Biomass and Bioenergy 93 (2016) 78–86

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: http://www.elsevier.com/locate/biombioe

Research paper

Exposure to biological and chemical agents at biomass power plants

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ARTICLE INFO

Article history:
Received 3 February 2016
Received in revised form
19 May 2016
Accepted 24 June 2016
Available online 5 July 2016

Keywords:
Bioenergy
Power plants
Occupational hygiene
Exposure
Biological agents
Chemical compounds

ABSTRACT

The increasing use and production of bioenergy means that the number of employees working in this area will inevitably grow, making it ever more important to know the health and safety issues involved in the biomass supply chain. Our aim was to determine the exposure of employees to biological and chemical agents during various work tasks at different biomass-fuelled power plants in Finland. The study included technical surveys on biomass operations and occupational measurements at three CHP plants. Workers' main health risks were bacteria and fungi, which were easily spread to the air during heavy biomass processes. The exposure levels of actinobacteria, bacterial endotoxins and fungi were high, especially during the unloading of peat and wood chips. In addition, workers were exposed to mechanical irritation caused by organic dust, and chemical irritation caused by volatile organic compounds and components of diesel exhausts. Multiple exposures to these agents may simultaneously have synergistic health effects on workers' lower and upper respiratory tracts. During operations, workers were also exposed to endotoxins, actinobacteria and fungi, especially during the cleaning and handling of wood chips in silos and while working near screens or crushers. The measured concentrations exceeded the limit values proposed for these agents. The highest concentration of volatile organic compounds was found near conveyors. On the basis of these measurements, we suggested best practices for the power plants. The levels of biological agents in outdoor measurements reflected only low spreading of contaminants from power plants to the environment.

1. Introduction

The use of bioenergy in Finland has increased significantly during the last decade. In 2014, the total use of wood chips in heat and power plants was about 16 TWh, which – according to the 2020 target – should be increased to 25 TWh. The use of wood fuels in multi-fuel boilers is the most central and cost-effective way to increase the use of renewable energy in the generation of heat and power. The number of employees working with bioenergy is therefore expected to grow, making it increasingly important to know about the health and safety issues involved in the biomass supply chain. The exposure of people living near heat and power plants may also grow.

During storage, wood fuels are subject to biological and chemical reactions and decomposition caused by bacteria and fungi. A potential health hazard can be raised from airborne microspores [1]. Microbial dustiness in solid biofuels has been studied especially in Denmark [2–6]. The concentrations of microorganisms in straw and wood chip dusts were found high in rotating drum tests [2]. Correlations between endotoxins, total bacteria and fungi, and total dustiness were found significant for outdoors stored baled straw and wood chips from piles [4]. During the outdoor storage of forest residues, low volatile hydrocarbons, such as terpenes, are emitted into the air in the gas phase [7]. Also hexanal from fatty acid oxidation has been found to be an important volatile compound emitted during the storage of solid wood fuels [8].

Occupational hygiene measurements during processing of solid biofuels at power plants have been reported in a few papers

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http://dx.doi.org/10.1016/j.biombioe.2016.06.025

[3,9–12]. In these studies, levels of airborne microbial components varied between the workplaces in the plants and between the plants. The personal exposure levels to endotoxin, thermophilic actinomycetes, total bacteria and total fungi at the Danish biofuel plants were high when compared with suggested exposure limits [3]. Higher concentrations of endotoxin were found at straw plants than at wood-chip plants, while the opposite was measured for a fungus called *Aspergillus fumigatus*. In a Polish study [10] at a power plant co-firing biomass with coal, the highest bacterial and fungal concentrations were determined at workplaces related to reloading, screening and biomass transport via conveyor belts to silos. The results indicated that workers are exposed to bioaerosols containing potentially pathogenic bacteria and fungi. *Aspergillus fumigatus* was found in the air at all investigated workplaces.

Inflammation but no DNA damage in mice exposed to airborne dust from a biofuel plant has been found [5]. In addition, mutagenic activity of airborne particulate matter sampled in a biomass-fuel plant has been investigated [6]. Recently, Rohr et al. [11] reviewed the literature on known and potential occupational health and safety issues related to biomass-powered electricity generation. They suggested that pre-combustion risks, including bioaerosols and biogenic organics, should be considered further. Their results from the two biomass-based power generating plants indicated that the dust concentrations can be extremely variable. Workers may be exposed to many different agents at the same time during work in biomass-burning power plants. Multiple exposure of workers depends on many things, such as the fuels and chemicals used, storage of fuels, work tasks, the usage of protective clothes and respirators, and the weather.

