Ambient Air Contamination by Micron and Submicron Particle from Welding Operations

Hans O. Lannefors[1] and K. Roland Akselsson[2]
[1]*Department of Nuclear Physics*
Lund Institute of Technology
Sölvegatan 14
S-22362 Lund, Sweden
[2]*Department of Environmental Health*
University of Lund
Sölvegatan 21
S-22362 Lund, Sweden

INTRODUCTION

Recent concern about air quality in work environments has initiated much effort to decrease the exposure of workers to polluted air. Space ventilation as well as the less energy-consuming source ventilation have been applied. The contribution to the ambient air pollution level from the ventilation air of the work environment may appear insignificant in view of the large dilution which takes place. However in this work, it is shown that an aerosol of industrial indoor origin may significantly contribute to the total pollution level in a city.

A major part of this work is to show that the combination of impactor sampling and analyses of size fractions by particle induced x-ray emission analysis (PIXE) is a very sensitive tool for revealing particulate matter of industrial indoor origin in the presence of particulate matter from other anthropogenic and natural sources.

EXPERIMENTAL

In a small Swedish town (population less than 50 000) with an industrial area employing of the order of three to five thousand workers, two sampling sites, I and DT, at rooftop locations respectively one and three storeys high were chosen. Site I is situated in the northern part of the industrial area and site DT about one kilometer NNW of this area and in the middle of the town.

The sites were fitted with single orifice cascade impactors of Battelle design (Mitchell and Picher, 1959) with an extra stage (stage 0) added for particles larger than 8 μm and with a Nuclepore 0.4 μm pore diameter back-up filter (stage 6) also added. The seven size fractions obtained with this device are: > 8 μm, 4-8 μm, 2-4 μm, 1-2 μm, 0.5-1 μm, 0.25-0.5 μm and, on the back-up filter, particles smaller than 0.25 μm. Sampling was performed in five 12-hours periods, during only two of which (1 and 2) air from the industrial area

Bulletin of Environmental Contamination & Toxicology,
Vol. 17, No. 5 © 1977 by Springer-Verlag New York Inc.

was recorded. See Table I.

TABLE I

Weather conditions during the sampling periods

Period	Date	Wind direction and speed (m/s)		
		08.00	12.00	18.00
1	June 11	Variable, 1-2	SW, 1-2	SE,5
2	June 12	S, 1	SE, 3-5	SSE,1
3	June 13	NW, 6-11	NW, 5-12	W,5-12
4	July 4	NW, 2-4	NW, 1-3	SW,5-6
5	July 9	NE, 2-7	NE, 2-10	E,3-10

The size fractions were sampled both on paraffin-coated thin polystyrene films supported by glass discs and in the filter (<0.25 µm) and then analysed using PIXE-methods. PIXE is a fast multielemental method (JOHANSSON et al, 1970 and 1975) offering good accuracy and precision (CAMP et al, 1975) and is especially suitable for such small samples as those collected with single orifice cascade impactors. In the arrangement used in this experiment, 2 and 3 MeV protons from a Van de Graaff accelerator were used for excitation and the characteristic X-rays were detected by a Si(Li) semi-conductor counter. Results for sulphur, iron, potassium, manganese, zinc and lead are reported to a typical accuracy of 20%.

RESULTS AND DISCUSSION

Figure 1 shows average size distributions of particulates containing sulphur, iron, potassium, manganese, zinc and lead respectively at the two locations and at the two different wind conditions. For comparison corresponding size distributions obtained in St Louis (AKSELSSON et al, 1975), North Florida (JOHANSSON et al, 1974 and 1976) and Bermuda (MEINERT, 1974) are shown. For sulphur and zinc there are no significant trends, but for potassium, iron and manganese there are between 2 and 30 times more on stage 6, 5 and 4 (corresponding to particles smaller than 1 µm) for periods 1 and 2 than during periods 3 to 5. This indicates a source of small particles south of the sampling sites. The lead data are not conclusive. However, there is a known lead source close at hand, south of the sampling site I, which may explain the abundance of large-particle lead for southerly winds at site I.

The industrial are includes several plants where welding operations are performed. Malmqvist et al (1975) have investigated the size distribution and elemental compo-

