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BIOLOGICAL EFFECTS OF MANGANESE

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Office of Research and Development
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BIOLOGICAL EFFECTS OF MANGANESE

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FOREWORD

The many benefits of our modern, developing, industrial society are accompanied by certain hazards. Careful assessment of the relative risk of existing and new man-made environmental hazards is necessary for the establishment of sound regulatory policy. These regulations serve to enhance the quality of our environment in order to promote the public health and welfare and the productive capacity of our Nation's population.

The Health Effects Research Laboratory, Research Triangle Park, conducts a coordinated environmental health research program in toxicology, epidemiology, and clinical studies using human volunteer subjects. These studies address problems in air pollution, non-ionizing radiation, environmental carcinogenesis and the toxicology of pesticides as well as other chemical pollutants. The Laboratory develops and revises air quality criteria documents on pollutants for which national ambient air quality standards exist or are proposed, provides the data for registration of new pesticides or proposed suspension of those already in use, conducts research on hazardous and toxic materials, and is preparing the health basis for non-ionizing radiation standards. Direct support to the regulatory function of the Agency is provided in the form of expert testimony and preparation of affidavits as well as expert advice to the Administrator to assure the adequacy of health care and surveillance of persons having suffered imminent and substantial endangerment of their health.

Studies of the health of populations which live in the vicinities of major air pollution sources are potentially valuable in understanding the effects of individual pollutants. They offer exposure levels which are intermediate between those encountered in industry, and those found in mixed urban ambient air pollution. Forty years ago two studies in Europe indicated that excess acute respiratory illness could be found in neighbors of manganese smelters. These studies were done, however, in small mountain valleys which had extreme pollution. The study here reported is an attempt to conduct a somewhat similar evaluation of a manganese plant and its neighbors in a more normal geographic situation.

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ABSTRACT

The biological effects of manganese were studied in a town on the coast of Dalmatia in which a ferromanganese plant has been operating since before World War II. The study focused on the question of whether the exposure to manganese can cause a higher incidence of respiratory diseases and, if it can, at what exposure levels. The study also considered the effects of manganese on the central nervous system and on blood pressure as well as a possible catalytic effect of dust containing manganese on the conversion of sulfur dioxide in the air.

The results obtained show that the rate of pneumonia is influenced by the exposure to manganese at the level of occupational exposure in the production of manganese alloys. The actual exposure followed the fluctuations in the manufacture of ferromanganese and can be assumed to range approximately from 0.15-20 mg/m^3 (mean values for 8-hour work). There are some indications that an even much lower exposure level may be associated with the morbidity from pneumonia in the population living in the manganese-polluted area. This lower-level effect, however, is still an assumption without enough firm evidence to establish it as fact.

A higher rate of acute bronchitis was recorded during a 4-year followup at an ambient exposure to manganese present at the comparatively low level of 1 $\mu g/m^3$. Two separate studies on the relationship between the incidence of acute respiratory diseases and exposure to manganese in groups of school children and their families partly proved this connection. The incidence of acute respiratory illness was higher in the town contaminated by emissions from the ferroalloy factory than on the island chosen as control. It is possible, however, that some other factors which were not sufficiently controlled might have influenced the obtained results.

The study also indicates that a higher rate of chronic nonspecific lung disease can be expected in occupational exposure to manganese at the 1 $\mu g/m^3$ level previously mentioned. A possible synergism between the exposure to manganese and smoking seems to be involved in such an effect.

The investigation supports the observations of other authors that a developed neurological effect of manganese is present in a very small number of subjects, even in conditions of a comparatively high exposure.

At the level of occupational exposure to manganese (in the ferromanganese plant), a hypotonic effect on systolic blood pressure was also observed. The mean values of diastolic blood pressure did not follow a relative decrease in the mean values of systolic blood pressure. The differences found in the behaviours of systolic and diastolic blood pressures may even indicate an effect of manganese ions on the myocardium.

The results concerning the possible effect of flue dust containing manganese on the conversion of sulfur dioxide in air in natural conditions indicate the existence of a catalytic action of manganese. The question still remains as to what extent the obtained results refer to the conversion of sulfur dioxide at comparatively low concentrations of manganese and sulfur dioxide in the ambient air.

This report was submitted in fulfillment of Foreign Research Agreement No. 02-513-6 by the Institute for Medical Research and Occupational Health, Zagreb, Yugoslavia, under the sponsorship of the U.S. Environmental Protection Agency. This report covers the study period from July 30, 1971, to July 30, 1976. The work was completed as of July 30, 1976.

