STORAGE AND PROCESSING OIL CONTAMINATION ON NEW HVAC COMPONENTS: DEVELOPMENT OF MEASURING METHODS

P Pasanen[1], V Asikainen[1] and J Liesivuori[2,3]

[1] University of Kuopio, Department of Environmental Sciences, Kuopio, Finland
[2] University of Kuopio, Department of Pharmacology and Toxicology, Kuopio, Finland
[3] Kuopio Regional Institute of Occupational Health, Kuopio, Finland

ABSTRACT

The HVAC components are usually made of galvanised sheet metal which is covered by a corrosion protection and also lubricant oils are used in machine tools in manufacturing of the components or ducts. The aim of this study was to test and develop a consistent method to determine oil concentrations on component surfaces. Two swiping methods and a filter contact method were tested. In all of them the analysis based on IR-spectrometry. The results show that oil concentration is quite high and unequally distributed on the surface of the sheet metal containing corrosion protection oil. The concentrations were low on the sheets treated with chromium acid. The filter contact method showed the best recovery 91% ± 2% while the recoveries were 55-65% with the swiping methods. The detection limit for the filter contact method was 4 mg/m^2 and 1 mg/m^2 for the others.

INTRODUCTION

The HVAC-components are most often made of galvanised sheet metal, which needs corrosion protection to avoid hydroxylation of the zinc surfaces during storage and transport from steel mill. Traditionally oils are used for corrosion protection just before the final reeling in of the sheet metal. However, these viscous fluids form a sticky layer on the surface decreasing cleanliness and hygiene of manufactured components [5]. Manufacturing of some components needs to make sharp bends or bows in which lubrication is necessary to decrease friction between machine tools and the sheet metal. A part of the lubricant remains as a thin layer on the interior surface of the product where it increases dust accumulation on the surface and serves as a potential growth media for microbes [3,8]. Evaporation of hydrocarbons from oil residue decreases the perceived quality of the air passed through dirty ventilation system [5, 1].

In recent years, builder contractors, and customers have started to demand clean and high quality HVAC components, and therefore, solutions to manufacture oil free HVAC components have been sought. Therefore, air duct manufacturers use mainly sheet metal which is corrosion protected by chromium acid treatment or organic inactivation process of he zinc surface. However, sampling and analysis methods for the oil residues have not been available. The proper and well validated quantification method for oil on a surface is firstly needed by a manufacturer who will develop methods to produce components with low oil residues. Secondly, the validated analysis method is needed by designers and building contractors who will order a clean and odour free HVAC system in order to ensure high IAQ for the building. The aim of this study was to develop a consistent method to determine the concentration of corrosion protection oils and lubricants on the surfaces of the HVAC-components. In this work three different sampling methods were tested in laboratory and they were also applied in the field.

MATERIAL AND METHODS

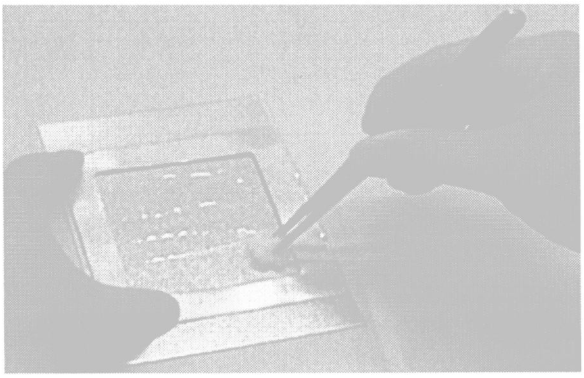
Test surfaces and sampling strategy

Performance and recovery of three different sampling methods were tested. Two first of the methods based on swiping technique and the third based on direct contact of sampling filter to the surface. Two kind of commercially available galvanised sheet metal were chosen as test surfaces. One material was protected against corrosion with chromium acid and the other surface was treated with corrosion protection oil mist (approximately 200-500 mg/m^2) at the steel mill before they were reeled in for trade.

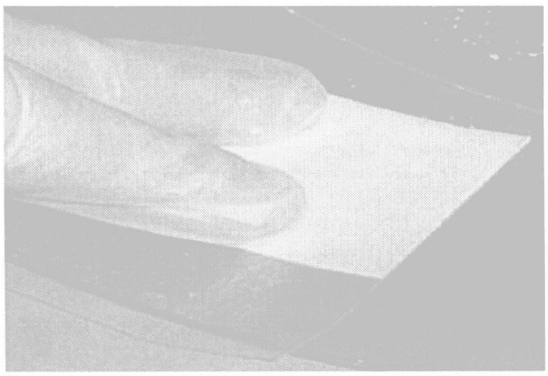
Ten sampling sites with three sampling areas were randomly chosen on the surfaces of the oil treated sheet metal. By this arrangement the possible unequal distribution of the oil on the surface will not disturb the comparison of the methods. The oil concentrations on the surface of chromium acid treated sheet metal were analysed with the glass wool swiping and the filter contact methods. Field samples were collected from bends and ducts at the factory. The analysed components were just waiting for packing and consignment.

