Transition from landfilling of Municipal Solid Waste to waste-to-energy - Evaluation of the impact on dioxin emissions

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Introduction

The term "dioxins" refers to a group of similar chlorinated organic compounds known as polychlorinated dibenzo-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs). According to WHO (2016), long-term exposure to dioxins is associated with impaired immunological, neurological, endocrine, and reproductive systems. These chemicals are generated as a result of activities such as burning fuel, incinerating waste, burning of landfill sites, making pesticides, and bleaching pulp and paper using chlorine. (Cheng & Hu, 2010; Kulkarni et al., 2008; Ruokojärvi et al., 1995.). Until last decades, waste incinerators have traditionally been identified as one of the most significant sources of toxic emissions, including not only dioxins but also heavy metals (Kim et al., 2008; Shibamoto et al., 2007; J. B. Wang et al., 2009). Due to the harmful effects of dioxins emissions, the dioxins emissions are regulated strictly by legislation in municipal solid waste (MSW) incineration. Still, fear of dioxin emissions is one of the main arguments against waste incineration plant investments in many countries presented often by citizen activists.

According to Dwyer & Themelis (2015) research, dioxin emissions can be classified into two categories based on their sources: controlled industrial sources (energy generation and waste incineration) and uncontrolled open burning sources including landfill fires, forest and bush fires and backyard burning of waste. An estimation has been made by Dwyer & Themelis (2015) to evaluate the nationwide dioxin emission in 1987 and 2012 in the USA. The total emissions from controlled sources reduced by 95,5 % from 14 kg TEQ in 1987 to 0,6 kg TEQ in 2012. Furthermore, the emissions of open-burning sources raised up from 2,3 kg TEQ in 1987 to 3 kg TEQ in 2012.

This study aims to assess the changes in dioxin emissions in the countries that have carried out a significant and rapid transition from landfill to waste-to-energy (WTE) treatment, utilizing estimation method to determine the changes in dioxin emissions as a result of the adoption of WTE waste treatment methods and avoiding landfill fires.

Methodology

This study evaluated such countries that have committed significant transition from landfill to WTE treatment in a certain period of time in close history, in order to estimate the change in dioxin emissions caused by landfill fires and WTE technology. Through an analysis of statistical data, this research identified the United Kingdom (UK), Austria, Poland, Ireland, Norway, Finland, Lithuania, and China as countries that have quite rapidly increased their MSW management strategies by using WTE and reducing landfill treatment. In the study, a simple methodology was developed to estimate dioxin emissions from waste treatment processes, focusing specifically on WTE plants and landfill fires. This approach involves the calculation of emissions using specific formulas and emission factors tailored to the conditions of different countries. For emissions from WTE plants, the "WTE Dioxin Emission Estimation Formula," as derived from the work of Cudjoe and Acquah (2021), is utilized. This formula calculates dioxin emissions by considering the quantity of municipal solid waste (MSW) incinerated and a dioxin emission factor specific to WTE plants. The emission factors for each country were adapted from a comprehensive analysis by Wei et al. (2022). When specific data for a country were not available, emission factors from countries with similar MSW incineration volumes and behavior of MSW generation and management were selected. Regarding landfill fires, the "Landfill Fire Dioxin Emission Formula," based on Dwyer and Themelis (2015), is employed. This calculation requires the number of landfill fires, the mass of waste burned in each fire, and a dioxin emission factor. Due to the limited availability of relevant data related to number of landfill fires, amount of waste burned in them and dioxin emissions of them in different countries, the most recent data from the United States (2011) were applied uniformly across all countries in the study. The "MSW

Burned Ratio Formula" was introduced to estimate the proportion of MSW burned in landfill fires to the total landfill waste. This step was necessitated by the variability of landfill fire incidents and the scarcity of comprehensive data. Furthermore, the "Per Ton Dioxin Emission from Waste Treatment Formula" was evaluated to assess dioxin emissions per kiloton of MSW treated by both landfills and WTE facilities. This provided insight into the environmental impact of transitioning from landfilling to WTE for waste management. Lastly, the change in dioxin emissions during the transition period was calculated using the "Dioxin Emission Change Formula" and the "Dioxin Emission Rate Change Formula," highlighting the benefits of shifting towards more sustainable waste management practices. This methodology offers a rough estimation of dioxin emissions, emphasizing the need for accurate, country-specific data and adjustments in environmental impact assessments globally.

Results

The data presented in Table 1 presents the results related to the changes in dioxin emissions based on the amount of MSW treated by WTE and landfill. Notably, since all the selected countries experienced a significant increase in WTE and a decrease in landfill, the reduction in dioxin emissions in all countries is attributed to the increase in WTE. The findings highlight the potential for WTE to contribute to reducing dioxin emissions and enhancing environmental sustainability by providing a more sustainable approach to waste management practices.

Table 1. Changes in dioxin emission in each country

Countries	Time period	D1 (mg-TEQ/kt landfill+WTE)	D2 (mg-TEQ/kt landfill+WTE)	ΔD (mg-TEQ/kt landfill+WTE)
Ireland	2008 to 2014	12,6	5,0	-7,6
United Kingdom	2005 to 2018	11,6	3,5	-8,2
Norway	2006 to 2013	4,8	0,5	-4,3
Finland	2010 to 2019	8,9	0,5	-8,4
Poland	2012 to 2020	13,0	8,5	-4,5
Austria	2005 to 2020	3,8	0,7	-3,1
Lithuania	2013 to 2020	11,7	5,1	-6,6
China	2010 to 2017	10,6	7,7	-2,9

D_1: Total amount of dioxin emissions (mg-TEQ/kt $_{landfill+WTE}$) from landfill fire and WTE at the start point of transition period.

D_2: Total amount of dioxin emissions (mg-TEQ/kt $_{landfill+WTE}$) from landfill fire and WTE at the end point of transition period.

ΔD: Changes in the amount of dioxin emissions (mg-TEQ/kt $_{landfill+WTE}$) from landfill fire and WTE during transition period

The results indicate that the reduction of dioxin emissions related to landfilling and WTE in different countries was between 27,4 % and 94,4 % per each kiloton of treated MSW. The reduction is mostly result of decrease of landfill fires which were found to be the largest source of dioxin emissions in the study of Dwyer and Themelis (2015).

Conclusion

In conclusion, this research demonstrates with a simplified estimation that waste incineration, despite releasing dioxins, helps to reduce dioxin emissions of waste management significantly if the alternative treatment for the waste material is landfilling.

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