue gas and ash.

4.1.4. DRC concentrations from paper production industry

4.1.4.1. DRC concentrations in flue gas from paper plants

DRCs are formed during paper and paper pulp production industry mainly due to thermal activities to process materials and the use of organic chlorinated compounds to bleach paper pulp. This is considered as the pre-dioxin substance. Flue gas from the boiler after the burning process will be diverted through an electrostatic dust filtering system and then cooled down with water. The temperature of the gas flow after cooling is 250 - 400^{0}C. This is a suitable temperature for the formation of dioxins.

TEQ concentrations were relatively low in flue gas samples from paper production plants, at an average value of 100 pg WHO-TEQ/Nm^3 (ranging from 43.5 to 161 pg TEQ/Nm^3) which means that an investment into production technologies as well as waste treatment technologies will contribute to reducing the formation and emission of dioxins/furans. Congeners detected with a high levels in the samples are OCDD; 1,2,3,4,6,7,8-HpCDF and OCDF. The level of 2,3,7,8-TCDD detected in both 2 samples was very low and this congener has not been detected in one sample. Comparing the dioxin thresholds in the incinerator flue gas to Vietnamese regulation QCVN 30:2012/BTNMT, all flue gas samples from paper plants have a TEQ concentration below the thresholds. If this is compared to the acceptable level of dioxins in flue gas subject to the US standard (0.1 ng TEQ/Nm^3), only one-third of the samples exceed the TEQ concentrations.

4.1.4.2. DRC concentrations in wastewater from paper plants

Wastewater samples from one paper plant in Phu Tho were collected for dioxins/furans analysis. Paper and paper pulp production is an activity using water and different solutions in many phases such as cleansing of input materials, boiling materials, bleaching paper pulp and formation pressing, etc. Hence, wastewater from this activity is an issue of concern. Of the above phases, the bleaching of paper pulp is the most important factor which decides the end product quality. This is also the phase considered with a dioxin emission possibility due to the use of different chemicals for bleaching. In the case of the surveyed paper plant, paper pulp bleaching process goes through four stages. These are bleaching with oxygen, bleaching with a chlorinated compound, bleaching with alkali and using oxygen with sodium hypochlorite. Dioxins and related compounds are mostly likely formed in the stage using chlorinated compounds. The paper plant applies paper bleaching technology which reduces up to 15 kg of chlorine per one ton of paper pulp, meaning the a reduction of 50-70 percent of chlorine.

Chemical analysis of dioxins in wastewater samples from paper and paper pulp production activities are very low (from 1.98 to 2.76 pg TEQ/L) which show that if at the paper bleaching stage, chlorinated compounds such as chlorophenols are reduced, the formation of and emission of dioxins will also be significantly reduced. If the TEQ concentration analysed from wastewater samples of the paper and paper pulp industry is compared with dioxin thresholds in some of the industrial activities subject to Japanese standards, all the samples' values are below the threshold (10 pg TEQ/L).

4.1.5. DRC concentrations from thermal power industry

Thermal power is an industrial activity with the possibility to form and emit DRCs into the environment. The main source of emission is from fuel combustion such as coal, oil, gas and biomass, etc. High temperature, the availability of materials with carbon, chlorinated compounds and additive metals are basic factors which help to form dioxins. The higher the capacity that the thermal power plant has, the higher the risk of dioxin emission it is and it requires strict control right from the input material stage, through the production technology and especially waste treatment technologies.

4.1.5.1. DRC concentrations in flue gas from thermal power plants

Flue gas samples from two thermal power plants in Hai Duong and Quang Ninh were collected for analysis of 29 parameters of dioxins/furans/dl-PCBs. These provide important data to assess the baseline concentration and dioxin emission level in thermal power activity. Currently, the database on dioxin emissions from this industry is very limited. The TEQ concentration analysis (average and in range values) in the solid flue gas samples from thermal power plants is shown in Table 4.22.

Table 4.22. Dioxin concentrations from flue gas (pg/Nm^3) of some thermal power plants in Hai Duong and Quang Ninh provinces

No	Facility (no. of samples)	TEQ (pg/Nm^3)		Some technology features
		I-TEQ	WHO-TEQ	
Hai Duong				
1	Thermal power plant (n=2)	262 (171 – 353)	252 (167 – 336)	Flue gas from boiler Capacity: 2 assemblies of 400 MW and 600 MW
Quang Ninh				
2	Thermal power plant (n=2)	96.4 (17.6 – 175)	89.3 (17.3 – 161)	Flue gas from boiler Total capacity of 740 MW

At the thermal power plant in Hai Duong, the TEQ concentrations in two flue gas samples from the surveyed thermal power plant is 167 pg WHO-TEQ/Nm^3 and 336 pg WHO-TEQ/Nm^3. If only 17 parameters of PCDD/Fs are counted, these values will be 151 and 309 pg WHO-TEQ/Nm^3 respectively. The proportion of dl-TCDD/TEQ and PCBs/TEQ is very low. The sample with the higher concentration is the sample collected from the chimney of the (former) Soviet Union's technology assembly, with a capacity of 400 MW, which has been in operation since 1983. The sample with the lower concentration is the flue gas sample from a new technology assembly chimney, with a capacity of 600 MW, and commencing operations in 2000. Congeners detected with a high level include OCDD; 1,2,3,4,6,7,8-HpCDD; 1,2,3,4,6,7,8-HpCDF and OCDF; and dl-PCBs such as PCB 118, PCB 105 and PCB 156.

In flue gas samples from the thermal power plant in Quang Ninh, the TEQ concentrations are clearly varies. The more contaminated sample has TEQ concentration which is 10 times higher than the other sample. The TEQ concentration in these two samples is lower than those collected in Hai Duong. In the sample with higher TEQ concentration (161 pg/Nm^3), all 29 parameters of DRCs were detected. These are mainly Tetra and Penta-CDD and -CDF; main dl-PCBs detected are PCB 77, PCB 118, PCB 105, PCB 126. The other sample has low TEQ concentration (17.3 pg/Nm^3); the dioxin with the highest concentration is TCDD, making up 37.5 percent of the TEQ. Tetra and Penta-CDFs also have a high concentration. The main dl-PCBs are PCB-118, PCB-105 and PCB-77.

DRC emission in the flue gas from the thermal power industry is generally within the low range, similar to the paper production and electric arc furnace in the steel making industry. These levels were also below the Vietnamese regulation level of 0.6 ng/Nm^3 (or 600 pg/Nm^3).

4.1.5.2. DRC concentrations in wastewater from thermal power plants

Wastewater samples from thermal power plants were collected for analysis of dioxins/furans/dl-PCBs. This data was then used to assess the DRC contamination levels in wastewater and provides important information to propose acceptable levels of concentration of DRCs in the thermal power industry category. Two thermal power plants in Hai Duong and Quang Ninh were surveyed and samples collected for DRC analysis.

At the plant in Hai Duong, the average TEQ concentrations in four wastewater samples is 3.91 pg WHO-TEQ/L and the concentration ranges from 1.99 to 5.23 pg/L. The TEQ concentrations in the wastewater sample collected at the basin for slag which has gone through a preliminary treatment process of sedimentation and filtering for circulation is 1.99 pg/L. The pre-treatment wastewater sample from the boiler is 3.71 pg/L; the water sample collected at the boiler cooling ditch is 4.70 pg/L; and the water sample with the highest TEQ concentration (5.23 pg/L) is the slag waste water sample collected at the point before discharge into the sedimentation basin. Comparing to the Japanese standard on the DRC threshold in wastewater of some industrial activities of 10 pg TEQ/L, these wastewater samples do not exceed the standard value. Of the dioxins, OCDD has the highest level in all four samples (with the highest one up to 31.27 pg/l). Parameters of HxCDD are below the detection limit in two out of four samples. The furan congener with the highest level in the samples analysed is 2,3,7,8-TCDF. Many congeners of dl-PCB are below the detection limit such as PCB-77, PCB-81, PCB-123, PCB-126 and PCB-169. The congeners of PCB having high concentration in samples are PCB-105 and PCB-118.

At the plant in Quang Ninh, the average TEQ concentration in the samples is 0.87 (0.51-1.56) pg WHO-TEQ/L. The TEQ value is not high, but the proportion of TCDD/TEQ is a matter of concern as in all three samples this proportion is relatively high, ranging from 34.8 to 61.9 per cent. Apart from TCDD, congeners detected with a high level in the samples are OCDD; 1,2,3,7,8,9-HxCDF; 1,2,3,4,6,7,8-HpCDF; OCDF; PCB-118, PCB-105 and PCB-156. Similarly to the samples in Hai Duong, the dioxin residues in Quang Ninh are about 6 - 20 times lower than the Japanese standard value of 10 pg/L TEQ.

4.1.5.3. DRC concentrations in solid waste from thermal power plants

Solid waste samples were collected from a thermal power plant in Quang Ninh to analyse the concentration of 29 parameters of dioxins/furans/dl-PCBs with the number of samples n=3. One sample was collected in 2013 and two other were collected in 2014.

The average TEQ concentration in ash samples was 0.38 (0.27-0.52) pg/g. Compared to the dioxin concentrations in solid waste samples of other industries, such as waste incinerators, metallurgy, boiler or cement production, the TEQ concentration in the solid waste samples of the thermal power industry is very low. The sample collected in 2013 is fly ash from the (former) Soviet Union technology assembly, with a capacity of 110 MW. Dioxins and dioxin-like PCBs concentrations in the fly ash sample is 0.36 pg/g. If only 17 parameters of PCDD/Fs are counted, it would be 0.35 pg/g. Congeners of dioxins and furans which were not detected in the samples include Penta and Hexa-CDDs; 1,2,3,7,8,9-HxCDF; 1,2,3,4,7,8,9-HpCDF and OCDF. The main congener detected was OCDD. The most toxic congener 2,3,7,8-TCDD was also detected at a level of 0.15 pg/g. For dl-PCBs, the congeners with a high concentration in the sample included PCB 118 and PCB 105. Congeners such as PCB 81, PCB 126 and PCB 169 were not detected in the sample. Of the two samples collected in 2014, the congeners detected were mainly TCDD; OCDD; TCDF; 1,2,3,4,6,7,8-HpCDF; OCDF and two congeners of dl-PCBs, PCB 118 and PCB 105.

Overall, preliminary investigation suggests that dioxin emissions from thermal power industry in Vietnam were in low range as compared to other sectors such as waste incineration and metallurgy. However, for toxic and unintentionally formed substances such as dioxins, furans and dl-PCBs, small emission and releases may pose long term impacts to ecosystem and human health. The thermal power industry in particular and other industries in general, should invest in modern production and manufacturing technologies and advanced waste treatment technologies to minimize the formation and emission of DRCs into the environment.

4.1.6. DRC concentrations from the boiler industry

The general principle of industrial boilers is to use fuels such as coal, wood, oil or gas to boil water. Steam is formed and the pressure is then diverted for use in steam engines and steam turbines. Although boilers provide a safe energy source without causing fires or explosions, there remains the possibility of dioxin formation and emission into the environment due to the fuel used to boil water. Flue gas, wastewater and solid waste samples from boilers were collected at two boilers with distinct differences in terms of scale and technologies. This includes one small family-scale boiler at a malt production unit in Cat Que commune in Hoai Duc district of Hanoi, and an industrial-scale boiler belonging to an energy company located in an industrial park in Hai Duong.

Dioxins in the flue gas from a boiler in Cat Que are relatively high at 1,790 pg I-TEQ/Nm^3 and 1,650 pg WHO-TEQ/Nm^3. The congener with the highest level detected is 1,2,3,4,6,7,8-HpCDF (up to 3,000 pg/Nm^3), followed by congeners 1,2,3,4,6,7,8-HpCDD and 2,3,4,7,8-PeCDF. The most toxic congener 2,3,7,8-TCDD is also detected but at a low level (74 pg/Nm^3). Flue gas samples from the boiler in Hai Duong have a much lower TEQ concentration, at 22.9 pg I-TEQ/Nm^3 and 19.9 pg WHO-TEQ/Nm^3. The main congeners detected in this sample are 1,2,3,7,8-PeCDF; 2,3,4,7,8-PeCDF and 2,3,7,8-TCDF, and the main dl-PCBs are PCB 118, PCB 105 and PCB 77.

The TEQ concentrations in the ash sample from the boiler in Cat Que had a value of 12.6 pg WHO-TEQ/g. The congeners with the highest concentration are 1,2,3,7,8-PeCDF; 2,3,7,8-TCDF and 1,2,3,4,7,8-HxCDF. Congeners of Hx-CDD are not detectable. Dioxin levels in fly ash collected at the dust filtering device of the boiler in Hai Duong was 78.4 pg WHO-TEQ/g, higher than that of the sample in Cat Que. All 17 parameters of PCDD/Fs were detected. The main congeners available in the sample are 1,2,3,4,6,7,8-HpCDD and OCDD.

A dioxin concentration in the wastewater sample of the boiler in Hai Duong is 0.68 pg/L. The only furan congener detected is 2,3,4,6,7,8-HxCDF. Congeners of dl-PCBs with a high concentration are PCB 118, PCB 105, PCB 77 and PCB 156. The average and in range concentrations in three wastewater samples collected from the boiler in Cat Que is 1.09 pg/L, and the concentration ranges from 0.71-1.70 pg/L. The proportion of TCDD/TEQ is from 17.7 to 35.2 per cent. The main congeners are OCDD; 1,2,3,6,7,8-HxCDD; OCDF; 1,2,3,4,6,7,8-HpCDF; 1,2,3,4,7,8,9-HpCDF; PCB 118 and PCB 105.

The concentration in each flue gas sample of the boiler in Cat Que is high, although it is smaller in terms of scale and capacity compared to the boiler in Hai Duong. The contamination of DRCs in the boiler flue gas depends on the fuel used for heating and also the flue gas treatment technology. The fuel source for small boilers is normally not strictly controlled. This result indicates that outdated small scale boilers could be a potential source of dioxins and related compounds. Further investigations are needed to measure dioxin emissions in such boilers, which are commonly operated in craft villages in North Vietnam.

4.1.7. DRC concentrations from brick production activities

Brick production is also an industrial activity with the possibility to form and emit dioxins and DRCs into the environment as brick kilns require a high temperature by burning fuel such as coal, wood, sawdust and husks. For manual kilns, the input materials are not controlled, especially the use of waste fuels to reduce production costs, the burning temperature does not meet the required temperature for the kilns, the high level of oxygen and flue gas is discharged almost directly into the environment without being treated, and thus the risk of environmental contamination is a serious concern. To overcome disadvantages of the traditional brick kiln, the tunnel kiln technology is applied widely with advantages such as a high output, making maximum use of the temperature in the kiln to dry material, reducing the product drying duration, reducing carbonic gas emissions and environmental contamination due to flue gas.