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SECTION 1

INTRODUCTION

The results presented in this report have been obtained over a period of 5 years. The study focused on investigations of whether the exposure to manganese can cause a higher incidence of respiratory diseases and, if it does, at what exposure levels. The effect of manganese on the central nervous system has also been considered. A further aim of the study has been to determine how far the effect of manganese on respiratory organs may be enhanced by simultaneous action of sulfuric acid which may be formed by catalytic oxidation of sulfur dioxide on the surface of manganese particles, and to determine if this action occurs in flue gases and in the free atmosphere under natural conditions.

The study was carried out in a town on the coast of Dalmatia where there has been a ferroalloy (ferromanganese) plant since before World War II. The plant employs about 1,400 workers of whom about 450 are occupationally exposed to managanese. In addition to the production of manganese alloys, the plant produces electrodes. The plant is situated in the close vicinity of a residential area of the town so that a part of the inhabitants are directly exposed to the emissions of the plant. According to the last census (in 1971) the town has a population of about 31,000. The stack effluents are occasionally dispersed to distant town regions depending upon the wind direction.

The investigations have included:

1. Measurements of manganese and sulfur dioxide concentrations in air in the polluted area and measurements of manganese in the working environment and in the urine of exposed workers.

2. A retrospective analysis of absences from work caused by pneumonia and bronchitis in the ferroalloy factory.

3. An epidemiological survey of the prevalence of chronic non-specific lung disease and neurological disturbances and of arterial blood pressure values in workers occupationally exposed to manganese.

4. A followup of the incidence of acute respiratory diseases in the inhabitants of the town area contaminated by manganese.

5. A study of the rate of acute respiratory diseases in groups of school children and members of their families in the manganese-contaminated area.

6. A study of the possible catalytic effect of manganese-containing flue dust on the conversion of sulphur dioxide in air.

The report of the results obtained is divided into sections (4-9), and each section is written as a self-contained entity. Section 10 contains a discussion which summarizes the results. Following the discussion are references and a list of publications pertinent to the subject of this report.

SECTION 2

CONCLUSIONS

A retrospective analysis of the data on absenteeism due to pneumonia in workers occupationally exposed to manganese in the production of manganese alloys showed a higher rate of the disease compared with two other groups of workers with a much lower exposure. In another part of the study performed during a 4-year period on the population living in the manganese polluted area, there are indications that an even much lower exposure to manganese may influence the morbidity from pneumonia, but this relationship remains only an assumption without enough firm evidence to establish it as fact.

The same 4-year followup study indicated that an ambient exposure to manganese of the order of magnitude of 1 $\mu g/m^3$ is associated with a higher rate of acute bronchitis. Two additional 6-month studies of school children and their families support these results to some extent. The registered incidence of acute respiratory diseases was higher in the town contaminated by emissions from the ferroalloy factory than on an island chosen as control. A slight increase in forced expiratory volumes in children was also noticeable as one moved farther from the ferroalloy plant.

In addition to the influence on the rate of pneumonia, occupational exposure to manganese at an assumed level, ranging approximately from 0.5-20 mg/m^3, seems to produce an effect on the rate of chronic nonspecific lung disease. Smoking appears to be a synergistic factor which enhances the action of manganese. At the level of the same occupational exposure to manganese, a hypotonic effect on systolic blood pressure was also observed.

Only a certain number of workers with a comparatively high occupational exposure developed individual neurological signs (mainly tremor at rest) which might be connected with the action of manganese.

The results of the investigation performed in natural conditions suggest that flue dust containing manganese possibly has a catalytic effect on the conversion of sulfur dioxide in the air. The exact extent to which these findings can be attributed to the sulfur dioxide conversion at relatively low concentrations of manganese and sulfur dioxide in the ambient air and the extent to which they reflect the results of the processes within the plume remain to be determined.

SECTION 3

RECOMMENDATIONS

The study reveals several specific areas toward which additional work needs to be directed. Following the indications that low-level inhalation exposure to manganese may cause some adverse health effects, further studies are required to clarify the dose-effect and dose-response characteristics of manganese. Particular emphasis needs to be put on the pulmonary effects and on the central nervous system effects of low-level and long-term exposure, and the effects of manganese on blood pressure and heart muscle need to be better understood. As organo-manganese fuel additives could significantly increase the exposure of the general population if they come into widespread use, all potential biological effects of manganese, including those minor ones, such as the higher rate of cold or bronchitis, should be appropriately assessed.

In addition to the study of these biological effects of manganese, the catalytic action of manganese in the ambient air at small concentrations of manganese and sulfur dioxide, as well as the interactions of manganese with other pollutants, needs further study.

