OCCUPATIONAL HYGIENE AT A DRY WASTE TREATMENT PLANT IN FINLAND

Outi K. Tolvanen
Department of Biological and Environmental Science
University of Jyväskylä
Jyväskylä
Finland

(other authors in alphabetical order: K.I. Hänninen, S.H. Lappi, and P. Rantala; a separate list includes information about other authors)

ABSTRACT

A company owned by 15 municipalities in central Finland operates a waste management system on behalf of its owner municipalities. The waste disposal system in the municipalities is based on the source separation of waste. The company's waste processing plant, which is the largest in Finland, has been in operation since fall 1997. The plant processes the dry waste fraction by separating out the residual organic waste and metals and producing recycled fuel from the remainder.

Since the beginning the company has carrying out occupational hygiene measurements in the dry waste plant as a mean of monitoring the exposure of employees to microbes, endotoxins, dust, and noise. The influence of the waste treatment technique and the quality of the waste on the formation and disappearance of microbes has been of importance.

The concentrations of airborne microbes (bacteria, fungi, and actinomycetes), both viable and the non-viable, were determined with an Andersen six-stage impactor and by the CAMNEA method. The fungi were identified. Dust concentrations and endotoxins were measured according to Finnish Standard No. 3860 (1988). Also the noise level was determined.

The measurements were made when energy waste and dry waste were processed at the same time and when the dry waste was processed alone. Hygienic problems appeared to be greater during handling of the two waste types at the same time: the concentrations were then greater after the metal delimiter and on the sieve. The concentration of endotoxins was on average 1350 ng/m^3, which exceeds all recommended occupational threshold limits. Problems were also revealed at other measurement points in the process hall. As expected, concentrations were fairly low in the coffee room.

The findings led to immediate changes in the process, work safety measures, and protection guidelines. Studies towards long-term improvements were initiated as well.

INTRODUCTION

In environmentally sound waste treatment, the first step is the separation of wastes at home and in industry. The next steps are the recycling of bio waste by composting and the recycling and incineration of dry waste. When it has effectively sorted, the dry waste can be used as fuel. A new idea in waste management in Finland is to burn the dry waste as supplementary fuel in power plants along with peat and wood chips or other solid fuel. However, the waste to fuel concept presupposes effective source separation of hazardous materials, bio waste, and harmful waste components such PVC, as these may have cause adverse effects on the combustion process, boilers and the environment. Additionally, all waste components, that can be recovered as material, need to be source separated in order to provide maximum recycling of materials.

The processes involved in waste disposal must also be safe for employees. Organic dust of waste origin, including microbes, may be harmful to health. Microbes, especially fungi but also thermophilic *Actinomycetes* bacteria, may cause allergy and asthma (Terho, Haahtela &

Hannuksela 1993). Fungi typically are associated with allergic rhinitis (Millner et al. 1994). For example, 1-2% of the Finnish is allergic to *Penicillium* and *Cladosporium*, the most common fungi in air (Haahtela & Reijula 1997). Contracting a more serious sickness depends on the individual and the amount and duration of exposure. For example, acquiring hypersensitivity pneumonitis normally requires frequent exposure to microbe concentrations of 10^5-10^6 cfu/m^3 or short exposure to a very high concentration of 10^8 cfu/m^3 (Millner et al. 1994). Excluding allergies and asthma, fungal diseases are extremely rare in persons who do not already suffer from have diabetes, cancer, or some other serious disease.

Endotoxins are pieces of the cortical substance of Gram-negative bacteria. Personal exposure to airborne endotoxins may cause fever, headache, exhaustion, and other flu-like symptoms (Boutin & Moline 1987, Dutkiewicz 1997, Heederik & Douwes 1997). These symptoms are also referred to as ODTS, Organic Dust Toxic Syndrome. Exposure to endotoxins may lead to chronic bronchitis and reduced lung function (Heederik & Douwes 1997).