To assess the formation and emission levels of dioxins into the environment from brick production, wastewater and solid waste samples from one plant using tunnel technology in Dong Hy district in Thai Nguyen province, with a design capacity of 20 million bricks/year, were collected and analysed for 29 parameters of DRCs. This plant commenced operation in the latter half of 2011 and by 2014 it has been in operation for three years.

A dioxin concentration in the wastewater sample of the plant was 0.99 pg WHO-TEQ/L. This is a low content level, equal to the surface water samples collected from the environment. In this sample, only one congener of dioxin, OCDD, was detected at the concentration of 1.0 pg/L. The dl-PCB congeners detected were PCB 118, PCB 105, PCB 77, PCB 156 and PCB 189, of which PCB 118 had the highest concentration of 27.5 pg/L.

The average and in range values of the TEQ concentration in three solid waste samples collected at the brick production plant were 0.42 (0.21-0.78) pg WHO-TEQ/g. The sample with the highest TEQ concentration (0.78 pg/g) is the bottom slag sample. TCDD was detected in this sample with a concentration of 0.33 pg/g, accounting for 34 per cent out of TEQ. Other congeners with a high concentration were OCDD, OCDF and dl-PCBs such as PCB 118, PCB 105, PCB 156 and PCB 77. The sample with the lowest TEQ concentration (0.21 pg/g) was the sample of soil and coal ash mixture. The congeners that were mainly detected include OCDD, TCDF, PCB 118 and PCB 105.

In general, the TEQ concentration in the waste from the brick production plant using tunnel technology shows low, equal or lower values than the baseline levels usually found in the environmental media samples. However, with only one facility and a limited number of samples, it is not possible to provide overall comments on the formation and emission of DRCs from brick production activities, especially when manual brick kilns still exist. This fact warrants further comprehensive investigations.

4.2. Overall assessment of dioxin emissions from industrial activities in Vietnam

4.2.1. DRC emissions from industrial flue gas

Industrial flue gases are among the most important media in term of dioxins and other toxic chemicals. Flue gases contain various semi-volatile organic compounds and a large fraction of solid/dust particles is also present. Persistent organic pollutants such as dioxins and furans are strongly absorbed in particulates, can be transported a long distance and accumulate in water and biota through run-off. Dioxin formation and releases in flue gases are particularly important in some potential sectors such as waste incineration due to the relatively low temperature combustion (as compared to other sectors), as well as in sectors which involve some favorable factors for dioxin formation such as secondary metal production (zinc, copper, aluminium etc.).

In Vietnam, in general, there are flue gas treatment systems and air pollution control devices (APCD) in most of the industrial enterprises. However, technology is still outdated and there is a lack of an effective treatment. Regular monitoring of the dioxins and furans in stack gas has not been well implemented due to the lack of advanced sampling and analytical techniques.

Dioxin concentrations in flue gases from different industrial sectors revealed different patterns, depending on some key factors such as input materials, production technology, operation conditions and gas treatment (APCD) system. A summary of the dioxins and furans concentrations (expressed as pg toxic equivalency - TEQ/Nm^3) is illustrated in Figure 4.7. Several standards and regulation guideline values for dioxin emision in fuel gases proposed by Vietnam and international organizations and countries were also plotted for comparison and in order to understand the magnitude of contamination of dioxins in Vietnamese industrial sectors. The contamination pattern was in the order of waste incineration > non-ferrous metallurgy > cement production > thermal power plant > steel making > paper production. It is clear that dioxin emission from waste incineration in Vietnam has the highest levels, with some samples well exceeding the regulation threshold values for fuel gases. The national regulation threshold level for industrial hazardous waste incineration is 0.6 ng TEQ/Nm^3, while that for medical waste incineration is 2.3 ng TEQ/Nm^3. There are a number of samples of industrial hazardous waste incinerators which contain dioxin concentrations well beyond these regulation values. The lack of APDC, improper sorting of input materials and operation conditions, particularly the treatment system after the combustion chamber, may faciliate de novo synthesis of dioxins/furans. The levels of dioxins in flue gases of waste incinerators varied widely, ranging from 0.124 - 44 ng TEQ/Nm^3, in which some higher levels were found in an industrial waste incinerator, and lower levels were observed in small scale municipal waste incinerators.

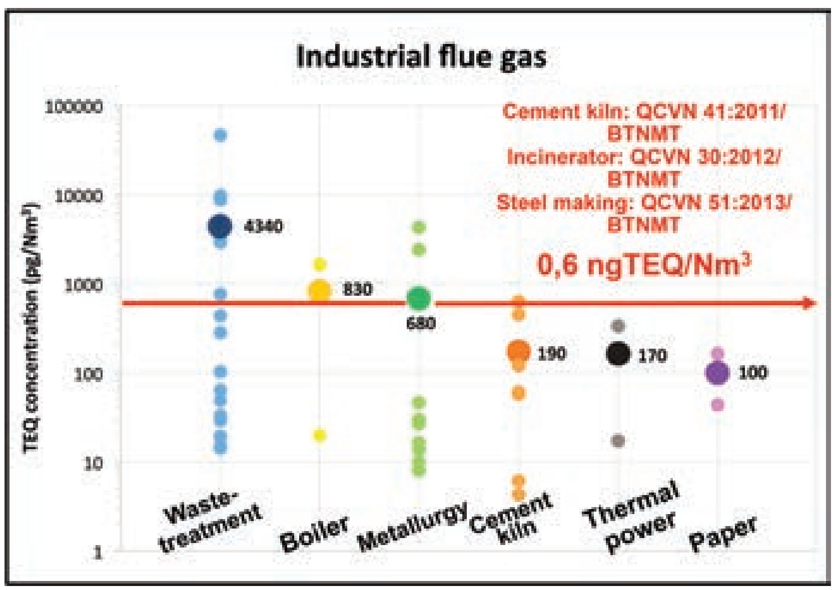


Figure 4.7. Dioxin concentrations in flue gas in different industrial sectors

In Europe, most of the hazardous combustion systems are equipped with rotating incinerators, thus ensuring high combustion efficiency and low dioxin emissions. A report on dioxin emission in 15 EU member countries, together with Norway and Sweden, shows that dioxin emissions from hazardous combustion significantly reduced between 1985 and 1995. The total emission in 1985 was around 300g I-TEQ/year and reduced to below 200g I-TEQ/year in 1995, and is expected to continuously reduce in future (*Quaß et al.,2004*). A 1992 report by the European Centre for Ecotoxicology and Toxicology of Chemicals also provides a general picture of dioxin emission from the hazardous waste combustion system in some European countries. According to this report, most of the dioxin concentration in flue gas is below 0.1 ng TEQ/m^3. However, emission values higher than 0.1 ng TEQ/m^3 has also been detected at some of the waste combustion systems.

In Asian countries, many studies on dioxin emissions in industrial flue gas have been published. In Korea, two investigations showed average concentrations are 0.778 and 3.15 ng TEQ/Nm^3 (Sam Cwan Kim, 1999 and Donghoon Shin, 1999). In Taiwan, TEQ concentrations in flue gas ranges from 0.43 to 4.8 ng I-TEQ/Nm^3 (Moo Been Chang et al., 2002). The level of PCDD/PCDF in flue gas from industrial waste combustion systems in Siaogang district, Kachsiung city, in Taiwan are 0.137 and 10.245 ng TEQ/Nm^3 (Kao et al., 2007). Another piece of research in Taiwan shows the result for PCDD/PCDF ranging from 0.084 to 0.239 ng TEQ/Nm^3 (Jenshi B.Wang, 2009).

In general, dioxin emission in flue gas samples from industrial waste incinerators in Vietnam is similar or slightly higher than some other developing countries and newly industrialized countries in Asia. However, some exhaust samples with an unusually high TEQ concentration (up to 50 ng TEQ/Nm^3) show that dioxin formation and emission from incinerators in Vietnam is complicated and not easy to control, while not enough attention and investment is being directed to incinerator flue gas treatment technologies. If comparing TEQ concentration in flue gas to Europe, the dioxin emission levels in waste combustion activities in Vietnam are much higher and many samples have values exceeding the threshold of some European countries of 0.1 ngTEQ/Nm^3. This fact is a matter of concern because industrial waste as well as waste treatment facilities have increased in recent years. If regulations on dioxin emission levels are not followed strictly, waste incineration is not controlled regularly with periodic monitoring, and the incinerator facilities themselves cannot ensure the combustion technologies and do not have advanced technology to treat flue gas sources to control and minimize dioxin formation and emission. In term of flue gas samples, waste incineration and non-ferrous metallurgy are potential sectors that deserve particular attention.

For metallurgy, the average TEQ concentrations in flue gas samples collected at some of the metallurgy plants in Thai Nguyen is 680 pg/Nm^3 and varied markedly from 8.06 to 4,200 pg/Nm^3. This is the industrial activity with the second highest emission levels, just after waste treatment. The level of PCDD/F in flue gas samples from the metallurgy industry in Korea, such as zinc, aluminium, copper and lead production, ranges from 0.036 to 16.818 ng TEQ/Nm^3. In Taiwan, recent studies show the level of PCDD/F in flue gas samples from metallurgy plants as follows: secondary aluminium work plants is 10.6 ng TEQ/Nm^3 (*Lee et al., 2004*) and metallurgy industrial parks from 0.032 to 0.256 pg I-TEQ/Nm^3 (*Jenshi B.Wang et al., 2009)*. Survey results from secondary aluminium, steel and copper manufacturing in China show that the level of PCDD/F is in the range of 0.03-232 pg WHO-TEQ/Nm^3. Hence, PCDD/F emissions in the flue gas samples from the metallurgy plants in Vietnam were in similar range compared to some plants in other countries such as Korea, China and Taiwan.

Cement kilns are the industrial activity with the third highest dioxin emission level. The highest TEQ concentration in the cement kiln flue gas sample is similar to the maximum threshold of the incinerator's flue gas (0.63 ng TEQ/Nm^3) as compared to 0.6 ng TEQ/Nm^3). However, if comparing the TEQ concentration of cement kiln flue gas to Canada, the USA and European countries (0.1 ng TEQ/Nm^3), some of the analysed samples show higher values than those referenced standards. In 2001, the European Cement Association collected and analysed flue gas samples and the results show that the TEQ concentration ranges from 0.001-0.163 ng TEQ/Nm^3. So the TEQ concentration in cement kiln flue gas in Vietnam in general is still higher than in Europe. Although the input materials are not as complicated as those for the waste combustion activity, with large capacities, use of a high temperature, a big amount of ash and dust produced, plus the use of recycled fuels in the heating stage to reduce production cost, the cement production needs to focus on improving technologies for waste source treatment. This includes a dust filtering electrostatic system and a scrubber tower combining water cleansing and activated carbon spraying to minimize the formation of dioxins in cement kilns.

For thermal power plants and paper plants, the TEQ concentration in flue gas samples are all lower than the regulated thresholds. Hence, it can be initially concluded that these industrial activities are not the main DRC formation and emission source into the environment. However, it is necessary to increase the survey scale such as increasing the number of surveyed facilities and number of samples to obtain a more relialistic picture of contamination.

4.2.2. DRC emissions from industrial wastewater

Water is used for different industries, mainly for cleansing input materials, cooling equipment in the production systems and in the flue gas treatment system of wet-type chimneys. For some specialized industries such as paper and paper pulp production, water is present at all the stages of the production process, from material soaking and cleansing, to material heating, mould pressing and flue gas cleansing. Wastewater from paper production plants is always at risk of being contaminated with bleaching or dyeing chemicals. For facilities under waste treatment, especially wastewater, attention should be paid to contamination parameters in the water course after treatment and at discharge. Other industrial activities such as thermal power, metallurgy and cement production in general use circulated water, and thus the wastewater amount is not large. Although wastewater does not strongly accumulate non-bias compounds such as the DRCs mentioned in this report, in all wastewater samples collected and analysed throughout different industrial activities, DRCs were detected, with a TEQ concentration in some samples at a high level. The overall picture of the dioxin concentrations in the industrial wastewater samples is shown in Figure 4.8.

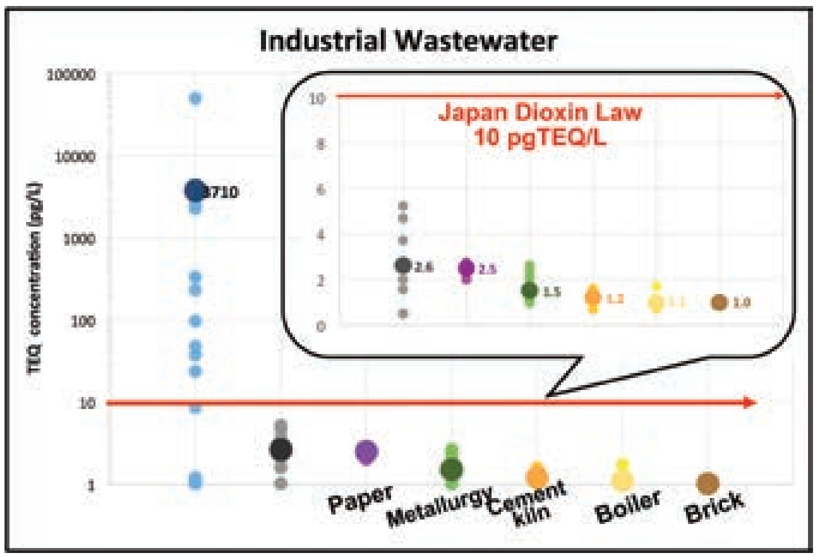


Figure 4.8. Dioxin concentrations in wastewater from different industrial sectors

Currently, Vietnam has issued some regulations on maximum limits for dioxins/furans in incinerator flue gas, soil and hazardous waste but not regulations on water (such as industrial wastewater, domestic wastewater and natural water). The threshold values used in this report are the Japanese standards of a maximum TEQ concentration of 10 pg/L in industrial wastewater, such as wastewater from cleansing activities, wastewater from treatment activities for waste containing PCBs, leachate water from landfills for incinerator solid waste and overflow wastewater from waste treatment facilities. This is a relatively strict standard, showing that environmental protection is taken seriously in Japan.

According to the survey and analysis results, the TEQ concentration in wastewater from industries in Vietnam such as **thermal power, metallurgy, boiler paper production, cement and bricks** is in general at the low end and does not exceed the threshold of 10 pg/L. For thermal power, metallurgy and cement, the low TEQ concentration can be explained by the fact that the input materials are not a high risk source for the formation of dioxins (such as hazardous waste and materials that contain dioxin precursor substances). In addition, the flue gas is filtered for dust before water is added for cleaning (water used for cleansing flue gas contains a lot of sediment and is considered as an environment for accumulating Darks) and the temperature of the kilns is controlled to reduce the formation of dioxins. In the paper and paper pulp production industry in particular, improvements in production technologies, especially the use of safer bleaching chemicals as compared to traditional materials, have ensured a low concentration of dioxins in wastewater.

