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A Review on Technologies of Removal of Dioxins and Furans from Incinerator Flue Gas

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Abstract

The demands of our society generate wastes that tend to increase in quantity as the standard of living increases. The most effective means of dealing with the problem is to reduce the amount of wastes generated. Incineration is one of the oldest technologies to reduce the amount of generated waste. But one serious drawbacks of this process is the emission of dioxins and furans in flue gas. Dioxins and Furans are regarded as very harmful chemicals which can have serious health effect causing cancer, reducing immunity. Various techniques are available for the treatment of flue gas emission depending upon the type of feed stocks. Some popular and effective methods are using sulphur compounds namely $(NH_4)_2SO_4$, pyrite (FeS_2), changing the operating conditions of incinerations etc. The main aim of this paper is to suggest a cost effective, efficient and a long lasting method to treat the flue gas so that the concentration of dioxins and furans can be reduced effectively as well as to eradicate the challenges associated with the process. The present review discusses the current views on methods to minimize dioxins and benzo-furans, namely polychlorinated dibenzo-dioxins (PCDDs) and dibenzo-furans (PCDFs), formation in different types of incineration systems. Municipal solid waste incineration system, hazardous solid waste incineration system and Bio medical waste incineration system has been considered in this case. This paper briefly introduces with the formation mechanism and the various sources including the precursors of PCDD/Fs formation so that it can be controlled during the combustion and later it discusses about an effective method to reduce the formation and fight with the associated challenges. The findings of this paper will help the stakeholders in decision making process in establishing a sustainable future of waste management and will set future directions for better and innovative research addressing the problems.

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Keywords:Incineration, Dioxins, Furans, flue gas treatment, removal technologies;

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1.0 Introduction

As the standard of living increases the quantity of wastes generated also increases and the most effective means of dealing with this problems of excessive generation of waste is to reduce its amount. In recent years, incineration of solid wastes has become one of the most widely used alternatives for waste management by the aid of combustion of both organic as well as inorganic solid wastes categorized as Municipal solid wastes, Bio medical solid wastes, Hazardous solid wastes (McKay1984, Weber et al. 2002). This process is considered as a strategic option for waste reduction and disposal. Incineration is also described as a thermal treatment processes as well as one of the several waste- to- energy (WtE) technologies. However, incineration does have its problems and one of the major and serious threats towards the environment and the society is the emission of flue gases. The gas contains bulk species, such as oxides of sulphur and nitrogen, fine dust, trace elements such as mercury and nickel, and super-toxics such as Polychlorinated dibenzo p-dioxins (PCDDs) and Polychlorinated dibenzo-furans (PCDFs) respectively. Dioxins are the generic terms for the polychlorinated organic compounds namely polychlorinated dibenzo p-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs)that are generated unintentionally from waste incinerators by two main pathways (Chang et al. 2011, Choi & Lee 2007, Liu et al. 2013); firstly homogeneous reactions at high temperature and the other one is heterogeneous reactions in the post combustion zone at low temperature. There are 210 Congeners in total out of which 75 Congeners belong to PCDDs and the rest 135 congeners belong to PCDFs and out of these 210 congeners,17 congeners are toxic in nature. Dioxins are actually the unwanted by-products and have generated a lot of controversies mainly, because they are among the most toxic environmental compounds on the earth and particularly 2,3,7.8-Tetrachloro dibenzo p-dioxin(TCDD) has the highest toxicity which is assigned a TEF value of 1 (Van den Berg et al. 1998) .According to US Environmental protection agency (USEPA) dioxins are the serious carcinogens which may destroy the immune system of the human body and interfere with the hormone regulation and today their traces are found in human bodies and commonly found in people living in the vicinity of industries (Gasiewicz& Park 2003). Hence due to their severe toxicities and potential to accumulate in the tissues of organisms PCDD/Fs have attracted great social, technical, scientific and local community's interest's (Kaivosoja et al. 2012, Stanmore 2004)and as a result flue gases must be cleaned of and treated before they are dispersed in to the atmosphere. This review focuses on the information regarding dioxins concerning the formation of dioxin compounds, sources, types of congeners briefly and highlighting on the minimization methods of PCDD/Fs from the flue gas. There are several methods practiced till date around the globe which can be broadly categorized as: 1) Good combustion practice coupled with end of pipe treatment, 2) selective catalytic reduction/oxidation, 3) uses of suitable inhibitors. The final section of the review focuses on one of the efficient and best possible technologies to be adapted from all the proposed techniques to execute the minimization of dioxins. Considering the above, following questions have aroused: More number of catalysts as well as proper inhibitors should be available that will work positively to inhibit the dioxins formation in the flue gas during incineration. A proper method should be proposed for the feedstock preparation which will help to irradiate the precursors for dioxins formation. The main objectives of this review is to present a brief picture of dioxin compounds starting from their formation, sources and the types of congeners that are toxic in nature then to explore different types of dioxin compounds treatment processes to minimize its formation in both the combustion and non-combustion stages and finally to explore the possibility of zeroing the emission of PCDD/Fs by using the appropriate technology. The method chosen to execute the whole work of this paper is a thorough study of the literatures available on the said topic for the last 20 years is done.

1.1 Formation of Dioxins

The formation of PCDD/Fs occurs mainly via two mechanisms. Firstly is the homogeneous reactions at temperatures between 773 K and 1073 K and the main mechanism behind the process is the rearrangement reaction of chlorinated precursors such as Chlorophenols (CP), Chlorobenzenes (CBs) in the gas phase and the PCDD/Fs formed undergoing this process are either called homogeneous PCDD/Fs or high temperature PCDD/Fs. Another mechanism is the heterogeneous reactions in the post-combustion zone at temperatures between 473-673 K and the main process is the surface catalytic effect of fly ash or soot which is famous as De novo process (Stanmore 2004, Huang & Buekens 1995)where the PCDD/Fs formed known as heterogeneous PCDD/Fs or low temperature PCDD/Fs, which may come from Chlorophenols, Chlorobenzenes (Addink & Olie 1995, Vermeulen et al. 2014)or from carbon in fly ash. The two pathways of dioxins formation are said to occur simultaneously and independently.