Volatile and often odorous compounds may also be harmful and trigger headache and nausea. Loud noise may cause tinnitus and hearing defect, permanent or temporary. Noise may raise blood pressure and cause nausea, insomnia, and stress (Jauhiainen et al. 1997).

Occupational hygiene in landfill areas, windrow composting areas (Tolvanen et al. 1998) and sewage treatment plants has been investigated on several earlier occasions in Finland. Poor workplace hygiene has been found to increase the risk of falling sick and to reduce job satisfaction. As new technology offers more effective ways to treat wastes, it is important to determined whether or not there are any associated problems in occupational hygiene. Concentrations may well be much higher inside waste treatment plants than in the open air waste treatment areas investigated earlier.

If careful attention is paid to working hygiene, the problems noted above can be prevented and the costs associated with employee absence and sick leave can be reduced.

MATERIAL AND METHODS

Dry waste treatment plant

The Finnish waste treatment plant Ressu, which is owned by 15 municipalities in central Finland, has been in operation since fall 1997. The plant is owned by a company. The plant processes the dry waste fraction by separating out the residual organic waste and metals and producing recycled fuel from the remainder.

There are two treatment lines in the plant: one for dry waste (household waste: paper, plastic etc.) and one for so called energy waste (wood, paper, etc. from industry and stores). The source-separated waste is crushed to a particle size of 200 millimeter and transferred on a conveyor belt to metal delimiters, which remove magnetic metals. A sieve removes fine aggregates and any residual bio waste. The waste is then crushed again, this time to a particle size 50 millimeter. At the end of the line the magnetic metals are removed again and the product is loaded onto trucks or is baled and wrapped in plastic for storing. The estimated capacity for the year 1999 is about 30 000 tones. This is below the design capacity but process development work is continuing. The plant operates in two shifts with three employees per shift. Additionally one front loader and varying numbers of other machines are needed. Figure 1 presents an overall view of the process.

Measurements to determine the level of occupational hygiene during the process were carried out in four places: 1) after the first metal delimiter, 2) on the sieve, 3) beside the bailer, and 4) in the employee coffee room.

Occupational measurements

Microbes. The concentrations of airborne microbes (bacteria, fungi and actinomycetes), both viable and non-viable, were determined with an Andersen six-stage impactor and by the Camnea method (Palmgren et al. 1986, Heldal et al. 1996). In the Camnea method, samples were collected by using a polycarbonate filters (pore size 0.2 micrometers, diameter 37 mm), sterilized filter cases, and a pump with flow rate 4 l/min. The measurement time was 30 min. After collection the samples (filters still in their cases) were stored overnight in a refrigerator (+7°C). The next day, 6.5 milliliters dilution water was injected to the filter case and the case with the filter was shaken for 15 min. A solution was taken to a test-tube and dilutions of 10^{-1} and 10^{-2} were made. For determination of viable microbes, the diluted solutions were cultivated on four different substrates: malt extract agar and DRCB Agar for fungi, Plate Count Agar (PCA) for bacteria and actinomycetes, and Nutrient Agar (½-strong) for actinomycetes. Table 1 summarizes the incubation conditions. After incubation, colonies were counted and fungi were identified.

Table 1. Incubation temperatures and times for airborne microbes.

	Temperature	Incubation time
Fungi - mesophilic - thermophilic	 21-25°C 40°C	 7 days 3-4 days
Bacteria - mesophilic - thermophilic	 21-25°C 40°C	 5 days 5 days
Actinomycetes - mesophilic in PCA - thermophilic both in PCA and in ½-strong Nutrient Agar	 21-25°C 40°C	 14 days 11-12 days

After cultivation, sterilized formaldehyde was added to the original solution until the final formaldehyde concentration was 1%. The sample was filtered onto polycarbonate filter (pore size 0.2, diameter 25 mm, color black) and the filter was colored with 1 ml of 0.01% acridine orange. The color was allowed to work for about 2-5 min. Then it was sucked away and the filter was quickly washed with 3-5 ml of sterilized water. The filter was dried by water suction and then the filter was transferred to an object glass, a drop of immersion oil (Gargille non-drying immersion oil, Type B) was placed on the filter, and the filter was protected with a cover glass. Microbes were counted with the aid of a fluorescence microscope with magnification x 1000. At least 400 microbes were counted and the total number of microbes was calculated as microbes per cubic meter of air.