Regarding wastewater samples from **industrial waste incinerators and environmental contamination treatment facilities** in particular, many samples had a TEQ concentration that exceeded the threshold of 10 pg/L, and some samples showed heavy contamination (over 50,000 pg/L, more than 5,000 times higher than the threshold). The heavy contamination of DRCs in wastewater at some incinerators is because the input materials have complicated origins, and most of them are industrial and hazardous waste. Dioxins are normally formed and emitted subject to two mechanisms. One, material used for burning that contains DRCs and inefficient combustion will lead to the emission of undestroyed dioxins/furans into the environment via discharges from the incinerators. Second, materials with dioxin precursor substances, which are normally organic compounds with aromatic cores and chlorine elements, incomplete combustion processes plus the presence of chlorines will lead to a reaction between dioxin precursor substances with chlorine to form dioxins and furans. The dioxin contamination in wastewater from waste incineration activities has necessitated new requirements to control dioxins in wastewater – firstly to ensure combustion technology that reduces the formation of dioxins, and secondly investment in wastewater treatment technologies using methods such as UV, micro-organisms or absorbance substances.

4.2.3. DRC contamination in industrial solid wastes

Solid waste samples normally collected for analysis include input materials such as fly ash and bottom slagged ash. Of this, fly ash (also referred to as dust in flue gas) is considered as an environment that strongly accumulates different contaminants from heavy metal ions to organic compounds, including DRCs. In incinerators, cement kilns and metallurgy furnaces, bottom slagged ash after each combustion batch or production batch will be cooled down and then taken out. This will be used for landfilling or as materials for infrastructure construction after additives have been added. For both of these treatments, the risk for emission of toxic substances (if any) from slagged ash into the environment is subject to time and the accumulated amount in the waste. Fly ash in flue gas from nearly all furnaces/kilns is retained by a dust filtering system. The emission of DRCs into the environment depends on the dust filtering efficiency and the method of treating the retained dust from the filtering equipment. The TEQ concentrations in solid waste from industries such as thermal power, metallurgy, boiler, paper production, cement and bricks are shown in Figure 4.9.

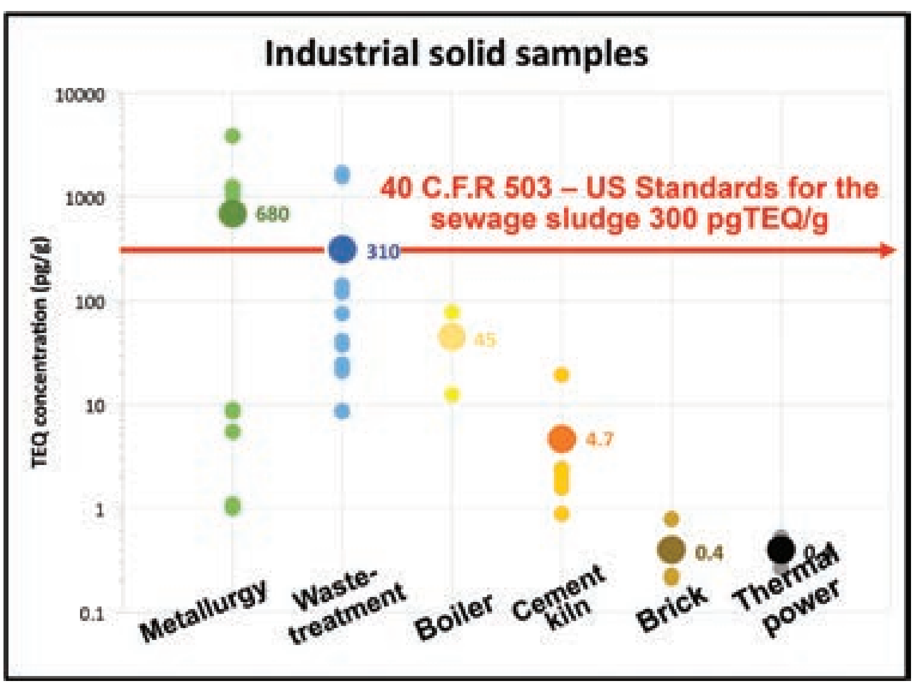


Figure 4.9. Dioxin concentrations in solid wastes from different industrial sectors

Dioxins in the fly ash samples of some metallurgy plants are remarkably higher than that of other metallurgy plants and industrial activities such as waste incineration and cement production. The industrial activity with the second highest dioxin contamination is waste incineration, followed by boiler activities, cement production and finally brick production and thermal power. A relative comparison of the TEQ concentrations in solid wastes from different industries shows the differences from exhaust and treatment waste media (of these two, the highest TEQ concentrations belong to the treatment waste).

There are no regulations on the dioxin thresholds in industrial solid waste in Vietnam, and the US standard on the maximum TEQ concentration in dry sludge from sludge usage or treatment, which is 0.0003 mg TEQ/kg dry sludge (equal to 300pg TEQ/g), can therefore be used. Using this threshold, solid waste samples from waste treatment and cement production activities do not exceed the guideline value. Only some of the fly ash samples collected from the chimneys of steel manufacturing plants which use an EAF furnace technology exceeds the threshold. The dioxin concentrations in some solid samples from metallurgy activities are similar to those in soil samples collected from AO/dioxin hotspots in Vietnam, at a level of 1,000 pg/g. This fact raises serious concern over the elevated dioxin emission in steel making industry releasing through fly ash. Facilities using EAF furnaces and blast oxygen furnace technology, especially those using scraps as input materials, need to proactively improve production technologies as well as waste treatment technologies by application of clean production and BAT/BEP (best available techniques/best environmental practices) programs for energy and resources efficiency and concurrently reduce emissions of greenhouse gases (GHGs) and toxic contaminants including dioxins and related compounds.

Part 5

DIOXIN CONTAMINATION IN THE ENVIRONMENT IN VIETNAM

DRCs are a group of very toxic substances, even if they exist in the environment at concentrations of ppb or ppt, they continue to pose long term impacts on the ecosystem and human health. Research on dioxins in human biological samples has been carried out since the 1970s, with the scale of research stretching across all three northern, central and southern regions. The two main emission sources of dioxins in Vietnam are dioxin contaminated hotspots from the war and industrial operations with the potential for dioxin generation. The level of dioxin concentration in the environment in AO/dioxin hotspots as well as industrial sites has been published in reports by the Office of the National Steering Committee, the Ministry of Natural Resources and Environment and the Ministry of Defence. In this report, the presentations, discussions and assessments are focused on dioxin contamination not related to environmental media from the two sources as mentioned above. One of the fundamental challenges to assessing the level of dioxin contamination in the environment in Vietnam is that the database on the presence, distribution and dioxin concentration in different parts of the environment remains limited.

Data on the distribution, concentration and typicality of congeners of PCDD/Fs and dl-PCBs used in this report includes research results by Vietnamese and Japanese scientists over the past 10 years. Most of this research was conducted in the south of Vietnam, as this region was seriously impacted by toxic chemicals, while it is also the largest economic center, with many industrial and processing zones with operations that have the potential for dioxin generation and emissions. In particular, analysis results of PCDD/F and dl-PCB concentration in the air, soil, sediment and ash by the Vietnam-Russia Tropical Center, Ministry of Defence, completed in 2013 and with survey locations in the northern region, are used in this study. This is a significant data set in assessing environmental pollution related to DRCs in Vietnam, with the emission sources not originating from the toxic chemicals used during the war.

To increase the objectivity of the discussions and assessments, references from local and international research over the past three decades has also been used. This research has been carried out in Vietnam, other countries in the region and worldwide. The data used in this report is up-to-date, and provides an initial sketch of the dioxin contamination in Vietnam. However, to obtain a more comprehensive and intensive assessment of dioxin contamination, further studies and research is necessary.

5.1. Dioxin contamination in environmental media in Vietnam

5.1.1. Dioxin contamination in sediment from Vietnam

Dioxins exist in water via three ways which are direct discharge into water, sedimentation and suspended particles which accumulate dioxins from the air and the erosion of dioxins from the contaminated land area through the water course or irrigation water. Dioxins can transport by water run-off to the lower areas, catchments, river mouths and then accumulate in the sediment.

The dioxin concentration in sediment in some areas in Vietnam is analysed in two studies by Shiozaki et al. (2009) and by Kishida et al. (2010). The sediment samples were collected from 2003 to 2005, in the north, centre and south-western region of Vietnam. The subjects of the study include rivers, sea sediment and marine sediment from mangrove forests, lagoons and lake beds.

Shiozaki et al. (2009) collected samples and assessed the contamination status of PCDD/Fs and dioxin-like PCBs in 12 sediment samples along the flow of the Sai Gon River and at the mouth of the Mekong River, as well as sea sediment samples collected at the seabed near Vung Tau city. The sampling duration was between 2004 and 2005. Kishida et al. (2010) collected samples and assessed the parameters of PCDD/Fs and dl-PCBs in 10 sediment samples at a mangrove forest in Can Gio, Ho Chi Minh City. In addition, three samples were collected from lagoons in Hue (rural area) and two samples collected from lakes in Hanoi (urban area). The sampling took place between 2003 and 2004.

The level of PCDD/Fs and dl-PCBs in sediment samples (average and in range values) of the two above studies is shown in Table 5.23.

Table 5.23. PCDD/Fs contamination in some types of sediment (pg/g dry weight) in Vietnam [Shiozaki et al., 2009; Kishida et al., 2010]

No	Location (number of samples n)	PCDD/F concentration (pg/g dry weight)	Reference
1	Saigon river (n=5)	∑PCDD/Fs: 1560 (890 – 2400) ∑dl-PCBs: 2500 (110 – 8400)	Shiozaki et al., 2009
2	Mekong river (n=2)	∑PCDD/Fs: 370 (220 – 510) ∑dl-PCBs: 350 (300 – 400)	
3	Vung Tau coastal area (n=5)	∑PCDD/Fs: 590 (340 – 970) ∑dl-PCBs: 1020 (25 – 4700)	
4	Can Gio (n=10)	∑PCDDs: 350 ± 160; ∑PCDFs: 36 ± 42 WHO-TEQs: 2.7 ± 1.7	Kishida et al., 2010
5	Hue (n=3)	∑PCDDs: 980 ± 1100; ∑PCDFs: 26 ± 11 WHO-TEQs: 2.9 ± 2.4	
6	Hanoi (n=2)	∑PCDDs: 390 ± 14; ∑PCDFs: 140 ± 71 WHO-TEQs: 9.6 ± 0.35	

In the study by Shiozaki et al. (2009), the levels of dioxins, furans and dl-PCBs, as well as the proportion of furans in TEQ in inland sediment, is higher than those collected offshore. The high proportion of furans in the inland samples might be attributed to the emission of PCDD/Fs from combustion activities. Remarkably high levels of dl-PCBs were found in samples collected in different locations, both inland and offshore. This means that heavily contaminated PCB points are located quite scattered. Activities using technical PCBs can be considered as an emission source of dl-PCBs, depending on the congener composition of the technical PCBs.

Dioxins and furans were discovered in all surface sediment samples. The total concentration of PCDD/Fs ranged from 250 to 1,800 pg/g dry weight. The average level was 650 pg/g. The average content in river and marine sediments was 1,560 pg/g and 520 pg/g respectively. The typical features of PCDD/Fs congeners in the river and marine sediments are similar with the main congener as OCDD; and the proportion of OCDD in the TEQ concentration ranges from 53 to 65 per cent inland and from 59 to 81 per cent offshore. This is a typical feature of the non-heavily contaminated areas in terms of PCDD/Fs.

The total level of dl-PCBs are in the range of 18 to 8,400 pg/g dry weight. The average dl-PCB level in the river sediment samples is 2,500 pg/g and in sea sediment samples 830 pg/g. Similar to PCDD/Fs, the level of dl-PCBs from samples collected inland is higher than those collected offshore. At different sampling locations, the profile of the PCB congeners is quite similar to the main congener of PCB 118, then PCB 105 and PCB 156. These are also main congeners present in technical PCBs.

The TEQ in sediment samples ranges from 0.73 to 16 (average 3.9) pg TEQ/g dry wt. or from 0.73 to 17 (average 4.1) pg TEQ/g dry wt. The TEQ value is similar to the study results of the sediment samples collected in the north of Vietnam (Hanoi) and lower than those in some of the developed industrial countries.

In the study by Kishida et al. (2010), Can Gio was selected for the survey because mangrove forests were sprayed with Agent Orange during the war. Sediment samples collected in Can Gio are the main subject of this study (number of samples n = 10); a smaller number of samples were collected in Hue and Hanoi for comparison.

The TEQ in sediment in Can Gio has a value of 2.7 ± 1.7 ng/kg dry weight, similar to samples collected in rural areas in Hue (WHO-TEQ = 2.9 ± 2.4 ng/kg dry weight) and lower than the samples collected in Hanoi (WHO-TEQ = 9.6 ± 0.35 ng/kg dry weight). Comparing the dioxin level in sediment in the two areas, one which was impacted by herbicides and another which was not, and it is clear that there is a decrease in the dioxin contamination level by defoliation chemicals in the environment. The reasons for this decrease are the destruction and transformation of dioxins under the impacts of light, temperature, and chemical and biological agents over a long period of time. In contrast, the formation of dioxins by industrial activities tends to increase and has become a source of concern which requires strict control.

The main congeners of dioxins in samples collected in Can Gio, Hue and Hanoi are OCDD, HpCDDs and HxCDDs. Of these, OCDD makes up the largest proportion in the total concentration. The proportions of HpCDDs and HxCDDs are the same; the most toxic congener 2,3,7,8-TCDD makes up a small percentage. The reasons for the high percentage of OCDD in sediment may be from natural sources and more importantly, from pentaclophenol (PCP). PCP is a growth stipulating substance for rice and forests. However, in Vietnam this substance is not widely used for cultivation but mainly for wood processing. The total furan concentration is significantly smaller than dioxins; the main congeners in samples collected in Can Gio are PeCDDs, HpCDDs and OCDD, in Hue TeCDDs, PeCDDs and HxCDDs, and in Hanoi TeCDDs and PeCDDs. Hence, there are no general rules governing the congener features in furans in sediment as there is for dioxins.

