SIZE DISTRIBUTION OF NANOPARTICLES GENERATED BY A HEATING STOVE BURNING WOOD PELLETS

DISTRIBUTION EN TAILLE DES NANOPARTICULES GÉNÉRÉES PAR UN POÊLE À PELLETS

DISTRIBUZIONE DELLE DIMENSIONI DELLE NANOPARTICELLE EMESSE DA UN STUFA A PELLET

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Summary

In this work we investigate the size distribution of particulate matter emitted from a heating stove burning pellet. The effect of fuel contamination by metal nanoparticle is also investigated by seeding the pellet with Cu nanoparticles. Pellet stove emit mainly nanometric particles. The initial transient regime is characterized by stronger oscillations over time and a larger amount of emitted particles respect to the stationary regime. The larger number of emitted particles are in the size range of 100 nm-1μm.
Keywords: *pellet stove ; nanoparticles; emissions*

Résumé

Dans ce travail nous avons étudié la distribution de taille des particules émises par un poêle à granulés. E 'a été également étudié l'effet de la contamination du carburant par des nanoparticules métalliques insémination de la pastille avec des nanoparticules de cuivre. Les enquêtes menées ont montré que le poêle à granulés émet des particules nanométriques principalement avec une taille maximale dans la plage comprise entre 100 nm et 1 μm. Il a été observé un régime transitoire initiale caractérisée par de fortes fluctuations dans le temps et une plus grande quantité de particules émises par rapport à l'état stationnaire.
Mots-clés: *poêle à pellets; les nanoparticules; les émissions*

Riassunto

In questo lavoro si è studiata la distribuzione delle dimensioni del particolato emesso da una stufa a pellet. E' stato anche indagato l'effetto della contaminazione del combustibile con nanoparticelle di metallo inseminando del pellet con nanoparticelle di rame. Le indagini condotte hanno mostrato che la stufa a pellet emette principalmente particelle nanometriche con un massimo nell'intervallo di dimensioni compreso tra 100 nm ed 1 μm. Si è osservato un regime transitorio

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iniziale caratterizzato da forti oscillazioni nel tempo ed una maggiore quantità di particelle emesse rispetto al regime stazionario.
Parole chiave: *stufa a pellets; nano particelle; emissioni*

Introduction

The use of nanoparticles with specific physical properties has generated much interest in the field of material science because of their potential utility in an extremely wide range of industrial applications. Nanosized materials are currently used in the automotive, aerospace, textile, cosmetic, food, computer, communications, sporting goods, health and medicine, energy, environmental, transportation, and defense industries (Hussain et al., 2006). An active field of research is devoted to characterizing the nanostructure and size dependent properties of nanoparticles and most of the types of nanoparticles investigated tend to be metals and metal oxides, fullerenes, nanotubes, and colloidal suspensions. Combustion is considered an energy-efficient synthesis method for engineered nanoparticles, but nanoparticle emission can also be an undesired by-product from medical and municipal waste by incineration. Finally it has to be mentioned the use of metallic nanoparticles seeded in fuels to reduce particle formation (Aruna et al., 2008; Vander Wal, 2002).
Results of numerous epidemiological and toxicological studies consistently show an association between various health effects and an increased dose of particulate air pollution. These results have driven most industrialized nations to develop regulations to limit the concentration of ambient particulate matter (PM) in order to protect and improve public health. One study reports that PM air pollution causes 800,000 (1.2%) premature deaths and 6.4 million (0.5%) years of life lost globally (Hussain et al., 2006). Specifically, ultrafine particles and particles containing or coated with organics and metals are considered to be the most toxic fractions and components of ambient PM.
Ultrafine particles create a greater inflammatory response, affect heart rate variability, and are more potent in inducing cellular damage and exasperating asthma than larger particles (Oberdörster et al. 2005; Stone and Donaldson, 2006). Furthermore, the well-accepted association between PM and premature death appears to apply also to the ultrafine fraction of particulate matter (Ibald-Mulli et al., 2002; Wichmann et al, 2000). Although ultrafine particles have insignificant mass concentration, they often dominate particle size distributions in terms of number concentration. Particle size affects toxicity because smaller particles provide a higher surface area per mass, enable a high deposition rate in the lung and can penetrate beyond the respiratory track to other organs in the body where they may initiate injury by oxidation and transport of toxic components (e.g. metals, organics) (Kreyling et al., 2009; Peters et al., 2006).
The world market for pellet fuels is rapidly growing. It is driven primarily by European demand for renewable fuels to replace fossil fuels in both power boilers and space heating. As with all energy options, there are environmental benefits and drawbacks associated with residential space heating with wood. Clear

environmental benefits are low greenhouse gas emissions and low acid precipitation impacts. The major environmental concerns are particulate matter (PM) and carbon monoxide (CO) emissions.
In this work we investigate the particulate matter emission from a heating stove burning pellet. The effect of fuel contamination by metal nanoparticle is also investigated. All the measurements have been performed at the facility constructed within the INESE project (Investigations on the Impact of Nanoparticles in Environmental Sustainability and Ecotoxicity) financed by the Italian Institute of Technology.

