steel plant, secondary brass smelter, crematory and hospital waste incinerator. The result of average dioxins and furans fluxes showed that the steel plant had the highest level of dioxins and furans emission (807 µg I-TEQ/h), followed by hospital incineration (408 µg I-TEQ/h) and solid waste incineration (67 µg I-TEQ/h). From an overall point of view, the results are within the expected range; most of them are similar to the situation in industrialized countries about 10–15 years ago. An exception on the positive side is the cement plant where the kilns represent best international state-of-the-art technology and operation. In 2010, PCD monitored dioxins and furans emission main sources. The selected sites were power plants, steel plants and crematories. The results showed that most air emission containing dioxins and furans were in accordance with Thai's standard except crematories, especially those that used coal and wood as fuel. Thailand, unlike USA, did not study backyard burning but waste incineration is a common main source of dioxins.

Key factors of dioxins management

Incineration is regarded as the primary source of dioxins because dioxins are known to be formed during the combustion of agricultural, industrial and domestic wastes and escape into the environment via exhaust gases from incinerators. There are two main factors that dominate dioxins emission: "What to burn?" and "How to burn?"

The major factor influencing dioxin formation from an incinerator is the presence of chlorine in combustion materials. Chlorine is found in various materials in municipal wastes such as wood, paper, food and plastic like PVC etc. **PVC is the center of debate because of the perception that it could potentially support the creation and release of dioxins into the environment during incineration of domestic and hospital wastes. But even without the presence of PVC in the waste composition, dioxin may still be formed during combustion because trace amount of chlorine salts such as sodium chloride (NaCl) particles are present in the air.[15]**

To find out whether the above is true or only a perception, many studies have been conducted to establish the correlation between the concentration of chlorine in the materials that are combusted and the amount of dioxins released. In the specific case of full-scale waste incinerators, some studies have found decreased dioxin formation with reduced chlorine input, while others have not[16]. There is no scientific theory that explains how or why the chlorine-dioxin relationship in full-scale waste incinerators should differ from that in other combustion systems. However, a very practical explanation for the inconsistent findings among studies of waste incinerators can be attributed to various factors such as combustion temperature and sulfur content in waste that are known to weaken and confound the results of such studies. Hence, the only apparent reason to attribute to PVC the reason for dioxin creation is the presence of chlorine in its molecule.

The life cycle assessment of PVC and of principal competing materials commissioned by the European Commission (EC) in 2004 concluded that the presence of PVC has no significant effect on the amount of dioxins released through incineration of plastic waste[17]. However, the quality of the report was questioned because it did not consider all key data and policy decisions. Moreover, it relied on quantitative life cycle assessment (LCA) that is deemed to be unsuitable for the task[18]. Hence we know that chlorine atoms are necessary for dioxin formation in combustion but there is no clear relationship between amount of chlorine and amount of dioxin formation.

Nowadays, the fundamental of the synthesis of dioxins in waste incineration has become clearer. There are more and more scientific evidences that temperature is the key parameter of dioxins emission in the combustion process. Numerous studies show the same relation between concentration of dioxins and furans and temperature in an incinerator[7][9] [15] [19] [20] [21]. Figure 5 shows that the concentration of dioxins and furans stay almost constant at up to 200 °C. However, at a temperature of 300 °C, it increases approximately ten times. At higher temperatures, the dioxins and furans concentration diminish again and the compounds are almost totally destroyed at 600 °C. Moreover, it has been demonstrated that the other parameters affecting dioxins emission from combustion sources are residence time, oxygen availability, feed processing and supplemental fuel, but not the concentration of materials containing chlorine. This theory was confirmed by the Green Purchasing Network (GPN), an organization promoting the concept and practice of Green Purchasing to government and private sectors in Japan. **In February 2014, GPN decided to remove an article in its green purchase guidelines requirement of labeling PVC[22] . The article was based on a misconception that incineration of PVC increases the generation of dioxins. GPN has concluded that the amounts of dioxins generated are not proportional to that of chlorine in the mass incinerated.** Because chlorine exists in many forms, such as salt in garbage, bleach in paper products, etc., and the amount derived from PVC is limited, burning anything can generate dioxins since traces of chlorine also exists in the atmosphere. **GPN is encouraging other organizations that have their green purchase policies to follow GPN's guidelines and promptly change their criteria to take advantage of the environmental performance of PVC products. Apart from the fact that PVC uses less fossil fuel as resource and serves much longer periods than other major plastics, PVC is easy to mechanically recycle.**

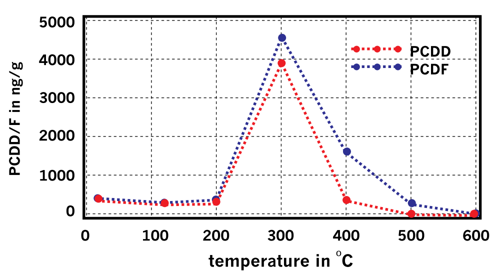

Figure 5: Formation of Polychlorinated dibenzodioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in fly ashes from waste incineration during annealing in air atmosphere[19]

Best practice and summary

To control and minimize dioxins emission from incinerators, proper incineration of contaminated material is recommended[7] [22]. The incineration process requires high temperatures, over 850 °C. For the destruction of large amounts of contaminated material, even higher temperature, around 1,000 °C or more are required.