The total concentration of dl-PCBs in sediment in Can Gio and Hue is similar or lower than in Hanoi. The average concentration of dl-PCBs in Hanoi is almost 40 times higher than that in Can Gio. The percentage of dl-PCBs per total PCBs in commercial PCB products usually accounts for one per cent, while the emission source from combustion activities makes up around 50 per cent. The dl-PCBs emission source is estimated based on the ratio of the total concentration of congeners PCB 126 and PCB 169 over total concentration of congeners PCB 77, PCB 126 and PCB 169. The percentage of (PCB 126 + PCB 169) / (PCB 77 + PCB 126 + PCB 169) in Can Gio ranges from 13 to 50 per cent. The average percentage is 19 ± 15 per cent. This percentage shows that the dl-PCB emission source into sediment in Can Gio is both from commercial use of PCBs and combustion activities. The average percentages of (PCB 126 + PCB 169) / (PCB 77 + PCB 126 + PCB 169) in Hue and Hanoi are 3 ± 3 per cent and 8 ± 0 per cent respectively. These percentages show that the dl-PCB emission sources in these two areas is mainly from commercial use. The significantly high dl-PCBs level in Hue is due to commercial PCBs, as well as electronic imported products containing PCBs, which are widely used in large urban areas such as Hanoi and Ho Chi Minh City. The main PCB congeners detected in sediment are PCB 118, PCB 105 and PCB 156.

Between 2013 and 2014, the Vietnam-Russia Tropical Center conducted surveys and sampling for analysis of 29 parameters of PCDD/Fs and dl-PCBs in sediment in areas in Hanoi, Thai Nguyen and Thanh Hoa. Dioxin contamination levels in sediment samples (average and in range values) is shown in Table 5.24.

Table 5.24. Dioxin levels in sediment (pg/g dry weight) in Hanoi, Thai Nguyen and Thanh Hoa

No	Location (Sample numbers n)	Description of sampling locations	
		WHO-TEQ	
1	Hanoi (n=6)	4.28 (0.92 – 6.70)	- Two samples collected in Cat Que Commune, Hoai Duc district: handicraft villages that use boilers and furnaces - Two samples collected in Nhue river and Kim Bai town, Thanh Oai district: main activity is agriculture - Two samples collected in To Lich river and South Dong Da Ward: Center of Hanoi

***Table 5.24. Dioxin levels in sediment (pg/g dry weight) in Hanoi, Thai Nguyen and Thanh Hoa** (cont.)*

No	Location (Sample numbers n)	Description of sampling locations	
		WHO-TEQ	
2	Thai Nguyen (n=5)	1.69 (0.81 – 2.80)	- Two samples collected in post environmental treatment culvert at a metallurgy plant - One sample of sediment after treatment of wastewater from one zinc production plant. - One sample collected from a brick production plant - One sample collected from an iron and alloy manufacturing plant
3	Thanh Hoa (n=3)	0.68 (0.43 – 0.86)	- One sample collected near the waste incinerator in Nga Van, Nga Son - Two samples collected in Nga Bach, Nga Son: fishing as main activity

In Hanoi, the sediment samples collected represent three different production actvities. The sample with the highest TEQ concentration was collected from To Lich river, a contaminated river flowing through Hanoi's center (6.70 pg/g). The sediment samples collected in a morning glory pond in Cat Que commune, Hoai Duc district, has the second highest TEQ concentration (6.64 pg/g). This sampling location is near a malt production facility. The samples with the lowest TEQ concentration were collected from La Ke ditch, Kim Bai, Thanh Oai (0.92 pg/g) and from Dac Di lake, Nam Dong, Dong Da (1.29 pg/g). This lake had been dredged two years before the sampling. The percentage of TCDD/TEQ in most samples is low, ranging from 8.6 to 21.2 per cent. Only one sample collected from a ditch for wastewater in Cat Que commune, discharging into the Day River, had a percentage of up to 67.9 per cent. The percentage of dl-PCBs/TEQ is also very low, except for the sample collected in Nhue River which has a percentage of up to 39.6 per cent. The typical congeners of PCDD/Fs detected are OCDD and 1,2,3,4,6,7,8-HpCDF. The most typical congeners of dl-PCBs are PCB 118, PCB 105, PCB 126 and PCB 77. The high percentages of PCB 118 and PCB 105 are related to the use and discharge of products which contain commercial PCBs.

In Thai Nguyen, four out of five sediment samples were collected in metallurgy plants. This is a typical industrial activity in Thai Nguyen and is also considered as an activity with the possibility to form and emit DRCs into the environment. Samples were collected at the post treatment stage of wastewater before being discharged into the environment, and thus had quite a low TEQ concentration, ranging from 1.34 to 2.801 pg/g. In which, samples collected from the zinc manufacturing plant (lowest TEQ concentration of 1.34 pg/g) will be used as material for brick production. The percentage of TCDD/TEQ ranges from 8.7 to 37.6 per cent. The percentage of dl-PCBs/TEQ is very low in general. The main congeners of CDD/Fs in the samples are OCDD and OCDF. Of these, dioxins make up a higher percentage than furans. The main congeners of dl-PCBs detected are PCB 118, PCB 105 and PCB 156.

Sediment samples were also collected at a brick production facility in Thai Nguyen. The TEQ concentration analysed was 0.81 pg/g, lower than that of the sediment sample collected from the metallurgy plant. In this sample, the percentage of TCDD/TEQ was 24.1 per cent. The main congener of dioxins was OCDD, with a level of 1,110 pg/g, and furan congeners were almost not detected. The detected dl-PCBs were mainly PCB 118 and PCB 105.

In Thanh Hoa, the average TEQ concentration in samples (0.68 pg/g) is in general lower than those collected in Thai Nguyen and Hanoi. The sample considered to be closest to the dioxin emission source was collected from a soil dune in the middle of the pond near the domestic incinerator in Nga Van commune, Nga Son district, and it had the lowest TEQ concentration (0.43 pg/g). In this sample, the percentage of TCDD/TEQ is not high (22.9 per cent). The main congener is OCDD (43.9 pg/g) and Penta and HexaCDD were not detected. The main dl-PCBs are PCB 118 and PCB 105. The remaining sediment samples collected from Nga Bach, Nga Son, where fishing is the main activity, have relative low TEQ concentration (0.76 and 0.86 pg/g). The percentages of TCDD/TEQ are 17.7 and 31.4 per cent. The main dioxin congeners are OCDD; 1,2,3,4,6,7,8-HpCDD and most furan congeners are below detection limits. The main dl-PCBs are PCB 118, PCB 105 and PCB 156; PCB 77, PCB 81 and PCB 123 were not detected.

The TEQ concentrations in sediment samples collected in Hanoi, Thai Nguyen and Thanh Hoa in comparison to the dioxin threshold in sediment in heavily contaminated areas subject to TCVN 8183:2009 is shown in Figure 5.10.

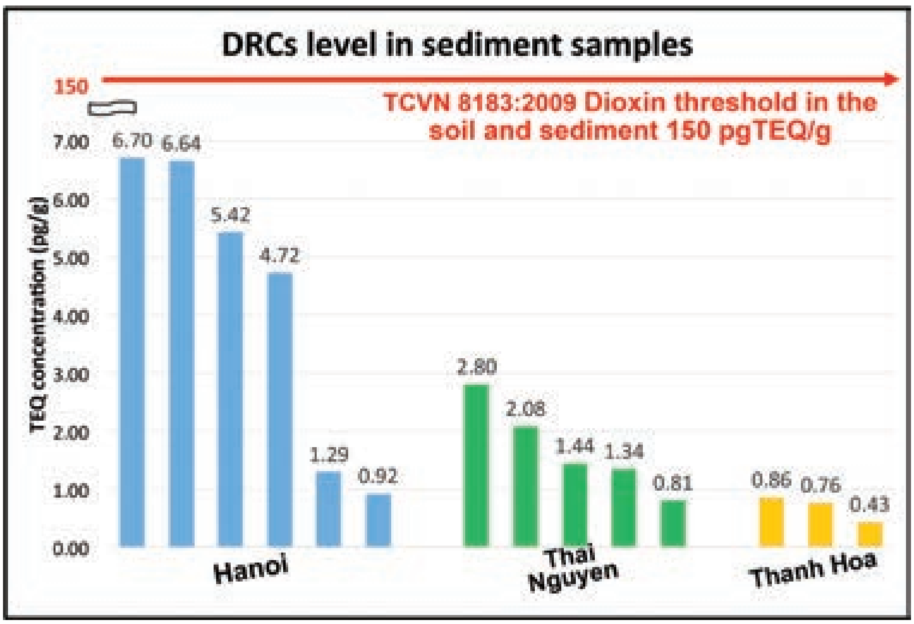


Figure 5.10. Dioxin concentrations in sediment samples in Hanoi, Thai Nguyen and Thanh Hoa

Hence, if comparing to the TEQ threshold for sediment in the heavily contaminated areas which is 150 pg/g, none of the samples in this survey exceed the threshold level. The most contaminated sample (6.70 pg/g; was collected in To Lich river) also has the TEQ concentration 20 times lower than the threshold. This data also provides useful baseline information on dioxins in sediment, which is valuable for the development of the standard guideline values of dioxin and related compounds in sediment.

5.1.2. Dioxin contamination in the soil environment in Vietnam

5.1.2.1. DRC contamination in soil originating from the AO/dioxin sources

During 1961 to 1971, the American army conducted 19,905 spray missions of toxic chemicals with nearly 80 million liters of herbicides, most of them Agent Orange/dioxin, affecting approximately 20,600 villages spread over an area of 2.63 million hectares in the south of Vietnam. Up to 86 per cent of the area was sprayed twice and 11 per cent was sprayed over 10 times. Areas directly impacted by the toxic chemicals include the northern part of the centre of Vietnam, the coastal region of the centre of Vietnam, and the highland, south-western and south-eastern regions. Of these, the south-eastern region is the most seriously impacted, accounting for 56 percent of the natural land area sprayed with toxic chemicals. The areas with the highest number of Agent Orange spray missions were the Ho Chi Minh trail, the sections running through Huong Hoa district (Quang Tri province), A Luoi (Thua Thien Hue province), Sa Thay and Dek Glei (Kon Tum province), and the south-eastern region where guerrilla bases C and Boi Loi (Tay Ninh province) were located, as well as guerrilla bases D and Tam Giac Sat (Binh Duong province) and Can Gio (Ho Chi Minh City).

After dioxins in herbicides have been dispersed into the air, if they drop on the ground they are absorbed by the soil surface and sand particles. Dioxins are normally found within a soil layer of 0-10 cm. At the layer of 10-30 cm, the possibility of finding dioxins is very little and if they are found, the concentration is very low. However, in loose and unconsolidated soil areas which easily absorb water, dioxins can transfer to deeper soil layers. Soil with heavy characteristics (more clay) has a better capability to absorb dioxins. The half-life duration of dioxins in soil under the decomposition of sunlight is one year. Under the same condition of spray, the dioxin concentration reduces more slowly than in agricultural soil, which is regularly impacted by cultivation activities and in contact with sunlight.

Dioxin contamination in forestry land in Vietnam is mainly related to herbicide spray missions during the war. After spraying defoliants, the US army continued with napalm bombing to burn withering trees and plants. The high temperature of this process was the cause of the generation of secondary dioxins. Dioxins in forestry soil are slowly decomposed due to lack of sunlight. There are studies which show that in the same area of forestry land, a second sampling carried out nine years after the first sampling had only seen a minor change in the concentration of 2,3,7,8-TCDD.

Dioxin contamination in forestry soil has been assessed through research carried out in typical herbicide sprayed areas in the central region, such as research in A Luoi district in Thua Thien Hue province from 1996 to 1999. The dioxin contamination in soil in A Luoi during the 1990s, around two decades after the end of the war, remained relatively serious. The most heavily contaminated areas are Son Thuy, A So, Ta Bat and Phu Vinh, which are all located within A Luoi Valley. These are communes which used to have US airbases or with areas sprayed with Agent Orange. The high percentage of PCDDs per total PCDD/Fs, as well the percentage of 2,3,7,8-TCDD in TEQ contributing over 80 to 99 per cent, shows that the origin of dioxin emission into the environment in these areas is from spray missions of defoliants.

From 1995 to 2000, some research centers in Vietnam, such as the Vietnam-Russia Tropical Center, Committee 10-80 and HV1 laboratory of the Hanoi National University, in cooperation with Hatfield Consultants and the Canada and Russia Academy of Science, conducted an analysis of 255 soil samples in Dong Nai, Binh Duong, Tay Ninh and Thua Thien Hue provinces. These are provinces affected by the herbicide sprays during the war. The studies discovered dioxins with an average concentration of 17.16 ppt at a depth of 10-30 cm, while in sediment in Dong Nai River (Bien Hoa), Cai River (Nha Trang), Nha Trang Bay, Bien Hung Lake (Bien Hoa) and Go Vap Lake (Ho Chi Minh City) there was an average dioxin concentration of 10 ppt.

According to the survey results by the Vietnam-Russia Tropical Center, in eight of the contaminated areas in Dong Nai, Da Nang, Binh Duong and Tay Ninh provinces, dioxins can transfer to a depth of 2.5 m, depending on the soil characteristics. A survey in Binh My commune, Tan Uyen district in Binh Duong province in 1998 on soil layers at a depth of 30, 60, 90, 120 and 150 cm, shows that there are no rules regarding the relation between dioxin concentration and soil depth. Another important finding by these studies is that even up to a depth of 150 cm, 2,3,7,8-TCDD is still discovered with a concentration of 8.4 ppt.

Another survey in Tan Binh commune, Tan Bien district, Tay Ninh province in 1998 also found no rule of relation between in-depth dioxin distribution. At a depth of 2.5 m, the TEQ is up to 30.86 ppt, and the concentration of 2,3,7,8-TCDD is 29.4 ppt, while at the near surface layer of 30 cm, TEQ is only found with a concentration of 9.35 ppt.

These surveys show that dioxins have the capability to move to a depth of not just 20-30 cm but up to meters deep. This depends on the soil quality, especially the content of humus and clay in the soil. A low content of humus and clay in the soil will increase the possibility of a deep penetration of dioxins. The point attracting attention here is the semi-decomposition duration of dioxins is significantly affected by the depth of the soil. With a surface layer (0.1 cm), the semi-decomposition duration of TCDD is from one to three years. In a layer from 0.1 to 20 cm, it is from nine to 15 years, and in a deeper layer of more than 20 cm the semi-decomposition duration is from 25 to 100 years. The deeper dioxins move into the soil, the longer time they will exist in the environment, threatening the ecosystem and human health.

