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Review Article

Present Status and Future Perspectives on Dioxins/Furans and Polychlorinated Biphenyls Policies in Malaysia

Abstract

Dioxins/furans and polychlorinated biphenyls (PCBs) are persistent organic pollutants (POPs) that are lipophilic and toxic in the environment. These contaminants are found in some soils, sediments, feed and food, especially dairy products, meat, fish and shellfish. The main pathway of human exposure to these pollutants is via food ingestion, estimated at over 95% of the total intake for non-occupationally exposed persons. They last a long time once they enter into the body due to their chemical stability and their lipophilic characteristic whereby they absorb by fat tissue and store in the body. Dioxins and furans contaminants are released through combustion, such as waste incineration, forest fires, volcanic eruptions and some industrial processes while PCBs are man-made chemicals and has been used because of their stability and low flammability as insulating materials in electrical equipment. Waste management is a general acute problem around the world. As one of the developing countries, Malaysia is undergoing economic growth, industrialization and urbanization, thus the proper management of larger quantity of waste being generated is of great concern. For this issue, hazardous waste from industries especially, is becoming a topic of one cannot deny that requires immediate attention. The efforts to reduce the emission of dioxins/furans and PCBs into the environment are being initiated when Malaysia agreed in the Stockholm Convention on Persistent Organic Pollutants in 2002. The toxicity of these contaminants in food/feed, air and sludge samples is monitored routinely. However, intensive measures to prevent the formation of dioxins/furans at the source have not been widely implemented. This paper describes the policies and regulations of dioxins/furans and PCBs in Malaysia. It also addresses the health risk assessment on certain food items and some potential strategic measures are recommended and evaluated.

Abbreviations

EC: European Council; EFSA: European Food Safety Authority; EPA: Environmental Protection Agency; PCBs: polychlorinated biphenyls; POPs: persistent organic pollutants; RASFF: Rapid Alert System for Food and Feed; 2,3,7,8-TCDD: 2,3,7,8-tetrachlorodibenzo-p-dioxin; TEF: toxic equivalency factor; TDI: tolerable daily intake; WHO: World Health Organization; WHO-TEQ: WHO-endorsed toxic equivalents; TEQ: toxic equivalents; TSCA: Toxic Substances Control Act

Introduction

Dioxins (polychlorinated dibenzo-p-dioxins), furans (polychlorinated dibenzofurans), and polychlorinated biphenyls (PCBs) are highly toxic environmental pollutants that categorized as persistent organic pollutants (POPs) that can cause adverse effects on human and ecosystem. Dioxins/furans are released through combustion or as unwanted by products [1,2] in the flue gas from municipal solid waste [3,4], industrial waste incinerators, the synthesis of chlorinated compounds and the manufacture of some pesticides, herbicides and fungicides [5]. Both dioxins and furans are also resulted from natural processes like volcanic eruptions and forest fires [6,7]. In contrast, PCBs are man-made chemicals and belongs to a group of oily stable chemicals which has been used because of their stability and low flammability as insulating materials in electrical equipment [8]. PCBs have been produced and used in dielectric fluids in transformers, capacitors, and etc in the past and were phased out nationally and regionally during the 1970-90s [9]. In 2004, PCBs, dioxins and furans were globally banned under the Stockholm Convention on Persistent Organic Pollutants (http://www.pops.int), which is an international environmental treaty with the aims to eliminate or restrict the production and use of POPs. However, despite being regulated,

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these compounds continue to persist in the environment [10] and are still detected in human and animals tissues due to improper handling and disposal of equipment containing PCBs [11].

Dioxins/furans are organohalogenated substances, which form a group of 210 congeners. However, only the isomers presenting chlorine in the 2,3,7,8 positions have been reported to be toxic to exposed organisms [12,13]. This reduces the number of compounds of interest to 17, seven dioxins and ten furans. These 17 congeners exhibit a similar toxicological responses with the 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), which is being the most toxic and carcinogenic for humans [14]. Out of 209 congeners of PCBs, 12 of them show toxicological properties similar to dioxins and therefore termed as dioxin-like PCBs (dl-PCBs). Due to large number of congeners, relevant individual congeners are assigned with a toxic equivalency factor (TEF) [15]. Each concentration of an individual congener in a mixture is multiplied with its TEF value, and the resulting TCDD equivalents are added up and expressed as WHO-TEQ (WHO-endorsed toxic equivalents) [16,17].