Experimental

Nanoparticle emission from a commercial pellet stove has been measured by an Electrical Low Pressure Impactor, ELPI (Dekati). The exhausts are conveyed from the stove to a large room where they are diluted with ambient air and measured.
Particles are sampled by means of a suction probe and sent to the ELPI where they are first ionized by a corona charger, then classified in the impactor, where they are separated in 12 stages on the bases of their aerodynamic size. For each stage, particles are collected on aluminum substrates and the number concentration of particles deposited on each substrate is obtained by measuring electrical charge by an electrometer. Particle ambient-background was measured before each measurement, diffusion losses in the sampling line were also measured. Particle concentrations were corrected for losses in the line and ambient background.
In order to measure the effect of combustion of metal-contaminanted fuel, Cu and Fe nanoparticles with mean diameter of 30-100 nm, suspended in alcohol (12.5 g of Cu nanoparticles in 2 l of ethanol), were added to commercial pellets. After drying, the sprinkled pellets were used as fuel for the stove.

Results

The typical size distribution of the number of particles measured in the ambient air, in the absence of combustion exhausts, is reported in figure 1.

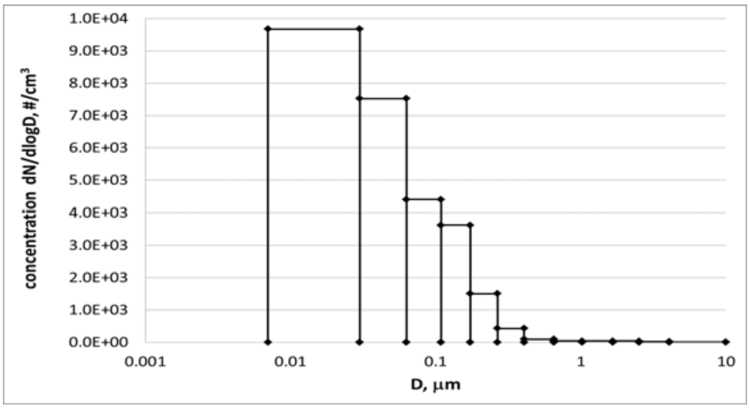

Figure1

Size distribution of the number of particles in the ambient air.

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The smallest particles, measured in the channel d=7-30 nm, are the most abundant, of the order of 1E4 particles/cm^3, and the distribution decreases rapidly for larger particles.
The mass concentration of particles measured at the chimney by ELPI, assuming unitary particle density, is reported in figure 2. Strong oscillation are observed over the time. The oscillations are more evident during transitory regime but are always observed.

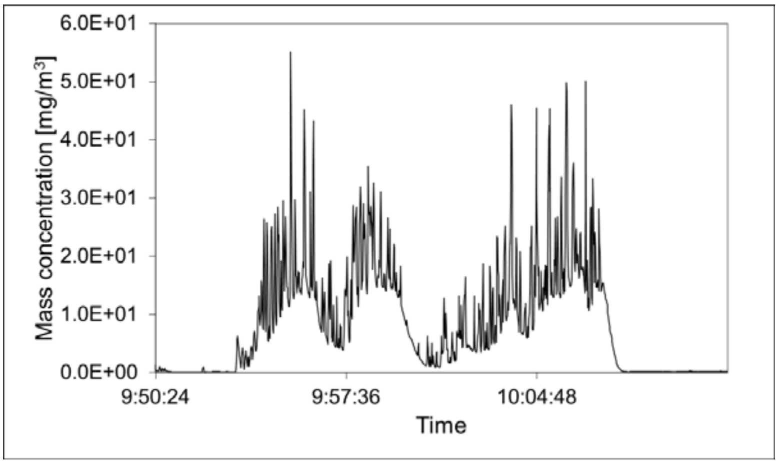

Figure2

Mass concentration of particles in the exhausts from the pellet stove measured at the chimney. Dilution Ratio DR=2.

In order to characterize average emissions, the size distribution of particles emitted by the stove have been measured in a smoke chamber. An example of the distribution recorded during the transient and stationary regimes is shown in figure 3.