5.1.2.2. DRC contamination in soil due to other activities

Environmental contamination by DRCs is becoming more serious and is a threat to human and animal health. These compounds are generated unintentionally during combustion or as by-products in organic chlorinated chemicals used in large amount, such as pesticides or wood treatment chemicals. In Vietnam, the most concerning emission source remains the Agent Orange/dioxin residue used by the US army in a large region in the center and south of Vietnam for clearing land and deforestation. Over the past four decades, in sprayed areas dioxins and furans have nearly decomposed under the impact of sunlight and cultivation to the base thresholds. However, in hotspots such as Da Nang, Bien Hoa and Phu Cat airbase, which were used to store and load herbicides on to the aircraft, the dioxin concentrations remain high.

Apart from dioxin emission from herbicides, combustion using a high temperature is still known as the main process leading to the emission of PCDD/Fs into the environment. The soil environment around plants, workshops and production units using a high temperature, such as urban waste incineration, medical waste combustion, metallurgy and energy also faces the risk of dioxin contamination. Although burning of biomass such as wood and straws also has the potential to produce dioxins at low concentration, with large amount of biomass burned in a careless way at uncontrolled temperature and oxygen contact, dioxin emission into the environment should also be taken into consideration. At open dumping areas in some developing countries, including Vietnam, a large amount of urban solid waste is gathered together with uncontrolled and smouldering burning, and this creates favourable conditions for the generation of dioxins and furans.

Nguyen Hung Minh et al. (2003) during 2000 to 2001 conducted surveys and collected soil samples from two dump sites in Hanoi and Ho Chi Minh City. The sampling collection location in Hanoi was Tay Mo commune's dumping site, in the Tu Liem district, which commenced operation between 1997 and 1999, and covers an area of 50,000 m^2 with a capacity of 1,360 tons/day and where the burning is not controlled. The sampling location in Ho Chi Minh City was Dong Thanh commune, Hoc Mon district. This dumping site started operation in 1990, covering an area of 300,000 m^2 with a capacity of 4,000 tons/day. Waste in the dumping site was treated by burning at low temperature. Soil samples were collected at a depth of zero to 10 cm at five points within an area of 25 m^2. The comparison samples were collected from urban or rural areas at least 30 km away from the dumping sites.

The concentrations of $TEQ_{PCDD/Fs}$ and $TEQ_{dl\text{-}PCBs}$ in the soil samples collected in Tay Mo had an average value of 95 (0.4-850 pg/g) and 7.30 (0.22-59pg/g), much higher than the same congener concentrations of samples collected in the comparison areas (1 pg/g $TEQ_{PCDD/Fs}$ and 0.097 $TEQ_{dl\text{-}PCBs}$). Meanwhile, total PCDD/Fs concentration in soil from Dong Thanh was only similar to the comparison samples collected in Hanoi (with an average concentration of 370 pg/g). The concentration of $TEQ_{PCDD/Fs}$ and $TEQ_{dl\text{-}PCBs}$ at the dumping sites and the comparison samples in Ho Chi Minh City do not show significant differences, in spite of the duration of operation, area and capacity of Dong Thanh, which is larger than the dumping site in Tay Mo.

In the soil with the highest concentration of PCDD/Fs in Hanoi, the proportion of dioxins and furans is similar. In each of these groups, compounds with four chlorine atoms in the molecule account for the highest proportion. Meanwhile, the remaining samples in Hanoi and Ho Chi Minh City all show the main congener of OCDD, making up to 60 to 80 per cent, as compared to total PCDD/Fs. This is also the popular feature of congeners for environmental samples which are not related to the herbicide origin. In almost all soil samples, the main PCB congener found is PCB 126. This congener contributes to over 95 per cent of the $TEQ_{dl\text{-}PCBs}$. Disseminating PCB congeners in commercial PCB compounds are PCB 77, PCB 105, PCB 118 and PCB 156, while PCB 126 exists at a low level. This means the sources of dl-PCB emission is combustion activities.

In 2013 and 2014, the Vietnam-Russia Tropical Center conducted a survey, collected samples and analysed 29 criteria of PCDD/Fs and dl-PCBs in the soil in Hanoi, Thai Nguyen and Thanh Hoa. The TEQ concentration in the soil samples (average and in range values) is provided in Table 5.25.

Table 5.25. DRC level in soil (pg/g dry weight) in Hanoi, Thai Nguyen and Thanh Hoa

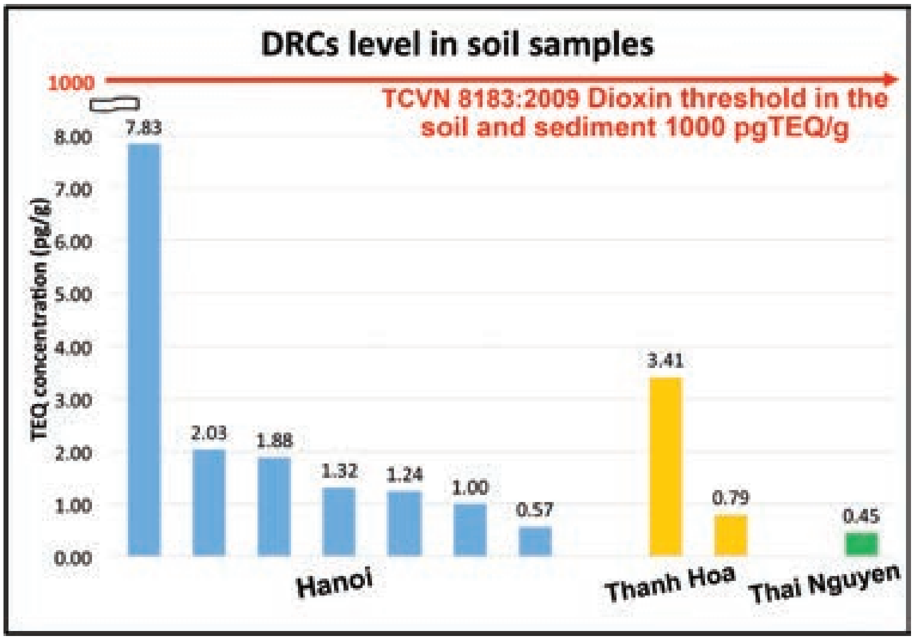
No	Location (Sample numbers n)	Features of the sampling locations	
		WHO-TEQ	
1	Hanoi (n=7)	2.26 (0.57 – 7.83)	- One sample collected from Cat Que Commune, Hoai Duc district: Cat Que, Hoai Duc: handicraft villages that use boilers and furnaces - Four samples collected from agriculture areas: Phuc Dien in Tu Liem and Kim Bai in Thanh Oai - Two samples collected from Nam Dong ward, Dong Da district: Hanoi center
2	Thai Nguyen (n=1)	0.45	Sample collected from a brick production plant
3	Thanh Hoa (n=2)	1.97 (0.79 – 3.41)	Sample collected from Nga Bach, Nga Son: fishing is the main activity

In Hanoi, soil samples were collected in areas with and without combustion activities. The sampling locations were in Hoai Duc, Tu Liem, Thanh Oai and Dong Da districts. In contrast to the TEQ distribution in sediment samples of this survey, the TEQ concentration in the soil samples have relatively concentrated values of 0.57 to 7.83 pg/g. Soil samples collected from the area with the incinerator of the malt production unit have the highest TEQ concentration (7.83 pg/g). The remaining samples all have a very low TEQ concentration from 1-2 pg/g. The percentage of TCDD/TEQ in almost all the samples is low, from 8.1 to 20.5 per cent (except for one sample collected from Nam Dong ward, Dong Da district, which has a percentage of up to 41.8 per cent). The percentage of dl-PCBs/TEQ is also low, ranging from one to 10 per cent. The most typical PCDD/Fs congeners found in all samples are OCDD and then 1,2,3,4,6,7,8-HpCDD. The most typical dl-PCBs congeners are PCB 118, PCB 105 and PCB 156. From the above analysis, it can be seen that dioxin contamination in soil does not have high typicality for the areas with or without combustion activities and the TEQ concentration in samples is low in general. The concentration of TCDD is low, while concentrations of congeners with more chlorine atoms, such as OCDD or HpCDF, are higher. This means the dioxin emission source is mainly due to combustion activity. High concentrations of PCB 118, PCB 105 and PCB 156 in soil samples show that there is a relation between environmental contamination by dl-PCBs and the use and disposal of products containing commercial PCB compounds.

In the two samples collected from the area where the main activity is fishing, in Nga Bach, Nga Son and Thanh Hoa, the TEQ concentration shows distinctive differences. The more contaminated samples have a TEQ concentration four times higher than the remaining sample (3.42 and 0.79 pg/g). However, with a limited number of samples, it is not possible to provide a conclusion on the contamination sources. The main dioxin congeners are OCDD and 1,2,3,4,6,7,8-HpCDD. In the high TEQ concentration sample, all furans were detected, while in the remaining sample Penta and HexaCDF were not detected. The main congeners of dl-PCBs detected are PCB 118, PCB 105 and PCB 156. The percentage of TCDD/TEQ in both samples was low (both at 15.3 per cent). This means that the environment in the area is not contaminated with dioxins from herbicides used during the war. The percentage of dl-PCBs/TEQ in these two samples was very low, at three per cent.

In Thai Nguyen, the soil sample collected from the area near the brick production plant has the lowest TEQ concentration, as compared to the other samples collected in Hanoi and Thanh Hoa (0.45 pg/g). In this sample, only some of the dioxin congeners were detected such as TCDD (0.21 pg/g); 1,2,3,4,6,7,8-HpCDD (0.99 pg/g) and OCDD (114.7 pg/g) and the only furan congener TCDF (0.29 pg/g). Detected dl-PCBs include PCB 7, PCB 118, PCB 105, PCB 167 and PCB 156. The congener with the highest level is PCB 118 (14.5 pg/g). The percentage of TCDD/TEQ in this sample has a high value (38 per cent), higher than the two samples collected in Thanh Hoa and most samples collected in Hanoi, whereas the percentage of dl-PCBs/TEQ is relatively low (6.1 per cent).

The TEQ concentration in soil samples collected in Hanoi, Thanh Hoa and Thai Nguyen in comparison to the dioxin threshold in soil in heavily contaminated areas, subject to TCVN 8183:2009, is shown in Figure 5.11.



Firgue 5.11. Dioxin concentrations in soil from Hanoi, Thanh Hoa and Thai Nguyen

All soil samples collected and analysed have a TEQ concentration not exceeding 10 pg/g, which is 100 times lower than the dioxin threshold for soil in heavily contaminated areas. According to QCVN 45:2012/BTNMT on the acceptable limit of dioxins in some types of soil, none of the samples have a TEQ concentration exceeding these thresholds. According to this regulation, the dioxin threshold for annual crops is the most strictly regulated at 40 pg/g. Other types of soil such as forestry soil, soil for perennial trees, rural land, urban land, land used for recreation purposes and commercial and industrial land have thresholds of TEQ ranging from 100 to 1,200 pg/g.

5.1.3. Dioxin contamination in the water environment in Vietnam

Water is not an environment which significantly accumulates DRCs as these compounds have weak bias and thus their solubility in water is very weak. Publicised studies as well as a database on the concentration and distribution of DRCs in the water environment in Vietnam are limited. In order to analyse DRCs with an ultra-trace level in water, there is the need for separation, extraction, sample enrichment techniques and the use of low limit detection equipment, and only a few laboratories in Vietnam can meet these requirements. Moreover, in water DRCs are easy to associate with suspended particles or accumulate in sediment and deposit, and thus the analysis results depend on sampling methods and the amount of deposit.

In 2013, the Vietnam-Russia Tropical Center conducted a survey, collected samples and analysed the concentration of 29 parameters of PCDD/Fs and dl-PCBs in water in Hanoi, Thanh Hoa and Nam Dinh. The analysis subjects include surface water (river water, ditch water and water from estuaries), domestic water collected from households, water used for fishery activities in Thanh Hoa and water at a tank after treatment at a hospital in Nam Dinh. The TEQ concentration in water samples (average and in range values) are shown in Table 5.26.

Table 5.26. Dioxin levels in water (pg/L) in Hanoi, Nam Dinh and Thanh Hoa

No	Location (Sample numbers n)	TEQ concentration (pg/g)		Features of the sampling locations
		I-TEQ	WHO-TEQ	
1	Hanoi (n=9)		0.79 (0.48 – 1.44)	- Five domestic water samples collected from households in Tay Mo, Tu Liem,; Kim Bai, Thanh Oai and Nam Dong, Dong Da - Four surface water samples collected from Nhue river, La Khe ditch (Tu Liem); To Lich river (Thanh Xuan) and Xa Dan lake (Dong Da)
2	Nam Dinh (n=2)		0.60 (0.58 – 0.63)	Water samples collected at the post treatment tank at a hospital in Nam Dinh
3	Thanh Hoa (n=3)		0.77 (0.42 – 1.25)	- One sample collected at Lach Xung, Nga Bach estuary, Nga Son - One sample collected at the shrimp cultivation pond, Nga Bach, Nga Son - One domestic water sample collected from a household in Nga Bach, Nga Son

In Hanoi, the TEQ concentration in domestic water samples has a value in the range of 0.48 to 0.85 pg/L. The sample with the highest TEQ concentration (0.85 pg/L) was collected from a household in the center of Hanoi, in Nam Dong ward in Dong Da district. The sample with the lowest TEQ concentration (0.48 pg/L) was collected from a household in Kim Bai town, Thanh Oai. Also in Kim Bai, one water sample from a drilled well used for domestic use was also collected for analysis. The low TEQ concentration (0.65 pg/L) shows that there is no serious dioxin contamination in the area. In domestic water samples collected in Hanoi, most of them did not have dioxin/furan congeners (except for some samples containing OCDD). The main dl-PCBs detected were PCB 77, PCB 118 and PCB 105.

For water samples collected in Hanoi, the TEQ concentration ranges from 0.58 to 1.44 pg/L, in general higher than those of domestic water samples. Surface water samples with the highest TEQ concentration were from the To Lich river, collected at the section flowing through Nga Tu So crossroads in Thanh Xuan district (1.44 pg/L). This river is considered as the water course for wastewater of the city and is also a hotspot for environmental contamination in Hanoi. In the water samples collected from To Lich river, TCDD (0.81 pg/L) and OCDD (1.50 pg/L) were detected. The main dl-PCBs detected were PCB 118, PCB 105 and PCB 77. The percentage of TCDD/TEQ is relatively high (42.4 per cent). In the remaining surface water samples, a few congeners of dioxins/furans (except for some samples containing OCDD) were detected, and the main dl-PCBs were PCB 118, PCB 105 and PCB 77.

