

OCCUPATIONAL SAFETY AND HEALTH IN WASTE COLLECTION AND RECYCLING: THE CORE RESEARCH PROGRAM*

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Abstract: The Danish CORE research program concerns exposures and occupational health in waste collection and recycling. Focus is on collection of household waste (mixed waste, bio-waste, recyclable paper, garden refuse, bulky waste) and employees in materials recovery plants (paper sorting and glass sorting plants), incineration plants, composting plants, and biogas producing plants. The program includes measurements of exposure to organic dust, microorganisms, volatile organic chemicals, and work load, as well as questionnaires and clinical studies with lung function testing and analysis of markers of allergy and inflammation. The background of the research program and the overall research plan are described together with some highlights of results.

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INTRODUCTION

According to the Danish Government's Action Plan 1993-1997 new waste collection systems will be implemented which will provide collection and recycling of half of the household waste within the turn of the century, the aim being to considerably decrease deposition of household waste at landfills. By the implementation of this plan, it is expected that the number of employees within the fields of waste collection, sorting and recycling will increase during the following years.

In response to the governmental action plan the Danish Environmental Protection Agency (Danish EPA) and the Danish Work Environment Service (WES) have jointly initiated the 5-year WES program "Program Concerning Health Problems and Their Solution in Relation to the Government's Action Plan for Waste and Recycling 1993-97", which aims at administrative measures and advisory services which prevent health problems to arise in the waste collection systems as well as in the sorting and recycling plants [18].

Associated with the administrative and regulatory program of the WES is a 5-year (1994-1998) research program Waste Collection and Recycling (CORE) which focuses on occupational exposures and adverse health effects in relation to collection, sorting and recycling of household waste.

This paper describes the overall research plan and the main elements as well as some of the results of the CORE research program with focus on bioaerosol exposure.

AIM OF THE RESEARCH PROGRAM

The overall aim of the CORE research program is to provide knowledge which can be used as basis by the WES for recommendations and regulations ensuring that initiatives in relation to the Government's Action Plan will not lead to occupational health problems. More particularly, the research program deals with exposure assessment in relation to occupational health, and by multi-disciplinary research it is attempted to provide information on relationships between symptoms, diseases

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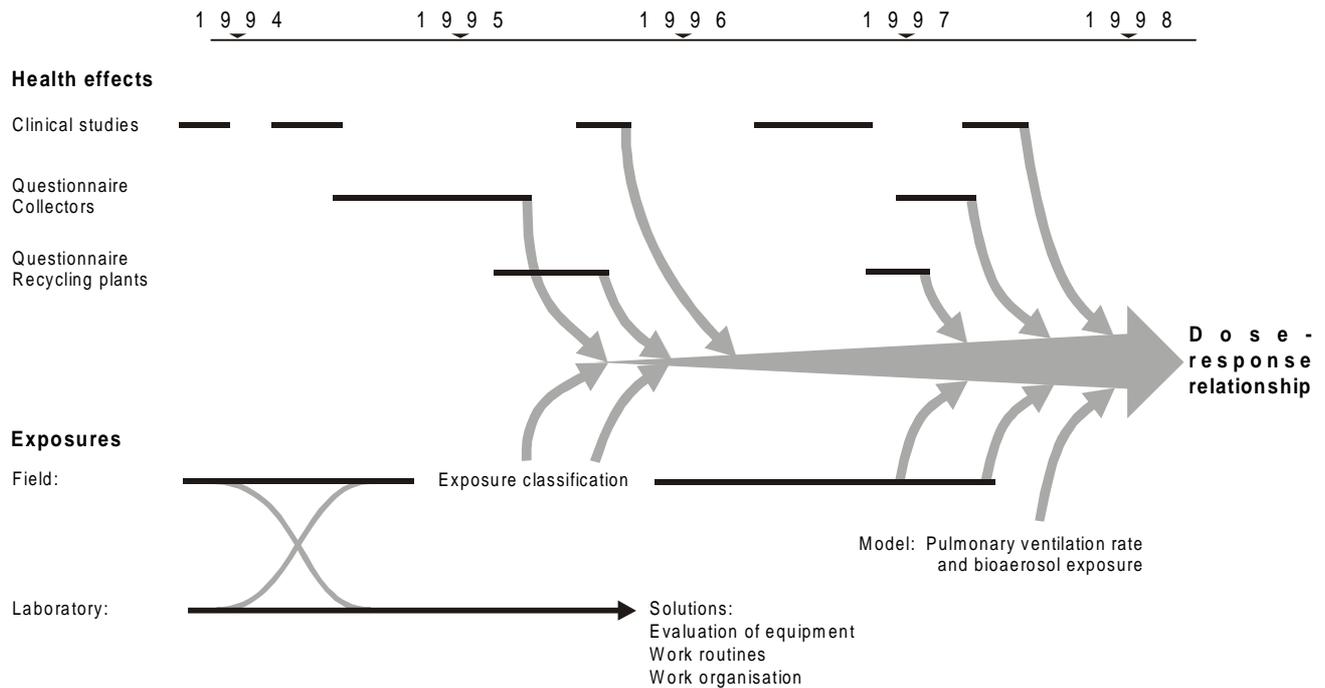