Sampling methods

Glass wool and cotton wool (200 mg) were used in **swiping methods**. The oil was collected from a surface by swiping it either with a glass wool or cotton wool samplers (Picture 1). The swiping sampler was prepared by immersing the wool in a test tube containing 2 ml of tetrachloroethylene (TCE) (Merck 100965 UVESOL) after which the excess solvent was pressed carefully back in the tube. A known surface area, 100 cm^2 bordered with a specimen, was swiped crosswise. After the sampling, the wool was stored to the test tube. The sampling method is analogous to that used in microbial contamination studies [2] and that used for analysis of PCB concentrations on surfaces [4].



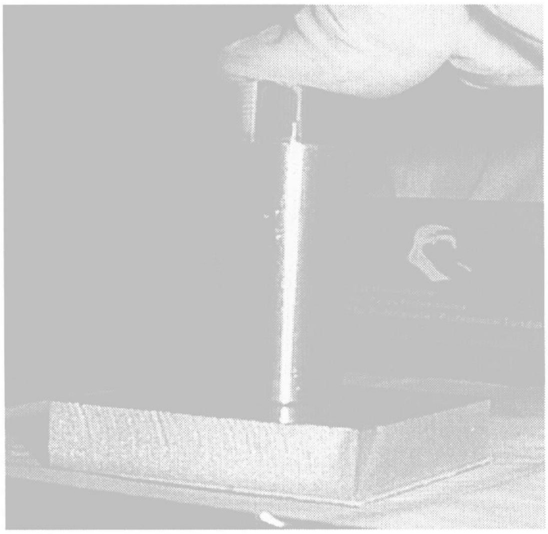
Picture 1. Oil sampling from metal surface by glass- or cotton-wool.



Picture 2. Oil Sampling from metal surface by filter contact method by pressing the filter with fingers.

Filter contact method based on the pressing an immersed glass fibre filter (Munktell filter MG 160) on the surface with a constant pressure. The filter was immersed in tetrachloroethylene (0,036 ml tetrachloroethylene/cm^2), after which it was placed and pressed the surface to be sampled. Three different pressurising methods were employed. In the first one, the immersed filter (A=19,6 cm^2 or 25 cm^2) was covered with a cleaned Petri dish or with a polytetrafluoroethene (PTFE) film and pressed with fingers (Picture 2). The force during sampling was approximately 39 N which gives 65 kPa pressure on the filter surface. In the second method, the immersed filter was covered with the PTFE film and pressed with a roller (Picture 3). The force in the roller was adjusted to 10 N, giving relative high pressure under the roll. In the third pressurising method, the immersed filter was pressed with a constant pressure device (Picture 4). The force in the device was adjusted in 42 N which gives 17.5 kPa pressure on the 25 cm^2 surface. The force control and adjustment were easiest with the last method. After the sampling the filter was closed in a test tube and the analysis was performed similarly to the glass wool and cotton wool samples.

Picture 3. Oil sampling of from metal surface by filter contact method where filter is pressed with BM-dustroller [6].



Picture 4. Sampling of oil from metal surface by filter contact method by pressing with a constant pressure device.

Analysis of the samples

Quantity of the oil in the samples was analysed according to the modified SFS standard method [7]. In order to evaporate the solvent the sample was kept in a dry bath for 15 minutes at 36°C. The oily contaminants were extracted by adding five millilitre of TCE, extracted in ultrasonic bath, centrifuged (3000 rpm, 23 °C, 10 min) and analysed by spectrophotometer with 3400-2500 nm wavelength. Quantification was done against a dilution series of the same processing oil or corrosion protection oil which was used on the surfaces studied.

All glassware and surfaces in contact with the samples were rinsed with the TCE and dried before use.

Recovery of the methods

Recoveries of all the sampling methods were tested preliminary by taking three successive samples from the same sampling area.