In the two samples collected in Nam Dinh, the TEQ concentration in general is low (0.58 and 0.63 pg/L). In one sample, congeners such as 1,2,3,4,6,7,8-HpCDD; 1,2,3,4,7,8-HxCDF; 1,2,3,4,6,7,8-HpCDF; 2,3,4,6,7,8-HxCDF and OCDF were detected, while in the other sample congeners such as OCDD, 1,2,3,4,7,8,9-HpCDF and OCDF were detected. The percentage of TCDD/TEQ in these two samples is 23 per cent and 33.8 per cent. The main congeners of dl-PCBs detected are PCB 118 and PCB 105. Other congeners were also detected, such as PCB 114, PCB 167 and PCB 156, in one sample at low concentrations.

In Thanh Hoa, the surface water samples collected from Lach Xung, Nga Bach estuary, Nga Son had the highest TEQ concentration (1.25 pg/L). In this sample, 27 out of 29 parameters of DRCs were detected (except for the two congeners of dl-PCBs, PCB 126 and PCB 169). The most toxic congener TCDD had a level of 0.67 pg/L and accounts for 50.8 per cent against TEQ. The main dl-PCBs congeners detected were PCB 118 and PCB 105. The water sample collected from a shrimp cultivation pond at the domestic water sample collected from Nga Bach had a low TEQ concentration (0.42 and 0.64 pg/L). Many parameters of dioxins/furans were detected, yet at low level. The main dl-PCBs detected are still PCB 118 and PCB 105.

The comparison of the TEQ concentration in water samples collected in Hanoi (n=9), Thanh Hoa (n=3) and Nam Dinh (n=2) is shown in Figure 5.12 below.

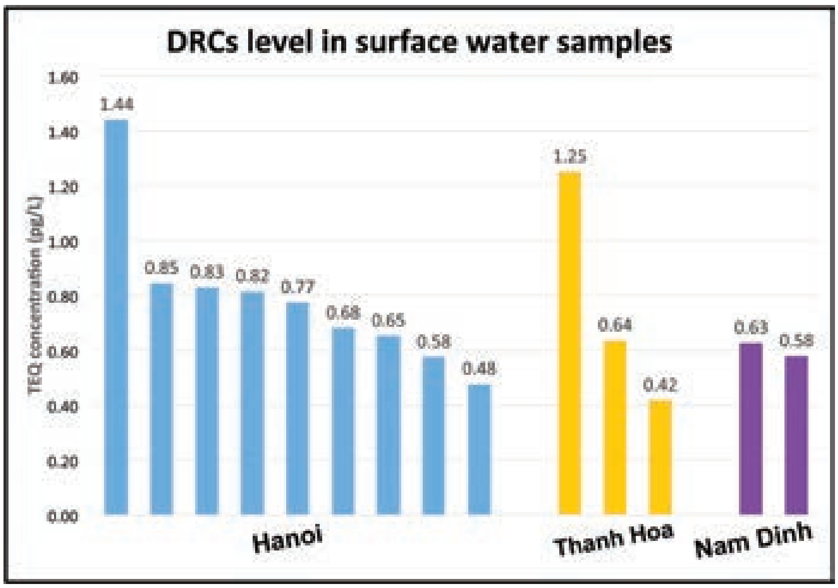


Figure 5.12. Dioxin concentrations in surface water from Hanoi, Thanh Hoa and Nam Dinh

The TEQ concentration in most of the water samples is not excessive of 1.0 pg/L. Only two water samples exceeded this – one collected from To Lich river, Hanoi, and another from Nga Bach estuary in Thanh Hoa, where the TEQ concentration is 1.44 and 1.25 pg/L respectively. In general, the TEQ concentration in water samples is low (average at 0.76 pg/L) and no samples have significantly high dioxin level. In Vietnam, guideline values on dioxin thresholds in the water environment (including both wastewater and water in the natural environment) are not promulgated, and thus a conclusion on the dioxin contamination in water is not issued.

5.1.4. Dioxin contamination in the air environment in Vietnam

Air directly affects humans and animals through respiration. Air pollution seriously impacts on human health and thus air monitoring is essential and should be regularly implemented. However, monitoring toxic contaminants like dioxins and related compounds at trace and ultra trace levels in air samples is difficult and requires sophisticated sampling and analytical techniques. Data on the concentration and criteria of DRCs in the air environment in Vietnam is very limited. The data presented below is the result of studies and surveys by the Vietnam-Russia Tropical Center in 2013 and 2014 in the provinces and cities of Hanoi, Thai Nguyen, Nam Dinh, Hai Duong, Quang Ninh and Thanh Hoa.

In Hanoi, air samples were collected in areas with different operations. For example, samples were collected from straw-burning paddies, from some small production units using boilers and furnaces, from a waste treatment plant with waste incinerators in operation, and from households in the city center and suburban areas where agriculture is the main activity. In the other provinces, air samples were collected from areas with different industrial plants in operation, such as metallurgy, boilers, waste incineration and thermal power, or from households in areas where fishery is the main activity.

The TEQ concentration in the air samples (average and in range values) is shown in Table 5.27.

Table 5.27. DRC level in the air (pg/Nm^3) in Hanoi, Thai Nguyen, Nam Dinh, Hai Duong, Quang Ninh and Thanh Hoa

No	Location (Sample numbers n)	TEQ concentration (pg/Nm^3)		Features of the sampling locations
		I-TEQ	WHO-TEQ	
1	Hanoi (n=7)	0.23 (0.07 – 0.37)	0.21 (0.06 – 0.36)	- One air sample collected at a straw burning paddy in Duc Giang, Hoai Duc district - Two air samples collected at a confectionery and soyal bean cake production facilities in Cat Que, Hoai Duc district - One air sample collected from one environmental treatment company in Tu Liem district -Three air samples collected at households in Tay Mo, Tu Liem district; Kim Bai, Thanh Oai district and Nam Dong, Dong Da district.
2	Thai Nguyen (n=4)	1.66 (0.21 – 5.56)	1.39 (0.17 – 4.63)	- Two air samples collected at a metallurgy plant - Two air samples collected at a zinc production plant using an electrolysis method
3	Nam Dinh (n=1)	0.43	0.41	Sample collected at the yard of the infection-controlling hospital
4	Hai Duong (n=1)	0.13	0.11	Sample collected at an energy company with boilers in operation
5	Quang Ninh (n=2)	0.052 (0.048 – 0.056)	0.052 (0.050 – 0.054)	Sample collected from a thermal power plant
6	Thanh Hoa (n=2)	0.23 (0.14 – 0.31)	0.20 (0.13 – 0.28)	- One sample collected at an area with a waste incinerator in Nga Van, Nga Son - One sample collected at a household at Nga Bach, Nga Son

According to the above table, the TEQ in seven air samples in Hanoi has a value within 0.06 to 0.36 pg/m^3. The sample with the highest TEQ (0.36 pg/m^3) is the open burning sample collected in the straw-burning paddy in Hoai Duc district. The second-highest concentration sample was collected in the nearby area of the waste incinerator, with a TEQ concentration of 0.33 pg/Nm^3. The remaining samples all have a very low TEQ, with the lowest concentration found at 0.06 pg/m^3 from a sample in Kim Bai town, Thanh Oai district, in an area where agriculture is the main activity. In the analysed air samples, no samples were found with exceptionally high TEQ. The percentage of TCDD/TEQ in the samples is low, ranging from 5.8 to 24.3 per cent. This value is similar to the percentage of TCDD/TEQ of other environmental units, such as soil and sediment, which were analysed in the same survey. There are no rules on the concentration distribution of congeners for the samples. In some samples, OCDD was the main congener detected. The remaining congeners were detected at very low concentrations. The distribution of PCDD/F concentration in the remaining samples is more complicated, such as in the air sample collected from the malt production unit in Cat Que, where furans have a higher level than dioxins. The main congeners are 1,2,3,7,8-PeCDF and OCDD. In the sample collected from the working area of an environment company in Tu Liem district and the sample collected in Kim Bai, the two main congeners are 1,2,3,4,6,7,8-HpCDD and OCDD. In the sample collected from a household apartment in Xa Dan street, Nam Dong ward, Dong Da district, all parameters of dioxins/furans were detected. The congeners with the highest concentration in this sample are 1,2,3,4,6,7,8-HpCDF, OCDF and OCDD. The typical detected dl-PCB congeners in this sample are PCB 118, PCB 105 and PCB 77. These are also regularly found congeners in commercial PCBs.

In the other provinces in this survey, the highest TEQ concentration (4.63 pg/Nm^3) was detected in the air sample collected at the metallurgy plant using electrolysis technology in Thai Nguyen. The other samples have a low TEQ concentration, ranging from 0.050 to 0.48 pg/m^3. This concentration is similar to the air samples collected in Hanoi. The percentage of TCDD/TEQ of almost all samples is low, in the range of 3.3 to 20.5 per cent, except for two samples with a relatively high TCDD/TEQ which were collected in Nga Van, Nga Son and Thanh Hoa (32.2 per cent) and especially the sample collected in Nam Dinh (62 per cent). The high percentage of the most toxic congener 2,3,7,8- TCDD leads to the question of technology renovation as well as better control of fuel sources for production units with incinerators. The main PCDF congeners found in the samples are 1,2,3,7,8-PeCDF and 2,3,7,8-TeCDF. Furans in general have a higher concentration than dioxins. The most typically found dl-PCBs congeners are also congeners used in commercial PCB compounds, namely PCB 118, PCB 105, PCB 77 and PCB 156. Congeners PCB 126, PCB 169 and PCB 189 exist in the samples with low concentration.

A relative comparison of the TEQ concentration in the air samples collected in Thai Nguyen (n=4), Nam Dinh (n=1), Hanoi (n=7), Thanh Hoa (n=2), Hai Duong (n=1) and Quang Ninh (n=2) is shown in Figure 5.13.

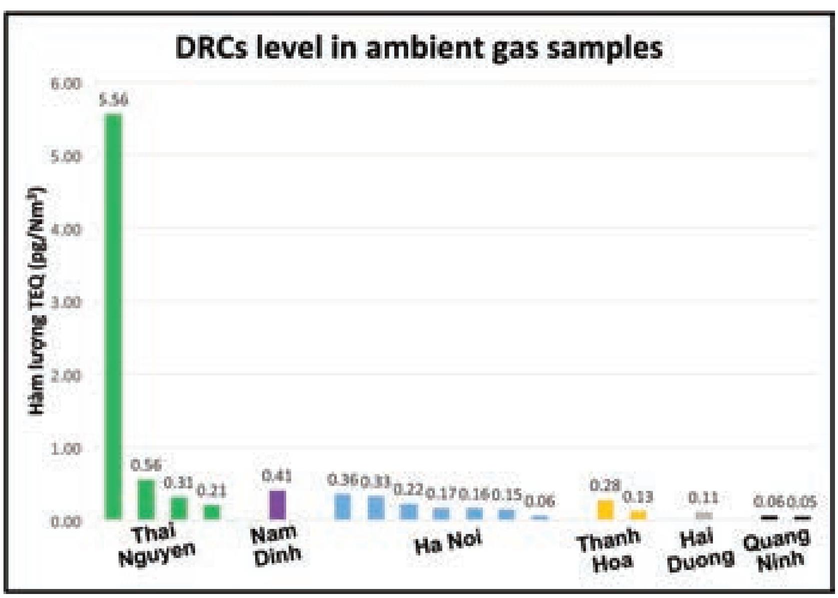


Figure 5.13. Dioxin concentrations in ambient air in several areas from Vietnam

Of the 17 air samples collected and analysed, 16 samples have a TEQ concentration below 1 pg/Nm^3. There is only one sample collected in Thai Nguyen (collected from a zinc production plant using an electrolysis method), which has a significantly high concentration (5.56 pg/Nm^3). In other areas, such as Hanoi, Nam Dinh or Thanh Hoa, samples which have a higher TEQ concentration, as compared to the remaining samples, were normally collected in areas with incineration activities. This includes the sample in Nam Dinh, which was collected at the yard of a hospital near a medical waste incinerator, the samples in Hanoi collected at a paddy with straw burning or the sample in Thanh Hoa collected near an area with an urban waste incinerator under operation.

5.2. Assessment of DRC contamination in the environment in Vietnam

5.2.1. DRC contamination in the sediment environment in Vietnam

Sediment is considered a substance that strongly accumulates DRCs, as these compounds are not very dissoluble in water. Thus, when they are discharged into the watercourse they tend to settle into sediment. In sediment, DRCs can still be dispersed back into the environment through animal activities as well as by being carried with sediment along the flow. Congeners of DRCs discovered even at low level in sea sediment have proven that they have a high possibility of spreading POPs. DRCs in sediment will directly affect organisms at the bottom layer and through that directly affect human health through the food chain. This means that if people consume aqua products from DRC contaminated areas, a risk of exposure to these compounds exists.

The distribution of the TEQ concentrations in the sediment media in Vietnam can be classified into three area categories: (1) the dioxin at heavily contaminated areas originating from AO/dioxin sources; (2) the dioxin from industrial activities, and (3) areas considered as background levels. The average TEQ concentrations in sediment samples represent the above areas compared to the threshold of 150 pg/g subject to Vietnamese standard (TCVN 8183:2009) is shown in Figure 5.14.

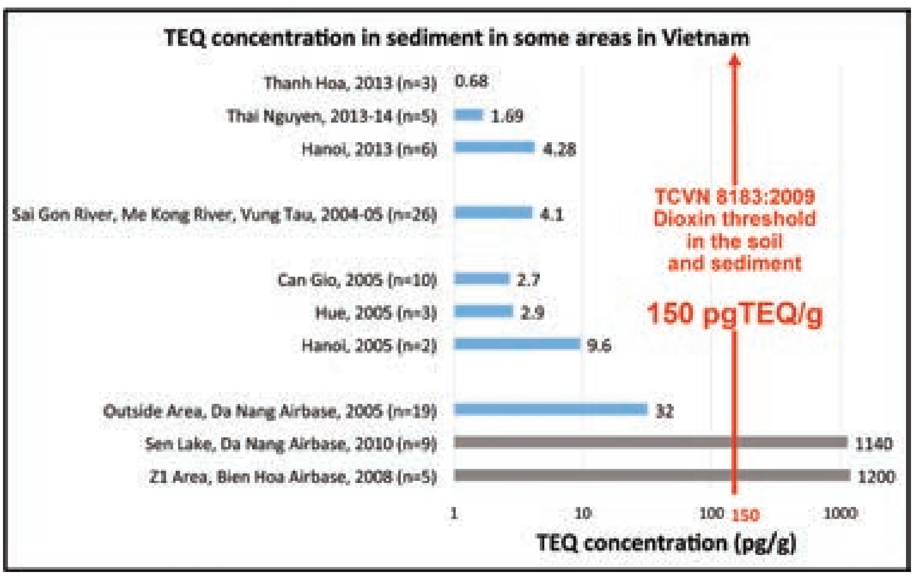


Figure 5.14. Comparison of Dioxin concentrations in sediment in several areas in Vietnam

The TEQ concentration in sediment samples collected in Hanoi, Thai Nguyen and Thanh Hoa in the 2013 and 2014 survey can be compared with the TEQ concentration in sediment samples collected in Can Gio, Hue and Hanoi (Kishida et al., 2010), sediment samples from Saigon River, the Mekong River and Vung Tau sea (Shiozaki et al., 2009) and some heavily contaminated areas from the war. These include sediment samples collected from Sen lake at Da Nang airport, outside Da Nang airport and ponds and lakes in the Z1 area at Bien Hoa airbase (done by the Office of the National Steering Committee 33, Committee 10-80, CDM Consultants and Hatfield Consultants). At the threshold of 150 pg/g, only the sediment samples collected from the airbases used for storage, loading and washing of the aircraft after spraying missions are considered as heavily contaminated with dioxins. Other sediment samples, including samples collected outside but close to the airbase, samples collected near areas with industrial activities and areas not affected directly by activities that have the possibility to emit dioxins, are not categorized as heavily dioxin contaminated sediment areas.