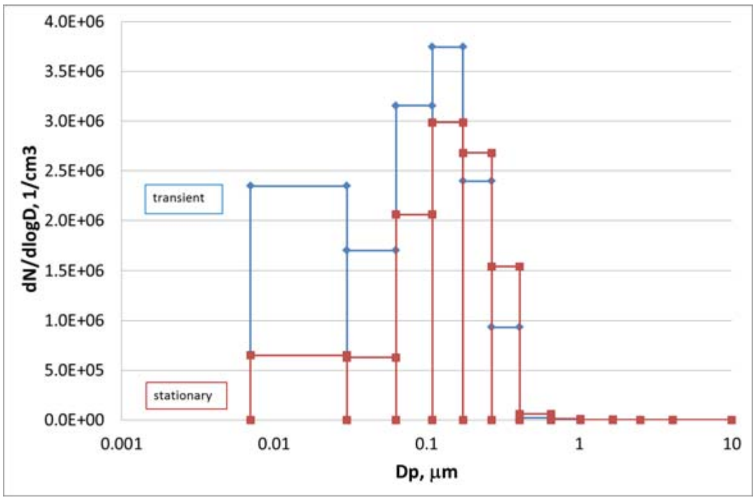

Figure 3

Size distribution of particles in the exhausts from the pellet stove measured in the chamber during the transient combustion and stationary regimes.

During the initial transient regime, a high number of particles is emitted. At the steady combustion regime a relevant reduction in the number of particles emitted is measured. The reduction is strong for particles smaller than 250 nm while for larger particles it is masked by the concurrent agglomeration process occurring in the chamber.

To study the emission of a wood combustion with the presence of metallic nanoparticles as contaminant, a suspension of copper nanoparticles was added to the pellet used to fuel the stove.

The suspension contained 12.5 g of copper nanoparticles with nominal diameters of about 30-100 nm, in 2 l of alcohol. The alcohol was evaporated and the pellets impregnated with nanoparticles were used as fuel in the combustor. The size distribution function measured in the chamber is reported in figure 4 together with the one measured in the chamber when pristine pellets were used. Particle smaller than 100 nm are more abundant when contaminated-pellets are burned, while the differences measured for larger particles are comparable to the measurement uncertainties due to noise and instabilities in the combustion regime.

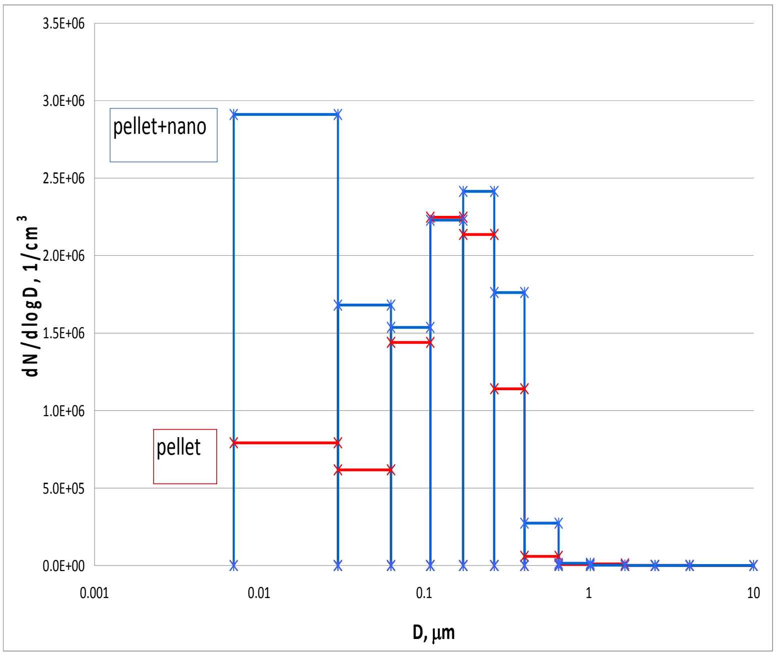

Figure 4

Number size distributions of particles collected inside the chamber. Pellet refers to the condition of only wood pellets combustion; Pellet+nano refers to the condition of pellets with the addition of copper nanoparticles.

Conclusions

The objective of this paper was the characterization of particles emitted by pellet stove. The amount of particles emitted measured over the time present an oscillatory regime since the mass concentration changes of about an order of magnitude over the time of just few minutes. Average emissions have been characterized in a smoke chamber, observing that the amount of particles emitted after the transient regime decreases noticeably, although a significant number of nanometric particles are emitted also in the stationary regime. The effect of Cu

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contamination of the pellet determine an increase of nanoparticles emission, in particular for particles smaller than d<100nm.

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