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CONTROL TECHNOLOGY AND MECHANISM STUDIES OF THE LUNG EFFECTS OF MIXED EXPOSURE TO DUSTS AND GASES

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In an earlier investigation, a major temporary effect on the lung function was determined, with a spirometer, in stevedoors on a ro-ro-ship exposed to diesel exhausts from trucks during a work shift. In the present study all the trucks used aboard were equipped with especially designed micro-filters mounted on the exhaust pipes. When the filter was in use, no significant effect on the lung function was measured. The removal of the particulate fraction of the exhausts by filtering modified, or possibly eliminated, the effect observed earlier. In designing an indicator of the biological effects of diesel exhausts the particle fraction should be taken into consideration.

Exposure to irritating agents constitutes one of the most common chemical risks in the working environment. Examples of irritating substances which may be found as air contaminants are most organic solvents, a number of lower aldehydes starting with formaldehyde, a number of inorganic gases such as sulphur dioxide, nitric oxides, organic acids, their anhydrides and halides, phosgene, the halogens, the hydrogen halides, ammonia, ozone.

This paper deals with the effects of particles and gaseous substances which were investigated separately in a field exposure situation. The principle could also be used in other exposure situations.

In an earlier investigation (1), the authors studied the health effects of mobile engine exhausts among the personnel on ro-ro-ships, in bus garages and car ferries. The concentrations recorded were: nitrogen dioxide 0.03 – 1.8 ppm, carbon monoxide 1.0 – 4.5 ppm, formaldehyde <0.5 ppm and dust 0.13 – 1.0 mg/m^3.

Pulmonary function was affected (restrictive type with an average decrease in FVC of 0.44 L and in FEV_1 of 0.3 L) during a working day with occupational exposure to diesel motor exhausts, but returned to normal after a few days without exposure. The decline in pulmonary function was judged as having no appreciable adverse short-term impact on individual work capacity. It was not clear to which substance or substances the effect could be ascribed.

METHODOLOGY AND RESULTS

In the present investigation, carried out in 1985, all the trucks that were used aboard a ro-ro-ship were equipped with especially constructed micro-filters (> 99.97 DOP, i.e. 99.97% degree of retention of dioctylphthalate mist with particle size 0.3 mm) made of glass fibre, and sealed with silicon resin in the ends. The dimensions of the filters were 600x600 mm and the depth was 300 mm, corresponding to 144 filters per package. The total filter surface per package was calculated to be 46.8 m^2. The filters were fitted on the truck exhaust pipes.

Measurements of exposure to the substances listed in Table 1 (direct reading instruments for carbon monoxide, nitrogen oxides, chemosorption for formaldehyde, the filter method for dust) were carried out during a whole work shift in all workers in the workplace who had not been exposed to exhaust gases during at least 3–4 days immediately before the study. The same substances were measured as in the earlier investigation without exhaust filters, with the man carried equipment and for respirable dust, with the stationary equipment.

Table 1

Daily means ($\bar{X}$) in the inspired air ± the standard error (SE) of some substances present in diesel exhaust gases in the 1985 investigation (with exhaust filters) and in 1983 (without exhaust filters). Gas concentrations in ppm and dust concentrations in mg per cbm

Substance	Trucks with filter			Trucks without filter			Hygienic limit*
	$\bar{X}$	SE	n	$\bar{X}$	SE	n	
Nitrogen dioxide	0.19	0.05	81	0.34	0.15	35	2
Nitric oxide	0.89	0.23	81	0.78	0.32	35	25
Carbon monoxide	2.14	0.36	81	2.23	0.89	35	35
Formaldehyde	0.27	0.05	62	0.03	0.16	17	0.8
Total dust	0.45	0.10	5	0.48	0.07	3	10
Respirable dust, %**	27	7	3	48	11	3	
Respirable dust (calculated)	0.12			0.23			5

* the 1984 Swedish 8-h time-weighted average hygienic limit value
** measured by stationary sampling

The subjects in this investigation (1985) were 18 non-smoking stevedoors, all men with an average age of 36 years (SD ± 7), who had been periodically exposed to diesel exhaust gases in the loading of ro-ro-ships during at least one year.