When the six-stage impactor was used for sampling, measurement times ranged from 60 s. to 5 min. The flow rate of the pump was 21.2 to 28.3 l/min. The total colony counts were corrected for multiple impactions by the positive hole method (Andersen 1958) and are expressed as colony forming units (cfu) per cubic meter of air.

Dust and endotoxins. Dust concentration (particles > 0.8 micrometer) and endotoxins were measured according to Finnish Standard No. 3860 (1988). The dust samples were collected onto Millipore cellulose acetate filters (pore sizes 0.8 micrometers, diameter 37 mm) and the endotoxins into fiberglass filters using pumps. The flow rate for dust samples was 5 l/min and measurement time one hour. For endotoxins, the flow rate was 2 l/min and the measurement time two hours. The dust samples were analyzed by weighing dried filters before and after sampling. The concentration of endotoxins was determined by the kinetic Bio Whittaker-QCL method, which relies on the use of the Limulus amebosyte lysate enzyme.

Noise. Noise level was determined according to the Finnish Standard No. 4578 (1982). Noise measurements were carried out with a Büel & Kjaer Sound Analysis Software BZ 7291 meter. The frequency band "A" and time emphasis "F" were used. Parameters that were measured were

- L_{Aeq} = middle sound level, the effective value of the measurement period,
- L_{AFmax} = maximum sound pressure during the measurement period,
- $L_{AEP,d}$ = daily personal sound exposure (EEC 88/186).

The measurement time for a single measurement was 2 min. Some 50-100 measurements were done in the processing hall: specifically, under the first metal delimiter, near the sieve, and near the bailer.

RESULTS AND DISCUSSION

Process operation. The Ressu waste processing plant is the first of its kind in Finland and during the first year of operation the process and operational development work has kept the operators busy. Although the process is functioning reasonably well, many small points are in need of further development to ensure that the total plant operates well. The dust collection system was known from the outset to be in need of improvement, with the result that this study was started before the process was finalized.

The decision for extensive automation in processing of the waste was a good one, as the direct contact with waste is minimized. Workers spend most of their time inside the machines or in the control room. However, improvements in the process (e.g. dust collection) and work safety are needed for the times when they must work in the process hall.

Concentrations of microbes

a) Processing the dry waste and the energy waste at the same time. When dry waste and energy waste were processed at the same time, number of viable microbes was largest near the sieve (Table 2). The most common microbes were mesophilic bacteria, wiht numbers of 1.4 x 10^5 cfu/m^3 (sampling by impactor) and 2.8 x 10^5 cfu/m^3 (sampling by Camnea method). Microbe concentrations were also high after the first metal delimiter and near the baler. Near the baler the total concentration of microbes (both viable and non-viable) averaged 1.7 x 10^8 microbes per m^3.

No threshold values for microbes in waste processing plants have been issued in Finland. For fungi, the Ministry of Social Affairs and Health in 1997 issued recommendation values of max 500 cfu/m^3 in winter and < 2500 cfu/m^3 in summer. For actinomycetes the corresponding value is < 10 cfu/m^3 in winter. For bacteria, the National Board of Health in Finland in 1990 issued a recommendation limit of 4500 cfu/m^3. These values are for residences, schools, offices and comparable buildings. Values apply only to mesophilic microbes and to samples taken by six-stage impactor. All these recommendation values were exceeded in the processing hall; the concentrations of bacteria for example, were 10-fold the Finnish recommendation value. Microbe concentrations also exceeded the Scandinavian proposed recommendation value of 5-10 x 10^3 cfu/m^3 for total microbe concentration (Sigsgaard et al. 1990, Malmros, Sigsgaard & Bach 1992). The concentration of fungi was also much higher than the normal concentration outdoors; according to Nevalainen & Terho (1993) the figure in summer is about 10^2–10^3 cfu/m^3.