Recovery for the filter contact method was determined with spiked samples with a known amount of the oil residue. Sample sheets (N=10) with equal size of sampling filters were cleaned and washed with TCE before application of corrosion protection oil (Mobilarna 778). The samples were taken from each sheet with the filter contact method by pressing the constant pressure device. The pressure used (17.5 kPa), (F=42 N) was kept constant for 10 s. The initial amount of oil on the surface was obtained by analysing also the remaining oil residue from the sheets (A = 25 cm^2). The sheets were extracted in ultrasonic bath with 10 ml of TCE. The total oil content on the sheet is the sum of oil obtained with the filter contact method and the result of the direct extraction of the sheet. Recovery of the method was calculated by following where C_1 is oil concentration measured by sampling [mg/m^2] and C_2 is oil concentration measured by extraction method [mg/m^2].

$$\text{Recovery}\ (\%) = \frac{1}{N} \times \frac{\sum_{i=1}^{N} (C_1)_i}{\sum_{i=1}^{N} ((C_1)_i + (C_2)_i)} \times 100\%$$

RESULTS AND DISCUSSION

Oil levels on the surface of the sheet metal covered by corrosion protection oil were measured with three sampling methods. The average amounts of oil on the surfaces ranged 0.5-0.9 g/m^2 (Table 1). The filter contact method gave the highest results compared to that of the both swiping methods. The results show that corrosion protection oil is not equally distributed on the surface of the sheet metal shipped from the steel mill. Results obtained with all of the methods showed relatively high but quite equal variations (relative standard deviations 20% for glass wool swiping, 16% for cotton wool swiping, and 21% for filter contact method) between the sampling areas. The unequal distribution of the oil on the sheet metal surface renders the estimation of the repeatability of the methods.

For the most effective method, filter contact method, oil levels ranged from 530 to 960 mg/m^2. This is agree well with the concentration informed by the manufacturer. The detection limits for the glass wool, cotton wool and filter contact method were 1, 1 and 2 mg/m^2, respectively. The swiping methods had lower recoveries which can be partly explained by the remaining solvent residue on the surface (see Picture1).

Table 1. Oil level on the surface of the oil covered sheet metal measured with three sampling methods.

Sampling method	**Cotton wool swiping (N=10)**	**Glass wool swiping (N=10)**	**Filter contact method (Pressing with fingers) (N=10)**
Mean [mg/m^2]	510	590	770
SD [mg/m^2]	100	100	160
RSD (%)	20	16	21
Range [mg/m^2]	380-680	470-740	530-960

The oil levels on the surface of the sheet metal treated with chromium acid, was measured with glass wool swiping method and with the filter contact method. The amount of oil on this surface was very low (Table 2). The oil concentrations glass wool swiping method ranged from the detection limit to 5 mg/m^2. Most samples (71%, N=17) were below the detection limit of 1 mg/m^2. The oil concentration with the filter contact method ranged from 2 mg/m^2 to 29 mg/m^2. Seventy percents (N=10) of the samples were below the detection limit of 2 mg/m^2. However, variation in the results is influenced by unequally distribution of the minor oil residues on the sheet metal shipped from the steel mill.

Oil concentrations of the air ducts (Table 2) and HVAC-components (Table 3) were measured with glass wool swiping and filter contact method (pressing by finger). The results show large range in the oil concentrations both in the air ducts and on the HVAC-components; fifty fold differences between the lowest and highest values were found. The filter contact method gave six fold oil concentrations compared to the swiping method. Due to variation in the oil levels, even on the different areas in the same component, several samples per component are needed to obtain reliable results.

Table 2. Oil concentrations on the surfaces the air duct measured by two sampling methods.

Sampling method	**Glass wool swiping (N=7)**	**Filter contact (pressing by finger) (N=22)**
Mean [mg/m^2]	7	58
SD [mg/m^2]	15	67
Range [mg/m^2]	0.5- 49	2.5- 272

Table 3. Oil concentrations on the surfaces of the HVAC-components measured by two sampling methods.

Sampling method	**Glass wool swiping (N=7)**	**Filter contact (pressing by finger) (N=22)**
Mean [mg/m^2]	6	40
SD [mg/m^2]	11	57
Range [mg/m^2]	1-32	8-260

Pressing technique affects the recoveries of the filter contact methods. When the contact filter was rolled with a BM-dustroller, the roller pushed some of the TCE solvent and oil sample out from the filter. A good performance of the filter contact method with better recovery compared to the swiping methods encouraged to develop a constant pressure device (Picture 4) in which the pressing force is controllable and sampling is easy to standardise. Recovery and repeatability of the filter contact method with constant pressure device was 91 ± 2 %.

CONCLUSIONS

Oil residues are one group of impurities on new HVAC components that decreases the quality of air passed through the system. Galvanised sheet metal which was covered with corrosion protection oil contained 500-1000 mg/m^2 of oil. While the oil concentrations were low on the sheet metal surface which was treated with chromium acid instead of oil. A wide variation in the oil concentrations were seen on the same sheet metal and also in the manufactured components. The variation should be taken account in sampling design.

The filter contact method showed the best recovery and repeatability and the method was good compared to the glass wool and cotton wool swiping methods.

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