



Lung cancer risk assessment at receptor site of a waste-to-energy plant



Mauro Scungio^a, Giorgio Buonanno^{a,b,*}, Luca Stabile^a, Giorgio Ficco^a

^a Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, via G. di Biasio 43, 03043 Cassino (FR), Italy

^b Queensland University of Technology, GPO Box 2434, Brisbane, Qld 4001, Australia

ARTICLE INFO

Article history:

Received 4 April 2016

Revised 14 July 2016

Accepted 18 July 2016

Available online 25 July 2016

Keywords:

Risk analysis

Ultrafine particles

ELCR

Waste treatment

Incinerator

Lung cancer

ABSTRACT

The toxicity of particulate matter emitted from waste-to-energy plants, is associated to the compounds attached to the particles, several of which have been classified by the International Agency for Research on Cancer (IARC) in the Group 1 carcinogens. In this paper a modified risk-assessment model, deriving from an existing one, was applied to estimate the lung cancer risk related to both ultrafine and coarse particles emitted from an incinerator whose people living nearby are exposed to. To this end, the measured values of Polycyclic Aromatic Hydrocarbons (PAHs), heavy metals (As, Cd, Ni) and PCDD/Fs (Polychlorinated dibenzodioxins/furans) emitted from an incinerator placed in Italy were used to calculate the Excess Lifetime Cancer Risk (ELCR) at the stack of the plant. The estimated ELCR was then used as input data in a numerical CFD (Computational Fluid Dynamics) model that solves the mass, momentum, turbulence and species transport equations to study the influence of wind speed and chimney height on the ELCR at receptor sites. Furthermore, combining meteorological data (wind speed and direction), and hypothesizing different exposure scenarios on the basis of time-activity patterns of people living nearby the plant, specific risk maps were obtained by evaluating ELCR around the incinerator. Results show that with the increasing of wind speed, the ELCR value downwind at the plant decreases and its point of maximum risk becomes closer to the stack. On the other hand, increasing the stack height decreases the ELCR, moving away from the stack the point of maximum risk. Finally, the risk maps for people living or working nearby the plant have highlighted that the excess risk of lung cancer due to the presence of the incinerator is below the WHO target (1×10^{-5}).

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Incineration is a technology aimed to reduce waste volume and to obtain electrical energy and heat for district heating. In their first applications, however, incinerators had a bad reputation since they were conducted without flue gas treatment, leading to large emissions in atmosphere of toxic combustion products such as polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/Fs) (Oh et al., 2006; Vehlow, 2012), Polycyclic Aromatic Hydrocarbons (PAHs) (Zimmermann et al., 2000) and heavy metals (Chang et al., 2000). In addition, incinerators have generated a strong debate in Western Countries because of their emission of ultrafine particles (UFPs) (Buonanno et al., 2012; Maguhn et al., 2003). The World Health Organization (WHO) through the International Agency for Research on Cancer (IARC) has recently classified airborne particles as carcinogenic to humans

(Group 1), since a “sufficient evidence” of carcinogenicity in humans has been demonstrated and a causal relationship has been established between exposure to these agents and human cancer (International Agency for Research on Cancer, 2013; Loomis et al., 2013). The potential negative health effects produced by particles are due to their ability to penetrate in the lungs, carrying toxic compounds with them. It is still not clear, in the scientific community, which particle characteristic is more responsible of the adverse effects on human health (i.e. size, morphology or chemical components), and in-depth research in this field is needed.

Nowadays, the Directive 2010/75/UE (2010) imposes a threshold limit value in terms of total dust emitted at the stack of the plants (i.e. total amount of particles emitted in terms of mass, 10 mg/m^3). In addition, looking at the scientific literature, modern incinerator plants emit very low amounts of particles if compared to fossil fuel, power plants, and vehicles (Buonanno and Morawska, 2015; Cass et al., 2000; U.K. Department for Environment, 1999; U.S. Environmental Protection Agency, 2000) when Best Available Techniques (BAT) are adopted for flue gas cleaning in modern plants (European Commission, 2006; Vehlow, 2015).