Concentrations were much lower in the coffee room than in the processing hall. The most common microbes in the air were bacteria; the number of thermophilic bacteria (sampling by Camnea method) was an average 4400 cfu/m^3. The concentration of viable bacteria was not exceptionally high. In winter, the concentration of mesophilic fungi (sampling by impactor) exceeded the recommendation limit of 500 cfu/m^3 but in summer numbers were below the recommendation limit of 2500 cfu/m^3. Concentration of actinomycetes exceeded the recommendation value of 10 cfu/m^3. The concentration of mesophilic actinomycetes was high, especially in winter, about 2900 cfu/m^3 (sampling by impactor).

The total concentration of microbes (both viable and non-viable) was lower in the coffee room (about 4.3 x 10^7 cfu/m^3) than in the processing hall.

On average, 71.3% of the microbes in the processing hall were < 5 micrometers in size. Their percentage in the coffee room was 88.3%. Particles < 5 micrometers in size may penetrate to the alveolus and cause health problems (Terho, Haahtela & Hannuksela 1993).

The most common air-borne fungi in the processing hall were *Penicillium* spp. (40.1%), *Aspergillus* spp. (11.6%), *A. niger* (13.3%) and *A. fumigatus* (19.1%); in the coffee room they were *A. fumigatus* (39.4%), *Penicillium* spp. (21.2%), and *Cladosporium* spp. (18.6%).

b) Processing of the dry waste alone. In October 1998, measurements were made after the first metal delimiter and near the sieve when only the dry waste was processed. As presented in Table 3, the most common microbes in both places of measurements were mesophilic fungi. After the metal delimiter their concentrations averaged 1.4 x 10^5 cfu/m^3 (sampling by impactor) and 2.5 x 10^4 cfu/m^3 (sampling by Camnea method), and near the sieve the number was 3.6 x 10^4 cfu/m^3 (sampling by Camnea method). The determination of mesophilic bacteria was unsuccessful; there were over 300 colonies per substratum and to count them was impossible.

Near the sieve, the total levels of microbes during the processing of the dry waste were less than one-tenth of levels when the dry waste and energy waste were processed at the same time. The number of fungi was still quite high, however. After the first metal delimiter, there was no notable difference in microbe concentrations during the processing of the different waste fractions. In the processing of dry waste, the total concentration of microbes (viable and non-viable), both near the sieve and after the metal delimiter, was 1 x 10^8 microbes per m^3.

The amount of microbes < 5 micrometers in size was an average 75.1%. Again the most common fungi in the working air were *Penicillium* spp. (41.4%), *A. fumigatus* (7.3%), *A. niger* (19.1%), *Paecilomyces* spp. (9.7%), and *Cladosporium* spp. (8.6%).

Table 2. Microbe concentrations (cfu/m^3) in the working air when dry waste and energy waste were handled at the same time.

	Fungi		Bacteria		Actinomycetes	
	20-25°C	40°C	20-25°C	40°C	20-25°C	40°C
Metal delimiter						
- Camnea method	30 600 $^{n=1}$	3600 $^{n=1}$	86 700 $^{n=1}$	54 600 $^{n=1}$	1300 $^{n=1}$	2300 $^{n=1}$
- impactor	*	*	36 700 $^{n=1}$	35 400 $^{n=1}$	730 $^{n=1}$	710 $^{n=2}$
Sieve						
- Camnea method	141 000 $^{n=3}$	20 200 $^{n=3}$	276 400 $^{n=3}$	88 400 $^{n=3}$	4300 $^{n=3}$	2600 $^{n=3}$
- impactor	131 500 $^{n=4}$	94 000 $^{n=4}$	139 100 $^{n=2}$	38 200 $^{n=2}$	9800 $^{n=2}$	5800 $^{n=4}$
Bailer						
- Camnea method	49 600 $^{n=2}$	7000 $^{n=2}$	*	22 400 $^{n=2}$	1600 $^{n=2}$	1100 $^{n=2}$
- impactor	104 900 $^{n=4}$	10 000 $^{n=4}$	69 400 $^{n=2}$	86 700 $^{n=2}$	1000 $^{n=2}$	600 $^{n=4}$
Coffee room						
- Camnea method	310 $^{n=4, sum}$ 570 $^{n=4, win}$	** **	3300 $^{n=4, sum}$ 620 $^{n=4, win}$	4400 $^{n=4}$ **	50 $^{n=4, sum}$ 620 $^{n=4, win}$	50 $^{n=4, sum}$ 50 $^{n=4, win}$
- impactor	1600 $^{n=4, sum}$ 2500 $^{n=4, win}$	150 $^{n=4, sum}$ 660 $^{n=4, win}$	990 $^{n=2, sum}$ 1200 $^{n=4, win}$	620 $^{n=2, sum}$ 10 $^{n=4, win}$	320 $^{n=2, sum}$ 2900 $^{n=4, win}$	110 $^{n=4, sum}$ 80 $^{n=4, win}$