Combustion and incineration account for major sources of known environmental dioxin releases in the world. Prevention of dioxin formation, in any case, is of course the best way to protect human health and environment. In reality, we cannot completely prevent dioxin generation since there is chlorine atom contained in many materials and in the atmosphere. So dioxin management should focus on the dioxin combustion method rather than pick on a chlorine composition in waste. It has been proven that suitable incineration design can destroy dioxin and reduce dioxin emission. However, it is important to monitor the amount of dioxin contamination in the environment and food chain and account for the dioxin inventory in individual countries.

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DIOXIN

What are dioxins and toxicity?

Dioxin is a general name for a large group of chemical compounds with a similar structure that is made up of carbon, oxygen, hydrogen and chlorine atoms. This group of chemical includes dioxins, furans and polychlorinated biphenyls (PCBs). The number of chlorine atoms and their positions in the dioxin molecule are what determine the toxicity of different dioxins. The most toxic dioxin has four chlorine atoms in positions 2, 3, 7 and 8 which is often referred to as tetrachlorodibenzo-p-dioxin (TCDD) [1],Figure 1. TCDD is assigned a toxic equivalency factor (TEF) = 1, the highest value in its class, so other dioxin compounds that have less TEF means less toxicity[2]. Studies have shown that dioxin exposures in high levels have an increased risk of cancer[3].

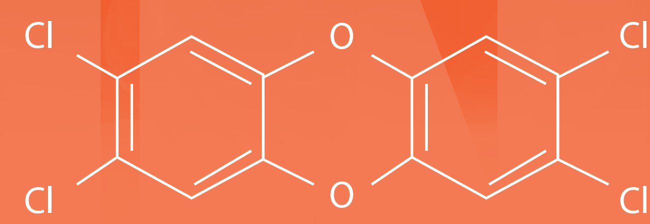

Figure 1: Structure of the most toxic dioxin 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin or TCDD

Dioxins and furans are chemical contaminants that are formed unintentionally[4] during combustion processes such as waste incineration, forest fires, and backyard trash burning, as well as during some industrial processes such as paper pulp bleaching, plastic processing and herbicide manufacturing. Dioxins did not exist prior to industrialization except in very small amounts due to natural combustion and geological processes but today, they are found in all humans, commonly found in persons living in more industrialized countries[5].

How can human expose to dioxin?

Most of the reported cases of dioxin poisoning and accidental contamination are intentional in purpose. For example, Ukrainian politician Viktor Yushchenko was exposed to the second-largest measured dose of dioxins[6]. Large amounts of dioxins were also released in a serious accident at a chemical factory in Seveso, Italy, in 1976. TCDD was released into the air and eventually contaminated a vast area. Investigations of these incidences were hampered, however, by the lack of appropriate exposure assessments[7]. Due to this accident, the European Commission has issued Directive 82/501/EEC, also called “Seveso Directive”, on major accident hazards of certain industrial activities to limit the consequences of such accidents[8]. Another well-known case of dioxins contamination occurred during the Vietnam war.

In normal situation, the general population is barely exposed to dioxin in high level since **dioxins are not manufactured as commercial products or ingredients. They occur as an unintended by-product of incomplete combustion (low temperature), photochemical and certain chemical processes, so dioxins exposures are clearly unfortunate and unintended incidents.** The primary cause of exposure to dioxins occurs by taking in food that are contaminated by these chemicals as a result of the accumulation in the food chain, and in high fat foods, such as dairy products, eggs, animal fats, and some fish[1][9]. The level of dioxin exposure considered safe (non-cancer risk) by US Environmental Protection Agency (US EPA) is 0.7 picograms* of dioxin per kilogram of body weight per day. The tolerable daily intake (TDI) limits set by the World Health Organization (WHO) and the European Union (EU) are between 1-4 picograms per kilogram of bodyweight per day. The limits are to allow or the uncertainty and ensure public safety in all instances. Particularly, the TDI has been assessed based on the safety of children born to mothers exposed all their lifetime prior to pregnancy to such a daily intake of dioxins[10]. It is likely that the TDI for other population groups such as adults could be somewhat higher. In daily life, the general population is barely exposed to dioxin in high level since dioxins are not manufactured as commercial products or ingredients. Figure 2 shows that the major portion of a person's average dioxin exposure comes from dietary exposure[11].