It is also useful to compare with the TEQ values from sediment samples in various regions around the world, as shown in Table 5.28. According to this table, the dioxin levels in sediment in Vietnam (except for heavily dioxin contaminated areas at some military airbases) is in general low and at the baseline level, and is equal to the levels in other countries in Asia such as Japan, Korea and Hong Kong.

Table 5.28. The DRC level in sediment in some areas in the world

Areas	WHO-TEQ (pg/g)		
	Min value	Average value	Max value
Homebush Bay	667.8	2094.9	4352.5
Port Jackson	31.5	711.5	4352.5
Umber Estuary, UK	14	ND	24
Italy	ND	ND	570
Venice Lagoon, Brentella Canal	427	ND	2857
St. Laurensharbour, Netherlands	352	ND	1849
Finland	0.7	ND	100
Frierfjorden, Norway	6234	ND	19,444
Germany; River Elbe	7	ND	150
South Africa	0.2	ND	22
Flordia	0.5	ND	78
Lower Great Lakes	3.3	ND	18
NY harbor	23	ND	880
Passaic River, NJ-NY estuary	310	ND	1400
Maine-Casco bay	1	ND	27
New Bedford Harbor, MA	10	ND	761
Lower Roanoke River , NC	0.3-34	ND	1200
Brazil, Guanara Bay	ND	ND	2000
Hong Kong Harbor	4	ND	33
Toyko Bay	3.3	ND	52
Korea – coastal zones	0.01	ND	5.5

Note: ND – Not detectable

5.2.2. Dioxin contamination in the soil environment in Vietnam

Soil does not strongly accumulate DRCs. Dioxin is normally found in the soil layer from 0-10 cm, while at a deeper layer from 10-30 cm or deeper, it is very difficult to find dioxins and if it is found, the concentration remains very low. In a tropical climate with strong sunlight as in Vietnam, dioxins in the surface soil layer will be decomposed by the impact of sunlight and cultivation activities, with a semi-decomposition duration of one year. However, in areas with porous soil and easy to absorb water, dioxins can penetrate into deeper layers. Soil with a heavy mechanism composition (more clay) has a better capability to absorb dioxins. Dioxins in deeper layers of soil or that are strongly absorbed into the clayish soil will become persistent and cause long-term impacts on the environment, the ecosystem and human health of those who live on the contaminated land and consume food from such land areas.

Similar to sediment, the TEQ concentration in soil can be classified into three categories: 1) heavily dioxin contaminated areas as a residue from the war; (2) areas heavily contaminated by dioxins from industrial activities and; (3) areas with TEQ at baseline level. The average TEQ concentration in soil in some areas, in comparison with the threshold of 1,000 pg/g subject to TCVN 8183:2009, is shown in Figure 5.15

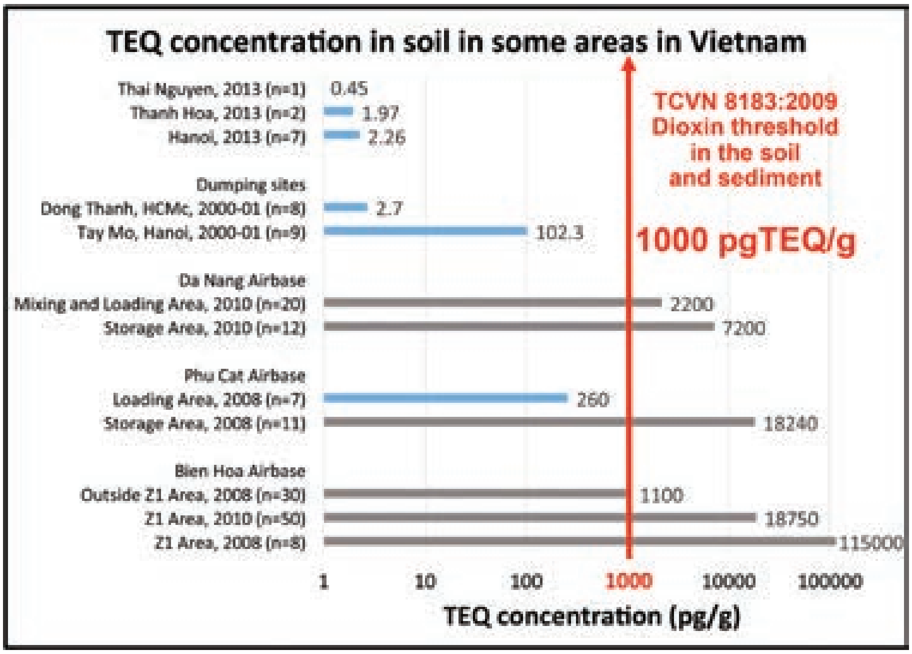


Figure 5.15. Comparison of Dioxin concentrations in soils from several areas in Vietnam

The TEQ concentrations in soil samples collected in Hanoi, Thai Nguyen and Thanh Hoa in the 2013 and 2014 survey is compared with the TEQ concentration in soil samples from the dump sites in Tay Mo, Hanoi, and Dong Thanh, Ho Chi Minh City (Nguyen Hung Minh et al., 2003) and some of the heavily dioxin contaminated sites from the war. These soil samples were collected from the storage, loading and washing areas at Da Nang airport, Phu Cat airbase and the Z1 area at Bien Hoa airbase (by the Office of the National Steering Committee 33, the Vietnam-Russia Tropical Center and Hatfield Consultants).

For dioxin contaminated areas due to herbicides at Da Nang, Phu Cat and Bien Hoa airbases, the TEQ concentration in the soil samples collected from the storage areas are normally highest. This is followed by the samples collected from the mixing and loading areas. The concentration is significantly reduced at the buffer, surrounding areas and areas outside the airbases. Samples collected from Bien Hoa airbase in 2008 show heavy dioxin contamination. The average dioxin concentration in the soil samples collected from the Z1 area is 115,000 pgTEQ/g – 1,000 times higher than the threshold of 1,000 pg/g. Even the soil samples collected at the buffer area have a content equal to the threshold (1,100 pgTEQ/g). The soil collected from the storage area of Phu Cat airbase, and the storage, mixing and loading areas at Da Nang airport all have an average dioxin level that exceeds the threshold.

For soil samples which were not collected from the herbicide hotspots, the TEQ concentration does not exceed the threshold of 1,000 pg/g. Samples collected from Hanoi, Thanh Hoa and Thai Nguyen in 2013 and 2014, and samples collected from the dump site in Dong Thanh, Ho Chi Minh City in 2000 and 2001, all have a very low average dioxin level, not exceeding 3 pg TEQ/g. Compared with regulations on dioxin concentration in soil in other countries such as Canada (used land <4 pgTEQ/g), Germany (<5 pgTEQ/g), New Zealand (agriculture land <10 pgTEQ/g), Sweden (<10 pgTEQ/g) and Japan (<1,000 pgTEQ/g), the TEQ concentration in soil in Vietnam (except for samples from hotspots) is at the baseline level and within the acceptable thresholds of countries with strict regulations, such as Canada and Germany. For soil samples collected at the Tay Mo dump site in Hanoi, the average dioxin concentration is around 100 pg TEQ/g. Although it is not a heavily dioxin contaminated soil, subject to TCVN, the unusual dioxin level shows the risk of environmental contamination as dioxins are formed due to slow and uncontrolled burning at the dump sites.

When the threshold of 1,000 pg/g subject to TCVN is applied, it is possible to classify heavily dioxin contaminated soil due to herbicides from other activities, as only soil samples collected at former airbases have a TEQ concentration equal to or excessive of this threshold. However, for soil types outside the hotspots it is necessary to develop and promulgate more suitable standards, based on the dioxin level in areas affected by industrial production which have the possibility to emit dioxins.

5.2.3. Dioxin contamination in the water environment in Vietnam

Investigations on dioxin contamination in the water environment in Vietnam are limited as the levels of these compounds in water are usually very low and requires specialized sampling and analytical techniques. The dioxin level in water is a matter of concern, as one of the dioxin exposure pathways to humans is the food chain, including fish and aqua animals which can bio-accumulate DRCs in their bodies. In addition, the dioxin concentration in the water environment also provides important data to study the distribution and balance of dioxins in the water environment and sediment, as well as in the water environment and organisms.

Dioxin contamination in the water environment in the areas surveyed in Hanoi, Thanh Hoa and Nam Dinh in 2013 had an average value of 0.76 pgTEQ/L and the concentration range was relatively narrow (0.42 to 1.44 pg/L). To assess the dioxin contamination in water in Vietnam, it is useful to compare to research from China, Taiwan and Japan. Lirong Gao et al. (2014) analysed eight water samples in Dongting Lake in the northeast of Hunan province in China. The sampling time was in 2004 and the average and in range values of dioxins in water in this lake were 0.28 and 0.17-0.37 pgTEQ/L. N Ngo Thi Thuan et al. (2011) analysed 21 groundwater, surface water and domestic water samples in Taiwan and the concentration range was 0.001-0.265 pgTEQ/L. In Japan, the dioxin concentration in water samples had the following values: Kahokugata marsh, sampling time 2002-2004, number of samples n=10, concentration range 0.11-1.6 pgTEQ/L; Unoke river, sampling time 2002-2004, number of samples n=9, concentration range 0.20-1.6 pgTEQ/L (Masao Kishida, 2013); Kanzaki river, number of samples n=12, average TEQ concentration in the suspended particle phase higher than that of the soluble phase (1.6 ± 0.51 pg/L and 0.14 ± 0.05 pg/L respectively) (Hitoshi Kakimoto et al., 2006). Hence, the dioxin concentration in water samples in Vietnam is similar to other Asian countries.

The guideline value for dioxins in surface water subject to the Japan environmental standard is 1.0 pg/L. If this threshold is applied, two out of the 14 water samples collected have a dioxin level that exceeds this threshold. The Taiwan Environment Protection Agency regulates that the acceptable dioxin level in water is 12 pgTEQ/L. If this limit is adopted, all water samples in this survey have a TEQ concentration at a safe level. To develop a dioxin threshold for the water environment in Vietnam, it is necessary to base it on actual analysis data in order to identify the baseline level in Vietnam. It is also useful to compare the levels to levels in other countries, and especially refer to the regulations and standards in effect in other countries in order to provide a proper threshold value.

5.2.4. DRC contamination in the air in Vietnam

Dioxins, furans and PCBs are categorised as semi-volatile organic compounds with a distribution coefficient between octanol – atmosphere (K_{oa}) in the range of 7-8 (for the isomers Mono-CDD/Fs) to the range of 11-12 (for the isomers Octa-CDD/Fs). The range of K_{oa} values influences the distribution of DRCs in the particle and gaseous phase in the atmosphere. When these compounds disperse into the atmosphere, their existence mechanisms are quite complicated. It depends on the characteristics of each congener whether they can have different partitioning beahavior in the gaseous phase or particle phase. They may drop to the ground and water and then accumulate into sediment or penetrate organisms' bodies through respiration or dermal contact. In addition, dioxins in the atmospheric samples also exhibit seasonal variations. Normally, the total concentration of Tetra to Octa-CDD/Fs in the atmosphere in the winter is from two to three times higher than in the summer.

Air contaminated with DRCs will have direct negative impacts on humans and thus it is essential to have appropriate regulations on safe and acceptable levels of dioxins in the ambient air environment. However, the database on dioxin level in the air in Vietnam is limited, and currently there are no regulations on the maximum acceptable levels of dioxins in the air. To have a basis for comparison, the Japanese standard for the dioxin threshold in the air of 0.6 pgTEQ/m^3 can be used. Pursuant to this standard, only one air sample collected from a zinc production plant in Thai Nguyen has a TEQ concentrations exceeding the threshold. Dioxin levels in the air samples in other provinces in the north of Vietnam are generally low, including the ambient air samples collected from areas with industrial activities, such as waste incinerators, boilers and thermal power plants.

In general, atmosphetic dioxin concentrations tend to decrease from urban and industrial areas to rural and lowest in the remote areas. Dioxin levels in urban air and in industrial areas ranged from 0.1 to 0.4 pg/m^3; the rural areas is from 0.02 to 0.05 pg/m^3 and the remote areas is below 0.01 pg/m^3. If the sample collected from the steel production plant with unusual high TEQ concentration is not counted, the average TEQ concentration in the other air samples is 0.22 pg/Nm^3. These levels were similar to those observed in air from urban areas of other countries in the world such as Italy, Blegium, Germany, Japan and Britain (R. Lohmann and K.C.Jones, 1998). This database will be a useful basis for the development of dioxin guideline values for air in Vietnam.

Part 6

CONCLUSIONS AND RECOMMENDATIONS

6.1. Dioxin emissions from industries in Vietnam

6.1.1. Conclusions

Different industries with different input materials, manufacturing technologies and flue gas treatment technologies have different formations and emissions of DRCs. The survey and analysis of the dioxin level in different types of flue gas samples, and wastewater and solid waste samples from industries such as waste incinerators, ferrous metallurgy (steel manufacturing), nonferrous metallurgy (zinc production), cement kilns, boilers, paper production and thermal power, was carried out over two years (2012-2014) in more than 20 industrial facilities nationwide. The results show that:

- Waste treatment facilities with incincerators are potential sources of dioxin emissions. There are a few stack gas samples with dioxin concentrations 100 times higher than the threshold, especially medium size incinerators for industrial hazardous wastes. The industries with the second highest emission of DRCs are zinc production, steel making and cement production. Industries such as thermal power and paper production in general showed relatively low dioxin emission in flue gases. None of the samples from those industries are excessive of the Vietnamese regulation and standard values.