sum = summer, win = winter
* = over 300 colonies
** = no growth

Table 3. Microbe concentrations (cfu/m^3) in the working air when only dry waste was handled.

	Fungi		Bacteria		Actinomycetes	
	20-25°C	40°C	20-25°C	40°C	20-25°C	40°C
Metal delimiter						
- Camnea method	25 400 $^{n=2}$	4200 $^{n=2}$	*	3000 $^{n=2}$	280 $^{n=2}$	610 $^{n=2}$
- impactor	137 100 $^{n=4}$	69 600 $^{n=4}$	36 400 $^{n=2}$	10 000 $^{n=2}$	13 000 $^{n=2}$	1000 $^{n=4}$
Sieve						
- Camnea method	36 400 $^{n=2}$	6500 $^{n=2}$	**	3500 $^{n=2}$	90 $^{n=2}$	190 $^{n=2}$

* = over 300 colonies
** = no growth

Endotoxins

There are many proposals for threshold values for endotoxins. The Dutch Expert Committee on Occupational Standards has proposed a threshold value of 4.5 ng/m^3 (Heederik & Douwes 1997). Malmros et al. (1992) have suggested a threshold value of 100-200 ng/m^3 and Rylander et al. (1983) a value of 100 ng/m^3. According to the Kuopio Regional Institute of Occupational Health, the irritation symptoms increase, when the concentration of endotoxin exceeds 25 ng/m^3. This value is used as a threshold in this study.

The concentrations of endotoxins were high in the processing hall. The recommendation value of 25 ng/m^3 was exceeded in every measuring place (Table 4). Concentrations in separate measurements varied from 29 to 1400 ng/m^3. The highest concentration, an average of 1350 ng/m^3, was measured near the sieve when the dry waste and energy waste were processed at the same time. When the dry waste was processed alone, the concentration near the sieve was just 345 ng/m^3. The situation was the reverse after the first metal delimiter: the concentration was higher when only the dry waste was handled Probably the quality of the waste affects the concentrations of endotoxins, but the clearly the level also varies within the hall.

The endotoxin concentration in the coffee room averaged 15.9 ng/m^3 and did not exceed the recommendation limit of 25 ng/m^3. However, the highest individual concentration was 62 ng/m^3, which exceeds the value of 25 ng/m^3 by about 2.5 times.

Table 4. Endotoxin concentrations in the working place, ng/m^3 and EU/m^3.

	ng/m^3 (n; min-max)	EU/m^3 (n;min-max)
Metal delimiter		
- dry waste + energy waste	170 (n=1)	1900 (n=1)
- dry waste alone	279.5 (n=2; 29-530)	3480 (n=2; 360-6600)
Sieve		
- dry waste + energy waste	1350 (n=2; 1300-1400)	15 500 (n=2; 14 000-15 000)
- dry waste alone	345 (n=2; 240-450)	4300 (n=2; 3000-5600)
Bailer		
- dry waste + energy waste	740 (n=1)	9300 (n=1)
Coffee room	15.9 (n=4; <0.03-62)	199.5 (n=4; <0.4-780)

Table 5. Dust concentrations in the working place, mg/m^3.