SECTION 4

MEASUREMENTS OF MANGANESE AND SULFUR DIOXIDE

MATERIALS AND METHODS

Measurement of Sulfur Dioxide and Manganese in the Ambient Air

Daily samples of sulfur dioxide and weekly samples of manganese were collected continuously at one site within the factory grounds and at five sites around the factory: site A, 750 m SE; site B, 2,000 m ESE; site C, 2,750 m SE; site D, 5,500 m SSE; and site E, 25 km WNW (control point).

Manganese was collected on membrane filters (35 mm collecting surface) and sulfur dioxide in sequence in a 1 volume percent solution of hydrogen peroxide at an air flow of about 1.3 l/min. The total volume of the air sample was recorded by a gas meter. The air sample entered the sampling system through an inverted funnel connected with the sampling train. In this way large particles were removed from the air stream. Sulfur dioxide was determined by the acidimetric method and manganese by atomic absorption spectrophotometry. Measurements were made over a 4-year period, from 1972 to 1975.

Measurement of Manganese Concentration in the Indoor Air of the Ferroalloy and Electrode Plant

In the ferroalloy plant, samples of the total dust were collected during one shift at a rate of 1-2 l/min using Casella personal samplers on the same membrane filters as the outdoor samples. They were dissolved in 20 ml of diluted nitric acid, evaporated to dryness, and treated with concentrated hydrocholoric acid to dissolve metallic oxides and precipitate silica which could interfere with analysis of samples of manganese. After that they were reevaporated to dryness, wetted again with a few drops of hydrochloric acid, dissolved with water and partly neturalized with a few drops of ammonium hydroxide to an approximate pH of 5-6, and analyzed with atomic absorption spectrophotometry.

In the electrode plant which is within the same factory grounds, three types of samples were collected: a total dust on glass fiber filters, a total dust on membrane filters, and respirable dust on membrane filters. The glass fiber filters were determined gravimetrically, and the membrane filters were analyzed for the content of manganese in the same manner as were the samples from the ferroalloy plant.

Measurements of manganese concentration in the indoor air of the ferroalloy and electrode plant were first made in April 1972 and then repeated in July 1974.

Measurement of Manganese Concentration in Urine

Twenty-four-hour samples of urine were collected from a number of workers in the ferroalloy plant, in the electrode plant, and in a light metal plant which is situated about 5 km SSE of the ferroalloy and electrode plants. As the concentration of manganese in the normal urine is very low (1-8 μg/l), it was necessary to preconcentrate the sample before analysis. The preconcentration was performed in two steps. In the first step a sodium-diethyl dithio carbamate was used as a complexing agent, and the compound was extracted with chloroform at pH 6.5. In the second step a thenoyl-trifluoroacetone-manganese complex was extracted with ethylpropionate at pH 8, and this final extract was analyzed by atomic absorption spectrophotometry.

With the two steps of concentration of manganese, the analysis could be done in only 100 ml of mineralized urine. The two different types of extractions were chosen because of the pH of extraction. Namely, at pH 8 the precipitate was formed in the sample, and it was not possible to get a quantitative extraction. On the other hand, chloroform was not a suitable solvent for analysis by atomic absorption spectrophotometry. Therefore, in the second step the complex manganese compound was extracted with ethylpropionate. Samples for the measurement of manganese in urine were collected in April and May 1972.

RESULTS

Concentration of Sulfur Dioxide and Manganese in the Outdoor Air

Figure 1 shows the yearly cycle of monthly mean airborne manganese concentrations at all six sites for the whole period of measurement along with the monthly production rate. Mean annual and maximum weekly concentrations for the 4 years of measurement at each site appear in Table 1. Yearly cycles of monthly mean sulfur dioxide concentrations for the whole period are shown in Figure 2, and mean annual and maximum daily concentrations in Table 2. Table 3 shows the frequency distribution, for the whole 4-year period, of the obtained weekly concentrations of manganese at three measuring sites within 0.75-2.75 km from the ferroalloy factory.

According to the measured concentrations of manganese in the air, the town area was divided into three zones. Zone I was defined as the part of the town nearest to the ferroalloy plant, with mean yearly concentrations of manganese between 0.236-0.390 $\mu g/m^3$ and a population of 8,680. The central part of the town, with mean yearly concentrations of manganese between 0.164-0.243 $\mu g/m^3$ and with 17,105 inhabitants, was defined as Zone II. Zone III was the part of the town 3.5-6 km from the ferroalloy plant, which had mean yearly concentrations of manganese ranging from 0.042-0.099 $\mu g/m^3$ and 5,296 inhabitants. Figure 3 shows the map of the whole area under study, and Figure 4 shows the zoning of the town area polluted by emission from the ferroalloy plant.