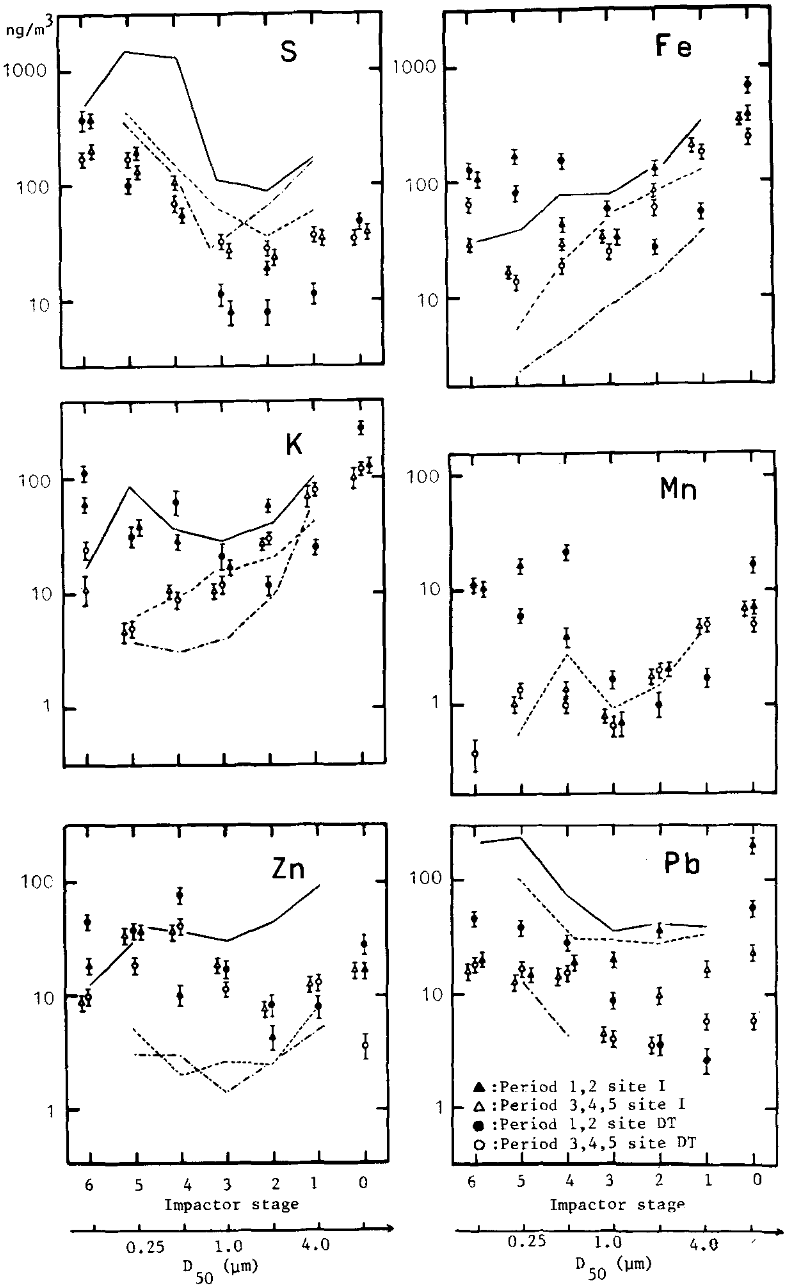

Figure 1. Size distributions of particles containing sulphur, iron, potassium, manganese, zinc and lead at the downtown, DT, and industrial area, I, locations obtained with different weather conditions. Filled symbols denote measurements with some intervals with industrial air. The results are compared with results from St Louis (solid), North Florida (dashed) and Bermuda (dot-dashed). D_{50} is the 50% cut-off aerodynamic diameter of the impactors.

sition of welding fumes from welding operations considered to be representative of this industrial area using the same kind of cascade impactors as are employed in this investigation. They report iron, potassium and manganese to be the major elements in welding fumes and that these elements are found predominantly as submicron particles. To investigate further whether welding operations in the industrial area might be the source of the excess submicron iron, potassium and manganese, a simple model for qualitative analysis was developed. The following assumptions were made: 1000 welders were employed in an industrial area of 1 km^2. Each welder was assumed to generate welding fumes with an average composition and size distribution as taken from Malmqvist et al (1975). The total mass of the elements detectable with PIXE was assumed to be 200 mg per minute per welder. All the generated particles in the size range sampled were supposed to escape to the outdoor air and the fumes spread evenly throughout a 100 metres thick layer in a 30-degree sector by a wind with velocity 2m/s. Table II shows the predicted concentrations for potassium, manganese and iron. The concentrations at site I and site DT are the same to within 10%.

TABLE II

Estimated concentrations (ng/ m^3) at site I and DT

Impactor stage	K	Mn	Fe
BF 6	(240)^x	73	550
5	390	85	470
4	970	210	950
3	73	20	110
2	26	9	63
1	36	20	210
0	79	46	1060

[x] The potassium stage 6 value is obtained from averaging of only 2 impactors while the remaining values are based on results from 5 impactors.

For the short transport distances involved here there is no significant difference in outdoor transport efficiency between particles of different size classes except for the heaviest particles on stage 0 for which sedimentation may be considerable. However, there may be differences in both indoor transport and escape probabilities.

The increases in concentrations observed for southerly winds (periods 1 and 2) at each site were calculated by subtracting the normal values, obtained by averaging the results from periods 3, 4 and 5, from the results of periods 1 and 2. Table III shows the ratios between these contributions and estimated values from Table II.