	Dry waste + energy waste (n; min-max)	Dry waste alone (n; min-max)
Metal delimiter	2.0 (n=1)	0.15 (n=2; <0.1*-0.3)
Sieve	3.88 (n=5; 2-6.7)	1.0 (n=2; 0.7-1.3)
Bailer	0.87 (n=3; 0.3-1.3)	-
Coffee room	< 0.1* (n=6)	-

* determination limit 0.1 mg/m^3

Table 6. Noise levels (dBA) in the processing hall.

	Under the metal delimiter	Near the sieve	Near the bailer
Measurement time	1 h 40 min	3 h 20 min	2 h 28 min
L_{Aeq}	77.6 (64.3-89.4)	82.5 (80.2-83.6)	58.7 (55.2-63.9)
$L_{AEP,d}$	77.3 (64-89.1)	84.9 (81.4-86.3)	58.4 (54.9-66.9)
L_{AFmax}	87.6 (74.2-101.1)	94 (84.9-98.4)	68.6 (57-85.6)

Dust

From the beginning, dust was experienced as a particular hygienic problem in the plant. However, the amount of dust (particles > 0.8 micrometers) was low (Table 5) and the Finnish threshold value of 5 mg m^3 for 8 hours (Ministry of Labour 1996) was exceeded only once, near the sieve, when dry waste and energy waste were processed in the same time. The concentration of the dust was then in a one separate measurement 6.7 mg/m^3. The average concentration was only 3.88 mg/m^3, however. Dust concentrations were lower when only dry waste was processed.

The concentrations of dust in the coffee room were < 0.1 mg/m^3, or in other words below the determination limit.

Noise

The average middle sound level L_{Aeq} and daily personal noise exposure $L_{AEP,d}$ did not exceed the Finnish threshold value 85 dBA (the Prime Minister's Office 1993), but in individual measurements this value was exceeded under the first metal delimiter and near the sieve (Table 6). The highest average value of L_{AFmax} was measured near the sieve and the lowest near the bailer. It is advisable to use ear protectors in the hall when waste is being processed.

CONCLUSIONS

Dust was experienced as the most serious problem in the Finnish dry waste plant. However, the amount of dust in the processing hall was actually quite low and the Finnish threshold value of 5 mg/m^3 was exceeded only once, near the sieve. In the future, the amount of particles will also be investigated with an automatic particle sampler, which measures particles 0.3 to 5.0 micrometers in size and divides them into four size classes.

The quality of the processed waste (dry waste or energy waste or both together) probably affects the concentrations of microbes, endotoxins, and dust. The effect seems to vary with the place of measurement. However, concentrations of bio aerosols were very high in the processing hall, especially near the sieve, where the most common microbes were mesophilic fungi. Most of the microbes were < 5 micrometers in size and are small enough to penetrate deep into the alveoli. Use of a dust mask is thus advisable, especially for those remaining in the hall for a long time. Using of ear protectors is also important, because from time to time the sound level during the process exceeds 85 dBA

Various protectors and masks are already common in the plant. More attention should now be paid to hand hygiene and the use of gauntlets.

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REFERENCES

Andersen, A.A. (1958) New sampler for the collection, sizing and enumeration of viable airborne particles. Journal of Bacteriology, 76, pp. 471-484.

Boutin, P. & Moline, J. (1987) Health and safety aspects of compost preparation and use. In: de Bertoldi, M, Ferranti, M.P., L'Hermite, P. & Zucconi, F. (eds.) Compost: Production, Quality and Use. London, UK: Elsevier, pp. 198-209.

Ministry of Social Affairs and Health (Sosiaali- ja terveysministeriö) (1997) Sisäilmaohje (Indoor air guide). Sosiaali- ja terveysministeriön oppaita, 1997:1, pp. 61-62, Helsinki, Finland.