Since these pollutants have a high lipophilicity and resist transformation properties, they can bioaccumulate in animal and human adipose tissues [18] through the food chains. Thus, consumption of fatty food is considered as the major source of human exposure to dioxins/furans [19-21] with foodstuffs from animal origin accounting approximately 90% of the human body burden [23-25]. Meanwhile, air inhalation or dust ingestion intake only contributes up to 2.6 % to the total daily intake [26]. Ingested dioxins and PCBs were absorbed from the gastrointestinal tract, but were not readily catabolized by drug metabolizing enzyme system, thus would accumulate in the body over long periods of time and persist for decades [27,28]. The toxic effects of these substances include immunological and endocrinological effects, reproductive toxicity, growth retardation as well as carcinogenicity [17]. In recent years, a number of studies on the occurrence of dioxins/furans and PCBs in various food samples and the estimation of human dietary exposure have been reported in several countries over the world [29-36]. Table 1 shows the recent occurrence information reported by the Rapid Alert System for Food and Feed (RASFF). This effort is done by European Food Safety Authority (EFSA), European Union with the aim to reduce these contaminants levels in the environment, feed and foodstuffs in order to ensure a high level of public health protection.

However, not many measures to reduce dioxin emissions have been taken by the developing countries including Malaysia. Along with the evolvement of the waste management policies, Malaysian government still unclear with the dioxins emissions policy although Malaysia agreed in Stockholm Convention on Persistent Organic Pollutants in 2002. In this paper, we review the present status of dioxins/furans and PCBs in Malaysia and address the health risk assessment on certain food items. Apart from that, some potential strategic measures are recommended and evaluated in order to help authorities to tackle the challenges of managing dioxins/furans and PCBs.

Environmental policy vesus food regulations

Responsibility of waste management often resides with national government in many countries; however privatization of waste management is practiced in Malaysia. Although the main motivation for contracting out the service to concessionaires is cost saving, but proper control by applicable laws and regulations is important. In fact, the control of industry emissions and hazardous wastes disposal is a challenge for the government. In the context of dioxins and furans, Environmental Quality (Dioxin and Furan) Regulations (2004) has been introduced and come into operation in May 2004 to overcome this problem. These regulations apply on incinerator facilities for municipal solid wastes, scheduled wastes, pulp or paper industry sludge and sewage sludge. The permissible air emission limit of dioxin and furan for these incinerators should not exceed 0.1 ng/Nm^3 TEQ. For food items, dioxins/furans and PCBs are not regulated in Malaysian Food Act and Regulations (1985) at this moment. However, most of the food manufacturers and related stakeholders are following the maximum levels for dioxins, furans and dl-PCBs in various food groups regulated in Council Regulation No. 1881/2006 by European Council (EC) [37].

Exposure monitoring

To date, data on emission of these pollutants into the environment is scarce. Only dietary exposure to dioxins/furans and dl-PCBs on selected foodstuffs [38,39] and certain environmental matrices (ambient air and soil) [40] were reported. According to the investigations, the dietary exposure on these contaminants from certain food was low among Malaysian population and does not pose a notable risk to the health of the average consumer. According to Leong et al. [38], the dioxin exposure in Malaysia was mainly attributed to seafood. This is in agreement with previous studies that fish is the main source of dioxins intake in Spain [30], America [41], China [42], Taiwan [43], Japan [44], the Nordic countries [45], and Italy [46]. In general, Malaysian could probably be considered to consume much less of the dioxins/furans than the population from industrialized countries such as Japan and those in European. A study from Tsutsumi et al. [47], stated that 60-80% of dietary intake of these contaminants among Japanese was through seafood. In Europe and North America, the primary sources of dioxins are meat, eggs and dairy products [48].

Due to the persistent, bioaccumulative and toxic nature of dioxins/furans and dl-PCBs, environmental monitoring of various biota e.g., guillemot (*Uria aalge*) eggs, blue mussels (*Mytilus sp.*) and Baltic herring (*Clupea harengus membras*, *C. harengus* on the Swedish west coast), is conducted by some European countries to follow temporal changes in these contaminants [49]. Exponential decreases in dioxins/furans in environmental matices, e.g. air emissions [50] and sediment [51,52] have been reported. However, the dioxin concentrations, in particular furans, in Baltic herring, have been relatively stable since the mid to late 1990s [53] and a general decrease for the levels of dioxins, furans and dl-PCBs

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Table 1: Recent occurrence information reported by the Rapid Alert System for Food and Feed (RASFF) on dioxins and dl-PCBs (from 1 January 2015 to 15 December 2016).