Figure 1. Illustration of the main elements and time schedule of the Danish research program on occupational health in waste collection and recycling.

and accidents on the one hand and exposure to dust, microorganisms and gases and physical and physiological loads on the other hand. By the increased focus on the working conditions it is assumed that the research program will contribute significantly to the general information on occupational safety and health in the field of waste collection and recycling.

MAJOR FIELDS OF ACTIVITIES

In accordance with the WES Program the CORE research program focuses on the following fields:

- Collection of household waste including collection of source separated biodegradable household waste, paper, glass and garden waste. Studies on the collection of industrial waste is not included.
- Glass sorting plants. The study does not include factories treating the sorted glass materials, e.g., bottle cleaning factories and glass factories.
- Paper sorting plants. Factories processing sorted paper materials (e.g. paper mills) are not included.
- Incineration plants.
- Plants for composting of household waste and garden waste.
- Plants for biogas production.

Studies on both waste collectors and workers at waste recycling plants includes several more or less overlapping phases: Exposure assessment and questionnaires on health and working conditions; identification of causes for problems identified in the questionnaires; and intervention studies related to the effects of technical or organizational changes in waste collection systems or at waste recycling plants.

ORGANIZATION OF THE RESEARCH PROGRAM

The CORE program is a multi-disciplinary research program involving 6-8 full-time scientists at 5 different departments of the National Institute of Occupational Health (AMI) in Copenhagen. The epidemiological part is performed in collaboration with the Occupational Health Clinic at the National Hospital of Copenhagen which is responsible for the clinical investigations. Associated with the research program is a steering committee with members from AMI, the Danish EPA and WES, and an advisory board with members from the industry and unions. In addition, recommendations and comments to the study protocol have been provided by an associated group of internationally recognized experts within the fields of bioaerosol exposure, microbiology, epidemiology, clinical research, and work physiology.

GENERAL RESEARCH PLAN

The research program contains two parts where the first primarily has concerned development of methods and investigation of health problems and working conditions among waste collectors. In the second part of the program, investigations of workers at various recycling plants are more dominating (Fig. 1).

In line with the WES program, the CORE research program is designed to give information on health outcomes related to musculoskeletal exposures and bioaerosol exposure. The backbone of the program is the epidemiological studies which include nationwide surveys of working conditions and symptoms of waste collectors

and workers in the waste treatment and recycling industry. Along with these surveys medical examination with focus on lung function and analysis of various markers of inflammation and allergy have been performed in selected groups of employees.

The exposure assessment includes measurements of exposure to bioaerosols by using personal sampling equipment followed by various microbiological analyses (enumeration of microorganisms by total microscopic count, cultivation of microorganisms, endotoxin). In addition, assessment of exposure to volatile organic chemicals has been performed by analyzing head-space air samples with combined GS/MS techniques.

Work physiology has been restricted to waste collectors where both field studies and laboratory experiments have been performed. The field studies include continuous recording of heart rate, periodic measurements of ventilation rate, and detailed observation of work processes, activity and body postures during handling of various types of waste collection equipment. The laboratory experiments have focused on measurements of external forces during pushing and pulling of wheeled containers with different loads, and by using biomechanical models internal (compression) forces acting on the spine have been calculated.