Dutkiewicz, J. (1997) Bacteria and fungi in organic dust as potential health hazard. Annals of Agricultural and Environmental Medicine, 4(1), pp. 11-16.

Haahtela, T. & Reijula, K. (1997) Sisäilman terveyshaitat ja ehdotukset niiden vähentämiseksi (Health hazards of indoor air and proposals to reduce them). Sosiaali- ja terveysministeriön työryhmämuistioita, 1997:25.

Heederik, D. & Douwes, J. (1997) Towards an occupational exposure limit for endotoxin? Annals of Agricultural and Environmental Medicine, 4, pp. 17-19.

Heldal, K., Skogstad, A. & Eduard, W. (1996) Improvements of the quantification of airborne micro-organisms in the farm environment by epifluorescence microscopy. Annals of Occupational Hygiene, 40, pp. 437-447.

Jauhiainen, T., Vuorinen, H.S., Heinonen-Guzejev, M. & Paikkala, S-L. (1997) Ympäristömelun vaikutukset (Effects of environmental noise), Ympäristöministeriö, Helsinki, Finland.

Malmros, P., Sigsgaard, T. & Bach, B. (1992) Occupational health problems due to garbage sorting. Waste Management & Research, 10, pp. 227-234.

Millner, P.D., Olenchock, S.A., Epstein, E., Rylander, R., Haines, J., Walker, J., Ooi, B.L., Horne, E. & Maritato, M. (1994) Bioaerosols associated with composting facilities. Compost Science & Utilization, Vol. 2, No. 4, pp. 8-57.

Ministry of Labour (Työministeriö) (1996) Työministeriön päätös työpaikan ilman haitalliseksi tunnetuista pitoisuuksista (Decision of Ministry of Employment regarding concentrations in the work place air known to be harmful), p. 17. Helsinki, Finland.

National Board of Health (Lääkintöhallitus) (1990) Asuntojen kuntoa ja hoitoa koskeva opas (Guide to the condition and care treatment of residences), 10 p. Rauma, Finland.

Nevalainen, A. & Terho, E.O. (1993) Sisäilman tutkimukset (Investigations of indoor air). In: Haahtela, T., Hannuksela, M. & Terho, E.O. (eds.) Allergologia. Duodecim, Vammala, Finland.

Palmgren, U, Ström, G., Blonquist, G. & Malmberg, P. (1986) Collection of air-borne micro-organisms of Nuclepore filters, estimation and analysis --CAMNEA-method. J. Appl. Bact. 61, pp. 401-406.