Forced vital capacity was recorded with a low resistant bellow spirometer (Ohio 740). At least two measurements were taken per person. The best result for each variable was

Table 2

Spirometric data, means ± standard errors for 18 non-smoking men, before and after a work shift

Time	FVC, 1	FEV 1 1	FEV %	MMF, 1/s
Before shift	4.96 ± 0.19	3.96 ± 0.17	79.8 ± 1.8	3.93 ± 0.29
After shift	4.84 ± 0.17	3.92 ± 0.19	80.4 ± 1.9	4.06 ± 0.31

chosen, even if this meant that the results were selected from different recordings (2). The following variables were recorded: FVC (Forced Vital Capacity), FEV_1 (Forced Expiratory Volume in one second), FEV% (Forced Expiratory Volume in one second as a percentage of Forced Vital Capacity), and MMF (Maximal Midexpiratory Flow). The results in Table 2 are reported in the form of mean values and standard errors of the means; Student's t-test was used in analysis (3).

When lung function test was done before and after the work shift and all exhaust pipes were fitted with a filter, there was no significant decline over the work shift in the lung function in contrast to what was observed in the first study (1983) when no filter was used.

DISCUSSION

It is concluded that the filtering modifies or possibly eliminates the acute lung effect. This was to be expected from the results of the first investigation (1983) showing no correlation between the lung effect and concentrations of gases that were measured, i.e. nitrogen monoxide, nitrogen dioxide, formaldehyde or carbon monoxide.

The concentrations of water soluble sulphate and nitrate ions on the particles retained by the filters were 0.5 – 1% of each ion. This is in rather good agreement with published data (4). The corresponding air concentration of the adsorbed ions would have been less than 0.002 mg/m^3 had no filtering been carried out. At the same time a concentration of 0.6 mg/m^3 nitrogen dioxide in the gas phase was measured. A possible explanation is that irritating substances adsorbed on fine dust particles were carried to the fine airways where they may have exerted an important effect on the tissues.

In laboratory experiments with guinea pigs, *Amdur* (5) found that zinc oxide potentiated the effect on the lung function of sulphur dioxide when humidity was sufficiently high. The zinc oxide alone had no effect on the lung function (6). Amdur explains the potentiating effect of zinc oxide by means of surface catalysed oxidation of sulphur dioxide to sulphuric acid. According to Amdur even very small amounts of sulphuric acid on the surface of particles below one micrometer may have an important effect on the lungs.

The potentiating of irritating gases by particles has been observed in man as well. When formaldehyde was adsorbed on wood dust or on paint particles effects were observed in the deep airways (7) and in the alveoli (8). Persons experimentally exposed

to gas concentrations of formaldehyde in the same range did not show acute lung effects (9).

Our earlier investigation (1) involved healthy persons who were not normally exposed to motor exhaust gases. These were exposed, in an exposure chamber, to motor exhaust gases diluted to a concentration of nitrogen dioxide close to the 1984 Swedish 8-h time weighted average hygienic limit, 2 ppm. The exposure lasted 3.5 hours. No effects on the lungs were observed. This can be explained by the fact that the concentrations of diesel particles were markedly decreased owing to their passing through the dilution apparatus and therefore being lower than in the work environment where concentrated exhaust gases were emitted directly into the air space and diluted by the unforced mixing processes in the work room.

To conclude, we have been able to manipulate exposure to a mixture of gases and particles in a practical work situation so that the mechanism of irritation can be studied, in this case by placing a provisional filter at the source of emission. We have thus pointed at the feasibility of a more permanent remedial action of a pollution problem. Such a solution demands, for instance, the construction of a rechargeable filter.

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Sažetak

KONTROLA, TEHNOLOGIJA I MEHANIZAM DJELOVANJA IZLOŽENOSTI PRAŠINI I PLINOVIMA NA PLUĆNU FUNKCIJU

U prijašnjem istraživanju nađen je značajan prolazni učinak ispušnih plinova kamiona na plušnu funkciju radnika za vrijeme smjene. U sadašnjem istraživanju svi kamioni imali su specijalne mikro filtre pričvršćene na ispušne cijevi. Pri upotrebi filtara nije primijećeno značajno djelovanje ispušnih plinova na plućnu funkciju. Uklanjanje određenog dijela plinova promijenilo je ili sasvim eliminiralo djelovanje koje je prije primijećeno. Stoga bi pri stvaranju indikatora za biološko djelovanje osobitu pažnju trebalo obratiti na tu frakciju ispušnih plinova dizel-goriva.

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