As in the wood-processing industry [12], bacterial and fungal components in biomass are also associated with diseases, ranging from toxic pneumonitis symptoms to severe chronic lung diseases such as asthma, chronic obstructive pulmonary disease (COPD) and allergic alveolitis [13–17]. The exposure level to micro-organisms has an impact on the occurrence of respiratory symptoms among biofuel workers [18]. Bacterial and fungal concentrations of $>10^4$ colony-forming units per cubic meter of air (cfu m^{-3}) should be considered a threat to workers' health [19]. For single fungal species such as thermotolerant *Aspergillus fumigatus*, a threshold limit value (TLV) of 500 cfu m^{-3} has been suggested. Due to their higher toxicity, mycotoxin-producing and pathogenic species have to be detected specially [20]. Endotoxins may be present in small particles below 1 μm, which are present in the air of solid biofuel plants [21]. The Nordic and Dutch Expert Group [22] has concluded that adverse health effects are expected after chronic occupational exposure at approximately 90 EU m^{-3}. Other organic and wood dust, diesel exhaust and gases from degradation processes may be harmful, particularly vaporous and gaseous agents in biomass-fuelled power plants. The Finnish Ministry of Social Affairs and Health has established occupational exposure limit (OEL) values for these agents in Finland [23]. The Finnish Institute of Occupational Health has established a reference value of 3000 μg m^{-3} for total volatile organic compounds (TVOC), which should not be exceeded in a good industrial environment. For high quality indoor environments, a target value of 300 μg m^{-3} has been established.

More surveys and measurements need to be carried out to assess the occupational hazards of modern energy production that utilises renewable biomass. It is important to assess the public health effects and provide recommendations for future scenarios. The aim of the study was to clarify the health and safety issues in the context of bioenergy supply chains. The main focus of this paper was to analyse the exposure of employees to biological agents and chemical compounds during various work tasks at different biomass-fuelled power plant sites in Finland.

2. Materials and methods

2.1. Measurements at power plant sites

Occupational hygiene measurements were carried out at three biomass- and solid recovered fuel- (SRF) fuelled power plants, located in different parts of Finland, in the autumn of 2012 and the winter of 2013. The selection of the combined heat and power (CHP) plants for case studies of the measurements was mainly based on the fuel variety, but other factors such as the age of the plant were also considered (Table 1). All the case power plants received at least one of the fuels by truck: rear-unloading, full-trailer trucks or rear-tipping trucks.

The research was carried out according to the process presented in Fig. 1. We performed a technical survey on biomass operations at the selected power plants to collect background information by interviews and observations regarding the power plant, the fuels used, their delivery chains, working habits, and occupational safety and health issues.

Workers' exposure to biological and chemical agents was measured during their normal duties. The collected air samples and measurements with direct reading instruments are summarised in Table 2. The stationary sampling points were reserved for source identification and mapping out concentration levels in different working areas. The personal exposure of workers during a work task was monitored from their breathing zones. Sampling periods varied from 38 to 430 min at stationary sites and from 26 to 170 min in breathing zones. Material samples of the fuels ($n = 23$) used were collected from fuel reception sites and from conveyors

Table 1
Basic information on case studies' combined heat and power plants.

Power plant	A	B	C
Boiler type	BFB[a]	BFB[a]	BFB[a]
Power (appr.)	75 MW_{fuel}	200 MW_{fuel}	170 MW_{fuel}
Age of plant	New	~10 years	Old
Fuels used	Wood fuels 100%: forest chips, used wood, whole-tree chips, stemwood chips, wood processing industry residues	Wood fuels 50%: forest chips, stumps, forest residues, sawdust Bark 20% Milled peat 25% Waste water sludge 5%	Bark and waste water sludge 50% SRF[b] 50%
Additives used	Elemental sulphur	None	Elemental sulphur
Flue gas cleaning	Bag filter	ESP[c]	ESP[c] + Scrubber

[a] Bubbling fluidized bed.
[b] Solid recovered fuel.
[c] Electrostatic precipitator.