The CORE research program has involved development or implementation of new methods. Of particular interest is a unique rotating drum designed for testing the ability of various waste types and recyclables to give off airborne dust and microorganisms [1], and an *in vitro* assay for testing of the inflammatory potential of organic dust [11]. In addition, it has been attempted to establish techniques for automatic enumeration of microorganisms in bioaerosol samples by using image analysis [16]. Finally, the Department of Occupational Medicine has implemented computer assisted telephone interviews (CATI) for carrying out large questionnaire studies in a cost efficient manner.

STUDIES RELATED TO WASTE COLLECTION

Assessment of bioaerosol exposure in waste collection has involved groups of waste collectors in different parts of Denmark. The studies have been designed to give broad information on the personal exposure level to organic dust and microorganisms that is associated with collection of household waste. Major focus has been on the significance of waste type (biowaste, mixed household waste, garden waste, bulky waste, recyclable paper), type of storage equipment (sacks vs. containers), type of collection vehicle (platform truck vs. compactor trucks with high and low loading of the waste), collection frequency (7 vs. 14 days collection schemes), and job description. The results of the different studies on bioaerosol exposure have been described in a series of reports [2, 4, 5, 20, 24, 28] and papers [3, 6, 22], and the

main findings have recently been summarized in a review [21]. Among other things, these studies have shown that the concentration of microorganisms and endotoxins in the breathing zone of waste collectors is low compared to that reported in other occupational settings with heavy organic dust exposure.

Some central issues such as the significance of storage equipment and collection frequency for the potential of the waste to give off airborne dust and microorganisms have been investigated in laboratory experiments. In this series of experiments, biowaste and garden refuse have been stored in different types of equipment for variable time and the ability of the waste to give off bioaerosols has subsequently been studied by using a rotating drum dustiness tester. The experiments have documented that the dustiness of stored biowaste is markedly affected by the storage equipment: Storage in paper sacks that allows the waste to "breathe" and evaporate water, increases the potential to release airborne fungi more than 100,000 fold compared to storage in more or less air-tight plastic bags or containers [1, 4].

On the basis of the large number of bioaerosol samples (ca. 200) from the breathing zone of waste collectors a principal component analysis has been made of the main parameters from the filter analysis (total counts, viable counts of fungi and various groups of bacteria, endotoxin, and dust). This study has shown, at least in this occupational setting, that enumeration of microorganisms by total counts (epifluorescence microscopy) is the microbiological parameter that provides the best exposure stratification for routine monitoring of workplace bioaerosol exposure [23].

In addition to bioaerosol exposures, waste collectors are also exposed to volatile organic chemicals (VOCs) and general air pollution. In order to evaluate the risk of exposure to VOCs from waste, air samples have been taken from the head-space of waste inside collection vehicles and containers. These studies have documented the presence of a wide range of different VOCs, some of which might be expected to cause irritation of the mucous membranes of the upper respiratory tract or having nauseating effects [33, 34]. The concentration of VOCs in the body of collection vehicles or in the head-space of waste containers is generally below the occupational exposure limit (OEL) [15, 34]. However, only a minority of the several hundreds of VOCs identified has an OEL, and it is not known to what extent these VOCs might act together. By summing up the concentration of related VOCs (e.g., sulfur containing compounds), the overall concentration inside containers may reach levels that could cause airway irritation and nausea [4, 31]. High concentrations of sulfurous compounds were particularly found in the head-space of containers and isolated bulk samples of garden refuse [32, 35], perhaps as a result of the abundance of actinomycetes in this type of waste [30].

Waste collectors often operate in areas with heavy traffic and are consequently exposed to diesel exhaust

containing various polycyclic aromatic hydrocarbons (PAH). In one of our studies we have demonstrated significant increases in urinary 1-hydroxypyrene (metabolite of PAH) during the working week suggesting exposure to PAH during waste collection. As there were no obvious difference between subgroups of waste collectors working in residential areas and the center of the city, the main source of PAH may have come from the collections vehicle [9].

The epidemiological studies are primarily based on a large questionnaire survey among ca 1750 waste collectors compared to ca 1100 municipality workers with outdoor work [15, 17, 29]. The self-administered questionnaire contained more than 350 questions related to working conditions, use of specific types of equipment, diseases, accidents and symptoms. On the basis of this questionnaire it is now clear that the prevalence of reporting nausea or symptoms related to chronic bronchitis are significantly elevated in waste collectors compared to those who are not exposed to household waste. Reporting of gastrointestinal problems appear to be most common during the summertime [12] where exposure to some of the microbiological parameters also is elevated [20, 21]. Waste collectors also seem to report accidents more frequently than the comparison group. Analysis of this set of data is still going on and major health outcomes are studied in relation to information on bioaerosol exposure by using a job-exposure matrix [7, 10, 14]. Questionnaire data on musculoskeletal complaints will be analyzed in relation to information on working conditions (handled equipment, organization, speed of work) as well as to data on mechanical load found in laboratory experiments (see below).