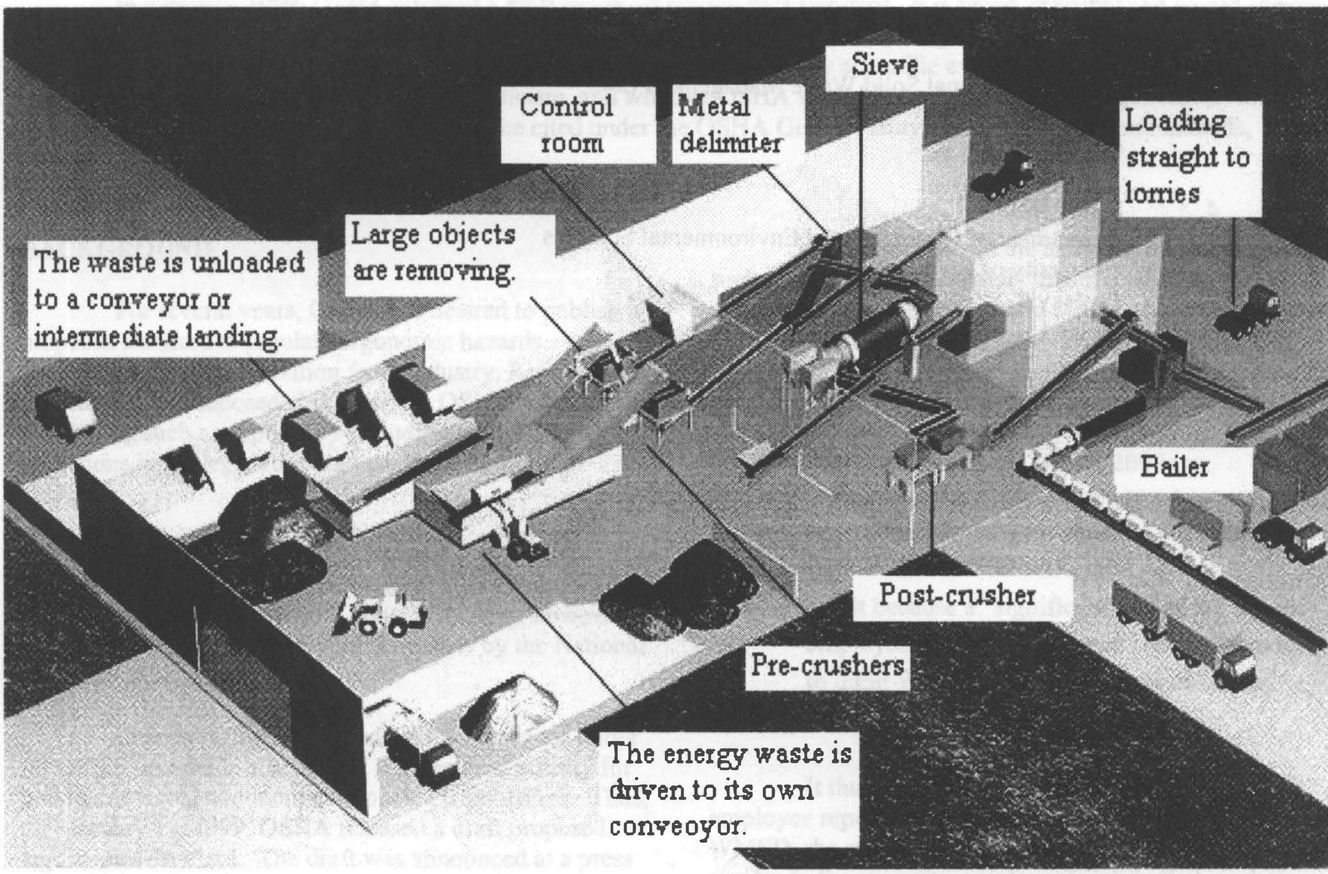
The Prime Minister's Office (Valtioneuvosto) (1993) Valtioneuvoston päätös työntekijän suojelemisesta työssä esiintyvän melun aiheuttamilta vaaroilta ja haitoilta (Decision of the Prime Minister's Office to protect employees from hazards and inconveniences of noise at the work place). No. 1404, pp. 3666-3670, Helsinki, Finland.

The Prime Minister's Office (Valtioneuvosto) (1992) Valtioneuvoston päätös melutason ohjearvoista (The Prime Minister's Office decision, guide values for noise level. No. 993, Helsinki, Finland.

Terho, E.O., Haahtela, T. & Hannuksela, M. (1993) Herkistymiseen ja sairastuvuuteen vaikuttavat tekijät (Factors affecting sensitizing and morbidity). In: Haahtela, T., Hannuksela, M. & Terho, E.O. (eds.) Allergologia. Duodecim, Vammala, Finland.

Tolvanen, O.K., Hänninen, K.I., Veijanen, A. & Villberg, K. (1998) Occupational hygiene in biowaste composting. Waste Management & Research, 16(6), pp. 525-540.

The dry waste plant Ressu. A cut-away view of the process.



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The list of authors n.o 2 – 4

2. Kari I. Hänninen
   Department of Biological and Environmental Sciences
   University of Jyväskylä
   Jyväskylä
   Finland

3. Pentti Rantala
   Tampere Regional Solid Waste Management Ltd.
   Tampere
   Finland

4. Sanna H. Lappi
   Department of Biological and Environmental Sciences
   University of Jyväskylä
   Jyväskylä
   Finland