TABLE III

The elemental ratios between excess concentrations and model contributions from indoor welding operations

Site/period	impactor stage	Fe/Fe_{mod}	Mn/Mn_{mod}	K/K_{mod}	mean[x,xx]
I/1	6	0.024	0.030	(0.056)[x]	
	5	0.098[xx]	0.040	0.029	0.024 ±0.010
	4	0.014	0.012	0.019	
I/2[xxx]	6	0.24	0.25	(0.34)[x]	0.23 ±0.06
	5	0.54[xx]	0.28	0.15	
DT/2	6	0.10	0.15	(0.37)[x]	
	5	0.29[xx]	0.13	0.13	0.11 ±0.03
	4	0.13	0.10	0.05	

[x] The model value for potassium on stage 6 is based on only two impactors. Potassium stage 6 was not included when deriving the mean value.

[xx] The model value for iron stage 5 is evidently too low. Iron stage 5 is not included in the average value given.

[xxx] Stage 4 site I period 2 was lost.

There are three observations supporting the hypothesis that welding operations are the source of the excessive concentrations found in sampling periods with wind blowing from the industrial area to the sampling sites. Firstly, the excess is found where and only where the welding aerosol is most abundant relative to the background, i.e. iron, potassium and manganese on stages 4, 5 and 6. Secondly, the ratios in Table III are about the same for a particular site and period. This observation also indicates the same transport efficiency for the three elements and the three size classes. All the potassium stage 6 values are high by a factor of about two. This may be explained by an uncertain model value as indicated in the first note to Table III. Also, the iron stage five values are too high by a factor 2 - 4, which may be due to the presence of another source for small particles containing iron. The other seven ratios are in good agreement although the magnitude of the industrial contribution spans over an order of magnitude. Thirdly the magnitude of the ratios are reasonable. In a quantitative model, the ratios should be one. Such values would be given e.g. by assuming a wind speed of 4 m/s and the sites being in the plume 5%, 0%, 50% and 25% of the time for cases I/1, DT/1, I/2 and DT/2 respectively. According to the sparse information in Table I, these assumptions are not unrealistic.

SUMMARY

Impactor sampling and PIXE analysis constitute a good combination in detecting the influence of fugitive emission and ventilation air on ambient air quality. In total filter samples heavier natural particles mask the increase in mass due to the smaller industrial particles. Multielemental analysis of many samples is important in finding unknown sources and in evaluating the effect of all the sources. PIXE is well suited for this kind of analysis.

The health effects of low-concentration air-pollution exposure on large population groups including such sensitive groups as children, elderly and sick people are not well understood, which is encouraging for sampling more basic information for epidemiological studies.

The increases of the concentration of iron, potassium and manganese are evident. Although the reported values are below air-quality limit values, there are some reasons for being careful. Firstly, the increases are most significant in submicron particles. Secondly, with different weather conditions and from other industrial areas, indoor contribution could be orders of magnitude larger. Thirdly, in PIXE analysis only elemental constituents heavier than about sulphur are detected and there may be other lighter constituents. It is, e.g., known that water-soluble fluorine is abundant in fumes from electrodes with basic coatings. Thus considerable attention should be given to the ambient air when planning means of improving work environment and when allocating new industrial areas.

ACKNOWLEDGEMENT

This work is supported in part by the Swedish Work Environment Fund.

References

AKSELSSON, R., C. ORSINI, D.L. MEINERT, T.B. JOHANSSON, R.E. VAN GRIEKEN, H.C. KAUFMANN, K.R. CHAPMAN, J.W. NELSON and J.W. WINCHESTER; Advances in X-ray Analysis 18,588(197

CAMP, D.C., A.L. VAN LEHN, J.R. RHODES, and A.H. PRADZYNSK X-ray Spectrometry 4, 123(1975).

JOHANSSON, T.B., R. AKSELSSON, S.A.E. JOHANSSON; Nucl. Ins Meth. 84, 141(1970).

JOHANSSON, T.B., R.E. VAN GRIEKEN, and J.W. WINCHESTER; J. de Recherches Atmosphériques 8, 761(1974).

JOHANSSON, T.B., R.E. VAN GRIEKEN, and J.W. WINCHESTER; J. Geophysical Research 81, 1039(1976).

JOHANSSON, T.B., R.E. VAN GRIEKEN, J.W. NELSON, and J.W. WINCHESTER; Anal. Chem. 47, 855(1975).

MALMQVIST, K., G. JOHANSSON, R. AKSELSSON, and T.B. JOHANS Report LUNP 7508, Depatrment of Nuclear Physics, Universit of Lund, Sweden 1975 (in Swedish).

MEINERT, D.L., M.S. THESIS, Department of Oceanography, Florida State University, Tallahassee, USA June 1974.

MITCHELL, R.I., and J.M. PILCHER; Ind. Eng. Chem. 51, 1039 (1959).