Subject	Type	Country range	Country and date of case
1. dl-PCBs and non-dl PCBs In Yeast Compound Feed From Italy With Raw Material From India And Derived Products From Belgium	Feed	dl PCBs range : 2.18; 7.02 pg WHO TEQ/g	Belgium , 6/10/2016
2. Dioxins In Green Tea Fannings From China, Via Germany	Feed	1.5 ng/kg – ppt	United Kingdom, 9/9/2016
3. Dioxins In Dried Citrus Peels From South Africa	Feed	1.17- 1.90 pg WHO TEQ/g	Germany, 23/5/2016
4. Dioxins in apple pomace from Ukraine	Feed	7.9; 9.15 pg WHO TEQ/g	Germany, 25/2/2016
5. Dioxins in complementary feed for fish from Brazil	Feed	5.42 pg WHO TEQ/g	Belgium, 1/12/2015
6. Dioxins and dl-PCBs in dried apple pomace from Poland	Feed	Dioxins value : 1.99 pg WHO TEQ/g dl-PCBs value : 2.10 pg WHO TEQ/g	Poland, 23/11/2015
7. Dioxins in fish oil from Denmark	Feed	8 pg WHO TEQ/g	Denmark, 5/10/2015
8. Dioxins and dl-PCBs in egg yolk powder from India	Food	Dioxins value : sum > 5 pg WHO TEQ/g (7 out of 12 samples) dl-PCBs value : >40 µg/kg ppb (12 out of 12 samples)	Germany, 23/9/2015
9. dl-PCBs in dried yolk powder from India	Food	6.13 pg WHO TEQ/g	Sweden, 1/9/2015
10. Dioxins in chilled sow half carcasses from Denmark	Food	4.6 pg WHO TEQ/g	Denmark, 1/9/2015
11. Dioxins in liquid horse fat from Mexico	Feed	5.97 pg WHO TEQ/g	Belgium, 31/8/2015
12. Dioxins in leonardites from China	Feed	2.29 pg WHO TEQ/g	Belgium, 7/8/2015
13. Dioxins and dl-PCBs in dried apple remainders from Poland, via Austria	Feed	Dioxins value : 2.528 pg WHO TEQ/g	Germany, 22/7/2015
14. Dioxins in organic eggs from the Netherlands	Food	3.44; 4.06; 3.88; 2.84; 3.39 pg WHO TEQ/g	Netherlands, 16/7/2015
15. Dioxins in sunflower fatty acid from Serbia	Feed	4.623 ng/kg ppt	Austria, 14/7/2015
16. dl-PCBs in eggs from the Netherlands	Food	22 pg WHO TEQ/g	Netherlands, 10/7/2015
17. Dioxins in valerian and passionflower vegetal extract from Spain	Feed	2.72 ng/kg ppt	Spain, 3/7/2015
18. Dioxins in in cod liver from Latvia, with raw material from Norway	Food	76.94 pg WHO TEQ/g	Germany, 26/6/2015
19. Dioxins in in fish oil from Latvia	Feed	8.6 ng/kg ppt	Lithuania, 12/5/2015
20. Dioxins in zinc oxide from Germany	Feed	9.53 ng/kg ppt	Germany, 5/2/2015
21. Dioxins and dl-PCBs in cheese from Romania	Food	8.7 pg WHO TEQ/g	Italy, 23/1/2015

values (in TEQ_{2005}) are documented [54]. Considering the potential of accumulation of these contaminants in the human body, food monitoring on the regular basis is recommended. To obtain a better understanding of the exposure, studies on human blood and even breast milk should be included in the monitoring plan.

Strategies

Waste incineration is one of the important methods of waste management in the country. However, this approach has been the predominant source of dioxins/furans formation. Attempt to reduce the amount of dioxins emitted from waste incinerators is an essential aspect of proper and comprehensive waste treatment. In fact, prevention of secondary pollution associated with waste management is crucial. In specific, the problems related to the formation of dioxins as a byproduct of waste incineration should be focused and eradicated. More assessments of the presence of dioxins/furans and PCBs from sources such as incinerators, landfill fires, bushfires, open burning and motor vehicles should be conducted to determine their levels in the environment and subsequently, food and population. These findings will provide useful information about the risk pose to human health and the environment as well as for appropriate management actions. From the experience of developed countries, some possible measures to prevent the dioxins formation included methods for achieving complete combustion, preventing de novo synthesis of dioxins, and highly effective methods for removing dioxins after they had been generated [55].

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Material recovery and recycling are encouraged to reduce the net amount of wastes requiring treatment and disposal. Usage of plastic bag made from PVC should be banned in order to reduce the emission of toxic substances such as dioxins/furans and other halogenated substances into atmosphere when they are burned at landfill or incinerator. Emphasis should be given to investigation on emission conditions and risk, the mechanism of dioxin formation in waste incineration facilities, which are the basic information for system design for dioxin management. Setting the tolerable daily intake (TDI) of these contaminants is essential and is a significant factor in establishing a system for dioxin reduction measures in waste treatment. At this point, Malaysia does not have specific TDI that set based on the background data, however regulatory limits established by international organizations such as WHO are adopted.

Involvement and support from policy makers are very important to the success of the program and the benefit of the entire population. Development or amendment of applicable laws and regulations and to improve financing of the waste treatment system including waste treatment facilities, maintenance and updating are some of the main aspects that should be look into. In addition, environmental standards for air, water, soil, and sediment quality need to be set and reviewed from time to time. Furthermore, a financial support system from government in promoting facility improvement and treatment in small and medium industries should be established.

Conclusions

Despite of low exposure of dioxins/furans and PCBs among the population was reported currently, intensive measures to prevent the formation of dioxins/furans at the source should be adopted. In fact, the essential viewpoint required for waste management policy today is to prevent shifting the burdens of the present generation to future generations.

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