**Picograms mean one trillion grams*

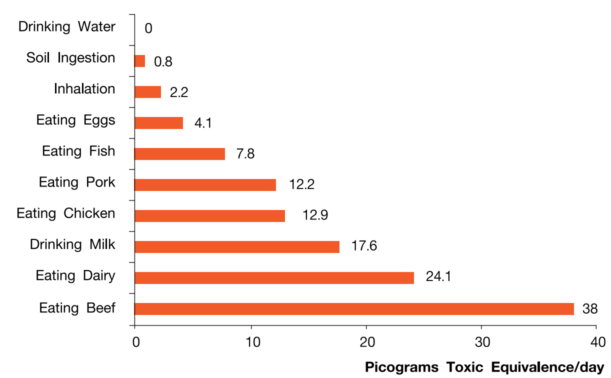

Figure 2: Sources of Daily Intake of Dioxin in North America

Sources of dioxins

Dioxins are released to the environment and the food chain in a variety of ways and in varying quantities, depending upon the source. **The largest release of dioxins today is open burning of household waste, municipal waste, medical waste, landfill fires, and agricultural and forest fires.** According to research, major sources of environmental release have been grouped into four (4) major categories[9] namely (i) incineration; (ii) combustion; (iii) industrial process and (iv) reservoir sources. In 1999, United Nation Environmental Program (UNEP) reported on initial findings obtained from national inventories of releases of dioxins and furans from Western Europe, United States, Canada, Australia and Japan[12].The report showed that incineration is the largest source of dioxin release in the environment at about 69%. However, UNEP's report on dioxins inventory cannot represent global emission of dioxin due to limited number of participating countries. It only presents a snapshot and trend on dioxins emissions and estimates of total releases of these compounds into the environment. US EPA report on inventory of sources and environmental releases of dioxin-like compounds[13] show that between 1987 and 2000, the amount of dioxin decreased by approximately 90% and in year 2000, backyard burning of trash is the highest dioxin source (Figure 3).

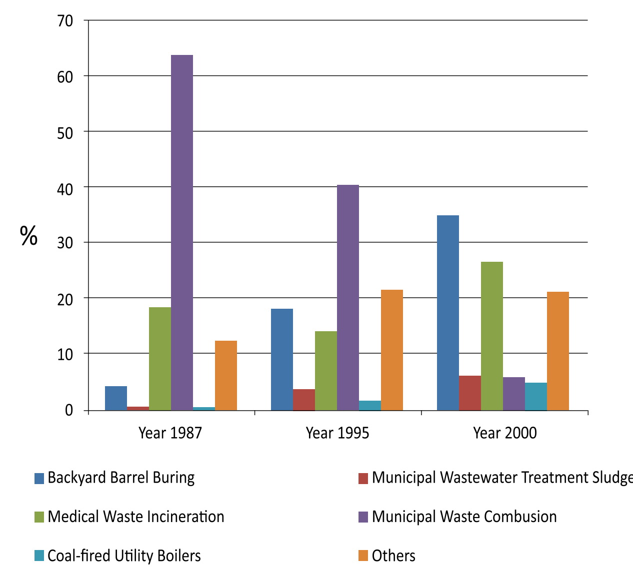

Figure 3: Sources of dioxin emission during 1987–2000 in USA

Furthermore, the US EPA's data shows dioxins emission from chloro-vinyl manufacturer in 2011 has been reduced 79% since 2000[14]. **The latest information from US EPA (year 2011) confirms that the key source of dioxins that released to environment is from backyard barrel burning and amount of dioxin emission from chloro-vinyl manufacturing is very small when compare with other sources[14] (Figure 4).** This result is the same trend of UNEP report about dioxin inventory.

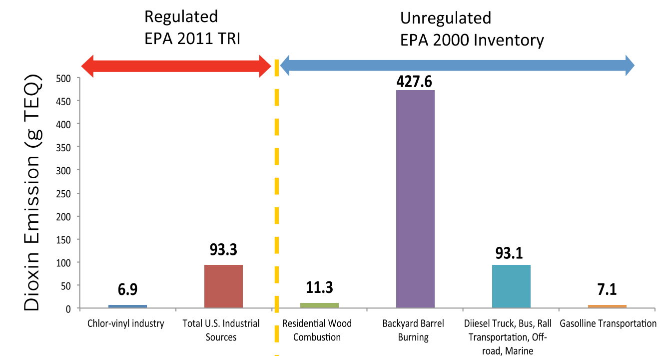

Figure 4: Putting Dioxin in Perspective in USA (2011)

Thailand also tried to identify the major origins of dioxins and furans as a basis to draw up measures of reducing dioxins emissions. This project was undertaken in 2001 by UNEP in coordination with the Pollution Control Department (PCD), The German Organization for Technical Cooperation (GTZ) and Euro Chlor. Seven (7) facilities were selected to represent industry sectors that were known to be potential emitters of dioxins and furans. The sampling facilities were a solid waste incinerator, cement plants with and without co-combustion of liquid hazardous waste and/or tires, secondary lead smelter,