- The TEQ concentration in most of the flue gas samples from industrial waste incinerators in Vietnam is similar and for a few cases, slightly higher than those in developing countries or newly industrialised countries in Asia. However, some flue gas samples with an unusual high TEQ concentration (up to 50 ngTEQ/Nm^3), suggesting that the formation and emission of dioxins in incinerators in Vietnam is complicated and not easy to control. Not enough attention has been paid to air pollution control devices (APCD) and there has not been appropriate investment. If comparing to the TEQ concentration in flue gas in European countries, dioxin emissions in waste incineration in Vietnam are much higher, and most of the analysed samples are in excess of the standard introduced by some European countries, which is 0.1 ngTEQ/Nm^3.This raises serious concern over the long term impacts of dioxins on human health, considering the fact that industrial and municipal wastes has increased gradually in recent years.

- Dioxins were also detected with TEQ concentrations in some industries at relatively high levels. The dioxin levels in wastewater from some of the industries such as thermal power, paper production, and metallurgy and cement production in Vietnam are in general low and none of the samples having the TEQ excessive of the threshold 10 pg/l (Japan standard for dioxins in waste water). Elevated dioxins concentrations were encountered in wastewater collected in some industrial waste incinerators and waste treatment facilities. Many samples with dioxin concentrations exceeded the threshold of 10 pg/l and there is even a sample with heavy contamination (up to 50,000 pg/l, 5,000 times higher than the referred threshold of maximum acceptable level). Dioxin contamination in wastewater from waste incineration warrants urgent attention for the development of regulations and technical measures to mitigate emissions of dioxins and other toxic contaminants in such waste treatment facilities.

- Industrial solid waste is a typical subject regarding DRC contamination in different industries. Solid waste samples normally collected include input materials, fly ash and bottom slagged ash etc. In which, fly ash samples (also referred to as dust in flue gas) are a strong accumulation environment of different contaminants including heavy metals and persistent organic pollutants. Dioxin residues in fly ash samples of some metallurgy plants is at significantly higher levels than in other industries such as waste incineration and cement production. The industrial activities with the second highest dioxin contamination in fly ash is waste incineration and the lowest one is cement production. Solid waste samples collected from incineration facilities and cement production plants are below the US threshold of 300 pg/g TEQ for sewage sludge. Only some fly ash samples collected at the stack gases of the steel manufacturing plant using EAF technology has dioxin concentrations that exceed this threshold. TEQ concentrations in some waste samples from metallurgy activity have similar levels as the soil samples collected from the AO/dioxin hotspots in Vietnam at around 1,000 pg/g. This is a matter of great concern in terms of dioxin contamination of industrial solid waste.

6.1.2. Recommendations:

- The survey on dioxin emission in industries in Vietnam implemented by the Office of the National Steering Committee 33, the Ministry of Natural Resources and Environment and the UN Development Programme in Vietnam provides one of the most comprehensive and up-to-date databse in Vietnam up to now. The results of this programme will be the basis for the development and revision of regulations and standards related to dioxin emission thresholds in industries in Vietnam. The results of the study show that industries associated with waste incineration and wastewater or solid waste treatment facilities and metallurgy, especially nonferrous metallurgy, are those with a possibility to emit dioxins at high levels and which require continuous surveying and studying.

- It is necessary to continue surveying dioxin emission levels in waste treatment facilities with incinerators in operation, in combination with a trial implementation of BAT/BEP (best available technology and best environmental practices) for waste incinerators to develop an economically effective waste incinerator model and a roadmap for reducing dioxin emission and other toxic compounds.

- For waste incinerators, the following issues need further consideration:

Industrial and medical waste incinerators

- Regulations on dioxin emission levels in industrial and medical waste incinerators are currently available and specialized organisations/agencies and enterprises are more or less familiar with these regulations. Dioxin threshold levels in the regulations could be strict but feasible. These regulation values should remain as a basis for examination and inspection. Dioxin emissions from incinerations depends on the following factors:

+ New or newly upgraded or renovated incineration equipment

+ Operations strictly follow the standardized procedures especially the chemical mixing at the flue gas treatment phase

+ Proper maintaining combustion and temperature in combustion chambers

+ Mixing and loading suitable waste materials while minimising input materials with possibility to emit contaminants

- Recommendations should be provided to waste treatment facilities to maintain their equipment in good condition, develop effective treatment procedures for different categories of waste, train professional staff, use BAT/BEP on a regular basis at their facilities and maintain stable measurement and examination schedules.

- For medical waste incinerators, currently medical waste incineration at medical facilities (hospitals) is limited due to small capacity incinerators and thus, waste incineration is not effective. A model for waste treatment in cluster should be focused on building new incinerators at provincial and district levels while upgrading current waste treatment facilities in big cities.

Municipal waste incinerators

- Recent communication and interaction with local authorities and environment businesses shows that there is a wish to have urban domestic waste incinerators, both now and in the future. Many local authorities and businesses hope to have incinerators with suitable technologies for urban waste treatment.

Domestic waste incinerators are essential. However, it is recommended to classify the target groups for this:

- For commune-level towns, rural district level towns or small and medium provincial towns with the amount of waste collected per day and night from 40-100 tons, it is suggested that an investment step from one to two modules of incinerators with a minimum capacity of 25 tons/day upward is selected. The investment of incinerators should be divided into stages, depending on the financial capacity, technology levels of businesses and emission/discharge amount. In the treatment assembly, other methods should also be integrated to minimise the waste amount for incineration.

- For large cities where waste collection is around hundreds to thousands of tons per day and night, incinerators from one to three modules should be selected with a minimum capacity of 40 tons/day upward.

- In terms of incinerator technology, rotary kiln stokers, fluidized bed furnaces or Stair-like stoker furnaces should be used. It is not necessary to import these furnaces if technologies are transferred for local fabrication and installation, and the costs of these furnaces will then be much lower while the requirements are still ensured.

- Currently, domestic waste incineration with the above kinds of furnaces is still popular, especially in surrounding countries like Korea, China and Japan. Thus, the investment for waste incinerators within five to 10 years and longer term would be still in the right direction.

- Incineration of domestic waste with an investment in furnaces with a capacity from 300-1,000 kg/h.

Monitoring and supervision roadmap

- Technical guidance should be provided to carry out standard performances, or the facilities volunteer to participate, under the condition that standard furnaces are available for trials of sufficient measures. A roadmap will then be issued to obtain a scientific basis for such a roadmap.

- The roadmap should be provided to an agency to monitor, remind and work closely with relevant stakeholders for each implementation step. This is currently difficult to achieve for government management organizations and environmental enterprises. Currently and in the near future, present adopted regulations should be maintained for enterprises to familiarise themselves with such criteria. These will be used as the basis for achievement and for management, inspection and investigation.

- In terms of monitoring, only incinerators and furnaces with the following conditions should be monitored:

  + Incinerators should have both primary and secondary combustion chambers.

  + In terms of the temperature in the incinerator, it should be stable during operation and ensured in the primary and secondary combustion chambers subject to the design documents.

  + In terms of an air pollution control device (APCD), regardless of wet or dry flue gas treatment technologies, the temperature of the gas after the secondary combustion chamber and before entering the APCD and when being discharged into the environment should be ensured and subject to the design documents. The flue gas treatment should be at least two levels of equipment upward.

  + The type of waste used for incineration during the monitoring and measurement should be in compliance with the designed function of the furnace/incinerator, such as medical waste for medical waste incinerators.

  + In terms of furnace capacity, at the time of measurement it should ensure stable operation and achieve at least 60 per cent of the furnace's capacity.

  +Regarding the time of measurement, the furnaces/incinerators must have been in stable operation for not less than 10 hours.

- In terms of monitoring parameters, apart from dioxins and furans, other heavy metal parameters such as Cd, Cu, Pb and Zn should also be monitored and flue gas sampling methods should be subject to the standards introduced by the US EPA.

- Monitoring and measurements should be associated with BAT/BEP applications, depending on the conditions of the waste treatment facility. If all the guidance and criteria above are followed, the measurements can be carried out at least twice per year for each BAT/BEP application programme with the objective of emission reduction.

- Regarding industries with a relatively high risk of emission but at high cost for investment, such as metallurgy, it is necessary to survey the production facilities with different input materials to obtain the most comprehensive picture of the dioxin emission status. It is also necessary to carry out and apply cleaner production/manufacturing processes to save energy and reduce greenhouse gases, while concurrently combining with BAT/BEP to reduce dioxins and other toxic organic pollutant emission.

- The development of Vietnam standards on dioxins is essential and should be completed first, before the development of Vietnam regulations, as this parameter is subject to the steel manufacturing emission regulations that will commence by 2017. In fact, the question of whether steel manufacturing businesses using EAF technology can meet the regulation's requirements or not still remains unanswered.

- To develop a standard on dioxin emission and toxic chemical parameters, there should a systematic approach as follows:

  + Survey the status of dioxin emissions from a number of industries with the possibility to emit dioxins. This survey should be based on the thermal process classification such as waste incinerators, metallurgy (ferrous/nonferrous), cement production (shaft kiln, rotary kiln) and not on the industry type.

  + For metallurgy plants using EAF electric arc technology, it is necessary to survey the plants which use 100 per cent scraps as input materials.

  + From the actual emission status, develop a roadmap for emission reduction which will be integrated into Vietnam standards.

+ For nonferrous metallurgy, initial surveys show that some of the zinc production facilities have a high possibility of emission. Continuous surveys of nonferrous metallurgy plants such as copper and tin production should be maintained in order to have a clearer picture. Cleaner production/manufacturing programmes and the use of BAT/BEP should also be adopted. Surveys should be closely incorporated with industrial facilities and linked with the upgrading programmes or technology procedure change of the plants. Surveys can be carried out one to two times per year.

- For other industries, the possibility of dioxin emission may be high in handicraft villages which are scattered throughout the north of Vietnam, especially handicraft villages related to thermal processes such as recycling of metals and small-scale boilers in villages for food and foodstuff processing. Open burning activities such as domestic waste burning in landfills, burning of joss stick paper, straw and handicraft brick furnaces also have a high possibility of dioxin emission. Surveys and measurements should focus on these activities.

- The issuance of standards and regulations on dioxin emission thresholds in industries should be implemented in parallel with the development and implementation of detailed technical guidelines or standards on the operation of assemblies and industrial facilities to reduce dioxin emission and other toxic chemicals, as well as training activities to raise awareness of dioxin emission in industries. The measurement and monitoring should be closely incorporated with surveys and assessments of BAT/BEP application in industrial facilities with the possibility of dioxin emission.

6.2. Dioxins in the environment in Vietnam

6.2.1. Conclusions

The survey on the dioxin level in the environment was carried out concurrently with the industrial emission programme. The environmental samples were collected from areas near different industrial activities and residential areas to assess the dioxin contamination status at the baseline and the role of industrial activities in dioxin contamination in the surrounding environment. This is the most comprehensive research in Vietnam so far, especially on target samples such as ambient air samples. The results are as follows:

- Dioxin concentration distribution in the sediment and soil in Vietnam can be classified in three categories: (1) heavily dioxin contaminated areas originating from the war, (2) areas contaminated by dioxins from industrial activities, and (3) areas with dioxin concentration at the baseline level. The dioxin concentration in sediment in some waste treatment facilities and industrial parks such as metallurgy plants is much higher than the baseline level, and there are samples where the content is equal or higher than those collected from AO/dioxin hotspots. The dioxin concentration in sediment in these areas is also within the range found in developed industrial countries, such as the USA, Australia, the Netherlands and Italy.

- The database on dioxin levels in the air environment in Vietnam is very limited and there are currently no regulations on the maximum acceptable dioxin levels in the air environment. In general, only one out 13 air samples collected in the northern provinces in Vietnam has TEQ concentrations exceeding the Japanese guideline values 0.6 pg/m^3. Dioxin levels in the air in Vietnam is generally in the low range. Samples with the highest TEQ concentration (4.63 pg/m^3) were collected from a zinc production plant. In general, ambient air at industrial areas was higher than in rural areas or residential areas. Esepcially, initial surveys show that the air is directly influenced by open waste burning (straw). In rural areas where open straw burning is carried out, the dioxin concentration is three times higher than in surrounding areas. Open waste burning is one of the activities with a high potential for dioxin emissions and which needs further study in the future.

6.2.2. Recommendations

- The dioxin levels in sediment, soil and air samples in base areas far from the sources of contamination are in general low. However, sediment from industrial parks such as metallurgy and waste treatment using incinerators has a relatively high dioxin level, exceeding the comparison standards many times. These areas require continuous surveys, especially in terms of treatment and containment of dioxin contaminated sediment and soil caused by industrial operations.

- The development of standards and regulations on dioxin levels in environmental samples requires further survey data in different areas in the country. Initially, it is recommended that only standard values should be introduced, together with warnings and technical guidance so as to obtain the standard values. Initial surveys show that industrial operations play significant role on maintaining dioxin concentration baseline in the surrounding areas. The application of BAT/BEP methods for industries will help to minimise dioxin emission and concurrently reduce dioxin contamination in the surrounding environment.

The recommended schedule for measurement and survey of dioxin emission (and some other parameters of other toxic chemicals) in industry and the environment are summarised in the following table.

6.3. Proposal for the plan on dioxin emission measurement and survey in industries and in the environment

Industry	Principle/orientation for survey	Frequency	Types of samples
Waste incinerator	- Combine with the BAT-BEP adoption programme - Only measure incinerators with capacity from 250 kg/h upward, normally from 250-1,000 kg/h, incinerators are required to achieve some technical conditions and capacity, etc.	Twice/survey programme	Flue gas, fly ash, wastewater, ambient air
Ferrous and non-ferrous metallurgy	- Combine with the cleaner production programme and BAT-BEP adoption - Electric arc furnace and blast oxygen furnace: monitor at facilities using 100 percent scraps as input materials - Non-ferrous metals: monitor main nonferrous metallurgy facilities	Once a year	Flue gas, fly ash, dust, ambient air
Small sized boilers at craft villages for food and foodstuff processing	- Combine with the surveys on BAT-BEP adoption programme, public awareness programme in reduction of dioxin emission	Once to Twice/survey programme	Flue gas, ambient air, fly ash, wastewater, sediment
Craft villages for plastic and metal recycling (aluminium, copper, tin, iron, etc.)	- Combine with the surveys on BAT-BEP adoption programme, public awareness programme in reduction of dioxin emission	Once to Twice/survey programme	Flue gas, ambient air, fly ash, wastewater, sediment, organism (fish, shrimp, etc.) collected from ponds and lakes in the surveyed area
Open burning: straw, solid waste at open landfill dumpsite in urban areas	- Combine with the surveys on BAT-BEP adoption programme, public awareness program in reduction of dioxin emission	Once to Twice/survey programme	Ambient air, ash, wastewater,soil/ sediment

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