* Corresponding author at: Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, via G. di Biasio 43, 03043 Cassino (FR), Italy.

E-mail address: buonanno@unicas.it (G. Buonanno).

A lot of experimental campaigns, aimed to study UFPs and mass fraction of aerosol emitted from incinerators together with its dimensional and chemical characterization, are available in scientific literature (Buonanno et al., 2009a, 2010a, 2010b, 2011, 2012; Maguhn et al., 2003; Ragazzi et al., 2013). Cernuschi et al. (2012) and Zeuthen et al. (2007) also analysed UFP stack concentration levels for incinerator plants with different emission control devices and plant operations. A numerical analysis on plume trajectory at the stack of an incinerator was proposed by Abril et al. (2009), König and Mokhtarzadeh-Dehghan (2002), while Scungio et al. (2015) carried out numerical simulations on UFPs number concentration downwind at incinerator plants as operational, flue gas treatment and environmental parameters vary. In the authors knowledge, however, there are very few studies on the evaluation of the exposure of people to UFPs and/or other pollutants emitted from incinerator plants at receptor sites. Moreover, the exposure evaluation solely could be misleading to perform a comprehensive evaluation of the health effect of a generic source on people living nearby. Therefore, health effect evaluations for people living at receptor sites should involve proper dose-response data (Sayes et al., 2007; Steenland and Deddens, 2004) in order to accurately carry out risk data for population.

In the present work, a modified risk-assessment model was applied to estimate the Excess Lifetime Cancer Risk (ELCR) contribution of both ultrafine and coarse particles emitted from an incinerator plant, through the risk model developed by Sze-To et al. (2012), which has been recently applied in estimating the lung cancer risk for the Italian population by Buonanno et al. (2015). ELCR gives an estimation of the extra risk of developing cancer in a population of individuals, for a specific lifetime exposure and chemical-specific dose-response data. In this work, the value of the ELCR at the stack of an incinerator was calculated applying the above mentioned risk assessment model using data of PAHs, heavy metals (As, Cd, Ni), PCDD/Fs, measured in emission from an incinerator located in Central-Southern Italy whose size/capacity is typical of most of the Italian plants. The calculated ELCR was then used as input data in a numerical CFD (Computational Fluid Dynamics) scheme, based on the $k-\epsilon$ turbulence model and already used in a previous work of the authors (Scungio et al., 2015), in order to analyze the influence of two amongst the main influence parameters on the pollutant dispersion (wind speed and chimney height) on the ELCR at receptor sites downwind at the plant, due to the inhalation of airborne particle emitted from the incinerator. In addition, by hypothesizing different exposure scenarios, on the basis of people activities, and using data of wind speed and direction measured in the proximity of the stack, the ELCR around the plant was evaluated through the definition of risk maps.

2. Methodology

2.1. Hazard identification

Estimating the risk related to exposure to particles containing PAHs, PCDD/Fs and heavy metals requires several major steps, as reported in U.S. National Research Council (1983): (i) hazard identification, (ii) dose-response assessment, (iii) exposure assessment and (iv) risk characterization. For many chemicals, the health risk assessment is related to the carcinogenicity of PAHs, PCDD/Fs and heavy metals, generally described in terms of their mass (U.S. Environmental Protection Agency, 2005). Cancer potency factors may be referred to cancer slope factor (SF), which represents the percent increase of the risk of getting cancer associated with exposure to a given dose of a chemical (expressed as mg of chemical per kg of body weight) every day for a lifetime. Therefore,

since SF is a plausible upper bound estimation of the probability that an individual will develop cancer, it may represent the toxicity value that quantitatively defines the relationship between dose and response. The SF for the Group 1 carcinogenic chemicals used in the risk assessment model were obtained from the Office of Environmental Health Hazard Assessment (Office of Environmental Health Hazard Assessment, 2009).