As a cross-sectional study the questionnaire does not give information on the incidence of health problems and diseases, and conclusions may be biased by the healthy worker effect. However, a 2-year follow-up of the cohort is currently being conducted in order to provide information on the proportion of waste collectors that have left their job as well as the main causes.

Along with the exposure assessment, clinical examinations have been made in some groups of waste collectors. Except for one group of workers, who used a bizarre technique for emptying plastic sacks with stored garden refuse into the scoop of compactor trucks [28], no clinical signs of work-related health effects have been found [8].

Field observations with quantification of work processes and body postures along with continuous recordings of heart rate have demonstrated that waste collectors have a quite varied type of work where heavy lifting of sacks or pulling/pushing of containers is mixed with periods of less work load. Although the average work load corresponds to heavy physical work, the waste collectors walk empty-handed in about one third of the work-shift. The relatively circulatory load, as calculated from the heart rate and age of the waste collectors, was

about 50% during a 3-hour active period [27], which exceeds the value recommended by the American National Institute for Occupational Safety and Health (NIOSH) for lifting in 2 and 8 hours periods. Moreover, the relative circulatory load seems to increase with age, suggesting that the normal decrease in physical capacity with age is not coupled with a similar decrease in work demand [25].

Laboratory experiments using combined video recordings and continuous recording of external forces during pushing and pulling of containers with different loads have enabled calculation of internal forces by applying biomechanical models. The data have shown that there is no correlation between the size of the external forces and compression of the spine in the lower back. The compression force on the lower back during pushing of 4-wheeled containers with a weight up to 100 kg on level ground did not exceed the maximum value of 3400 N recommended by NIOSH [26]. However, the laboratory experiments were performed under conditions far from those in the field, where holes and breaks in the pavement are likely to cause sudden peak forces that may result in musculoskeletal injuries.

STUDIES RELATED TO RECYCLING PLANTS

Studies in recycling plants were initiated in 1995 by a nationwide survey of working conditions and the general health of workers at five main groups of materials recovery facilities or waste treatment plants: paper sorting plants, glass and bottle sorting plants, biogas producing plants, composting plants and waste incineration plants. The working condition and symptoms questionnaire was administered to more than 750 employees at these plants by using the CATI technique. The data from this questionnaire study are currently being analyzed and a preliminary study of gastrointestinal problems has been reported [13].

Assessment of bioaerosol exposure has been performed in sorting plants for recyclable paper and bottles as well as in incineration plants which by number of employees are the most dominating types of waste treatment and recycling plants in Denmark. One of the results from this study that has been published by now concerns the finding of increased exposure to microorganisms in a recycling plant during manual sorting of paper and cardboard collected in bins directly at the households [36].

Along with the exposure assessment, a large clinical study involving more than 200 workers at selected paper and bottle sorting plants as well as 50 workers at mail sorting centers (control group) has been performed. The study has included clinical interviews, health examination with focus on lung function (including histamine provocation), blood samples for analysis of immunoglobulins and acute phase proteins, nasal lavage, and self-administered peakflow monitoring.

The nation-wide survey, the clinical study, and the exposure assessment have been performed in a way that allows grouping of the workers in different categories with respect to bioaerosol exposure. Thus, symptoms and clinical parameters will be analyzed in relation to general bioaerosol exposure parameters.

Studies related to composting have been given low priority in the CORE research program, first of all because the nation-wide survey revealed comparatively few employees in these types of plants. Secondly, there are extensive German and Dutch studies on compost workers in progress. However, a limited number of bioaerosol samples have been taken, and the rotating drum has been used for characterizing the ability of compost to give off airborne microorganisms [19].

PUBLICATIONS

The results from the CORE research program are published in reports in the series "Occupational safety and health in waste collection and recycling" (in Danish with an English summary), and findings of international interest are reported in scientific journals. Moreover, some of the studies are summarized in news letters (in Danish) in order to inform participating companies and their employees.

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