In order to account for the contribution of UFPs, a modified risk assessment model for particulate matter, based on the risk assessment model of Sze-To et al. (2012), was developed. This model uses a coefficient to correlate the particle surface area-based cancer potency of the pollutant, to the typically used mass-based cancer potency of the pollutant itself. Therefore, particle surface area was used as the dosimetry for hazardous pollutants in the form of UFPs, and mass was used as the dosimetry for super micron particles. The risk characterization equation for each pollutant is:

$$ELCR_i = \frac{SF_i}{BW} \frac{m_i}{PM_{10}} (c_f \cdot \delta_s + \delta_M) \quad (1)$$

where $ELCR_i$ is the excess lifetime cancer risk of the i -th pollutant, SF_i is the inhalation slope factor used to describe the cancer potency of the i -th pollutant, BW is the body weight of the receptor, m_i is the mass concentration of the i -th pollutant present on the PM_{10} mass (mg/m^3), δ_s (nm^2/d) and δ_M (mg/d) are the daily particle surface area (S) and mass (M) deposited doses. The conversion coefficient c_f ($6.60 \times 10^{-13} \text{ mg}/nm^2$) was obtained experimentally by Sze-To et al. (2012) through measurements and risk analyses due to the exposure to heavy-duty vehicle emissions. The c_f coefficient depends on the physical size rather than the chemical component of the particulate matter and, therefore, can also be used for different types of particulate matter.

In order to calculate the ELCR at the stack of the incineration plant, $ELCR_s$, an incinerator placed in the Central-Southern Italy was considered. Data on pollutant mass concentrations (Group 1 carcinogenic chemicals) and PM_{10} concentrations at the stack were obtained from the time series of such parameters as measured by the Italian Environmental Protection Agency (ARPA). In particular, all the available Group 1 carcinogenic chemicals for the considered plant are summarized in Table 1. PAHs carcinogenetic characteristics were expressed in terms of Benzo[a]pyrene (B[a]p), therefore potency equivalency factor (PEF) for PAHs were also reported in Table 1.

Table 1

Carcinogenic characteristics of the analysed PAHs, PCDD/F and heavy metals: inhalation cancer slope factors (SFs) and potency equivalency factor (PEF) for PAHs.

Chemical	Inhalation cancer slope factor (SF, $kg \text{ d } mg^{-1}$)	Potency equivalency factor (PEF) for PAHs
Arsenic (As)	1.51×10^1	–
Cadmium (Cd)	6.30×10^0	–
Nickel (Ni)	9.10×10^{-1}	–
Phenanthrene (PA)	3.90×10^{-3}	1.0×10^{-3}
Anthracene (Ant)	3.90×10^{-2}	1.0×10^{-2}
Fluoranthene (FL)	3.90×10^{-3}	1.0×10^{-3}
Pyrene (Pyr)	3.90×10^{-3}	1.0×10^{-3}
Benzo[a]anthracene (B[a]a)	3.90×10^{-1}	1.0×10^{-1}
Chrysene (CHR)	3.90×10^{-2}	1.0×10^{-2}
Benzo[b]fluoranthene (B[b]ft)	3.90×10^{-1}	1.0×10^{-1}
Benzo[k]fluoranthene (B[k]ft)	3.90×10^{-1}	1.0×10^{-1}
Benzo[a]pyrene (B[a]p)	3.90×10^0	1.0
Dibenzo[a,h]anthracene (DB[a,h]a)	3.90×10^0	1.0
Benzo[g,h,i]perylene (B[g,h,i]p)	3.90×10^{-2}	1.0×10^{-2}
Indeno[1,2,3-c,d]pyrene (In[c,d]p)	3.90×10^{-1}	1.0×10^{-1}
Polychlorinated dibenzodioxins/furans (PCDD/F)	1.16×10^5	–

Download English Version:

<https://daneshyari.com/en/article/4471130>

Download Persian Version:

<https://daneshyari.com/article/4471130>

[Daneshyari.com](https://daneshyari.com)