Concentration of Manganese in Indoor Air and in the Urine of Exposed Workers

Mean manganese concentrations and the range of the measured concentrations to which workers were exposed during the working shift at a given working place are shown in Table 4 for the ferroalloy plant and in Tables 5, 6, and 7 for the electrode plant. The measurements in Tables 4 and 6 were made in spring 1972, and those for Tables 5 and 7 in summer 1974. The corresponding concentrations of manganese in urine are summarized in Tables 8 and 9.

DISCUSSION

Outdoor Air Pollution

From the result of the 4-year measurement of manganese in the outdoor air, it can be seen that people living near ferromanganese plants are exposed to considerably higher concentrations of manganese than are people in the control areas. It should be stressed, however, that because of the entrance characteristics of the sampling system, only particles of approximately respirable size have been collected and, therefore, these data cannot be compared with the data obtained with a high-volume (HV) sampler, which collects particles up to 100 μm. Depending on particle size distribution, an HV sampler may yield results that are equal to or up to several times higher than the results of a low-volume (LV) sampler. This assumption has been supported in the results of some later measurements. From April to June 1976, at the three sites mentioned earlier, suspended particulate matter was collected by high volume samplers of the type described in the PHS Publication No. 999-AP-12.

Compared to the earlier data, obtained by analysing LV samples in the same period over 3 consecutive years (1973-1975), the manganese concentrations as measured by the HV sampler were 2 to 6 times higher (Table 10). However, it is difficult to explain why the ratio of the results between HV and LV samples was highest at the measuring site most distant from the factory.

Yearly cycles of manganese concentrations show a tendency toward summer maximums, partly because of climatic characteristics of the area (more frequent calm periods in summer) and partly because of the fluctuations in the production rate (Figure 1).

Manganese concentration decreases with the distance. At a distance of 5.5 km the concentration reaches the same level as in a city 60 km away that is comparable in all other respects except for the manganese source. The concentration is even lower at the control point 25 km away from the factory, although we observed occasional fluctuations of manganese in the air similar to those near the ferroalloy plant.

Sulfur dioxide concentrations were relatively low at all sites, with irregular fluctuations over the year, but relatively higher concentrations are more likely to occur in summer. The sulfur dioxide concentrations were at the same level as in other coastal cities of similar size in this area.

However, intermittent measurements of sulfate content in airborne suspended particulates have shown that the concentration of sulfate in the air in the vicinity of the ferroalloy plant is relatively higher than in other comparable coastal cities (see Section 9).

Indoor Manganese Concentrations

The concentrations of manganese measured in the ferroalloy plant in 1974 were, in general, lower than those measured in 1972, with the exception of the casting works, where the concentrations were at about the same level in both years. The lower concentrations during the second measuring period were expected because in 1974, only one out of four furnaces was producing manganese alloys. In contrast, during the measuring period in 1972, three out of four furnaces were producing manganese alloys. Even when only one furnace was producing manganese alloy, the concentration of mangaense at certain working places exceeded the maximum allowable concentration (MAC) values of 2 mg/m^3.

In the electrode plant the concentrations of manganese in the total and respirable dust, regardless of the amount of the total dust concentration, were rather low, well under the MAC values.

Manganese in Urine

The mean concentrations of manganese in the urine of occupationally exposed workers from the manganese alloy plant were only slightly above the upper range considered normal. (1-8 μg/liter; Cholak and Hubband, 1960.) On the other hand, they did not differ from the mean concentrations of manganese in urine found in workers from the electrode plant. Mean manganese concentrations in the urine of workers from the light metal plant situated 5,500 km from the ferroalloy plant were the lowest (6.7 μg/l). However, the frequency distribution of manganese concentrations in urine (Table 7) shows that in some cases even in workers from the light metal plant, manganese in urine exceeded the values of 21 μg/l.

It is known that manganese in urine has proved rather disappointing as a means of evaluating exposure to manganese aerosols. Only a small amount of manganese intake is excreted by urine. Persons exposed to high concentrations of manganese do not necessarily show high urinary concentrations of manganese. However, a rough correlation between urine levels and average air concentrations of manganese may exist (Tanaka and Lieben, 1969). On the other hand, manganese can be absorbed not only by inhalation, but also by ingestion. So the elimination of manganese in urine reflects both means of manganese absorption. It is possible that some of the workers in the rather distant light metal plant inhale a little more manganese at their homes or absorb it from some sources by ingestion.

TABLE 1. ANNUAL MEAN AND MAXIMUM CONCENTRATIONS OF MANGANESE IN THE AMBIENT AIR ($\mu g/m^3$)

Position of site in relation to ferroalloy factory	1972		1973		1974		1975	
	$\bar{C}$	C_m	$\bar{C}$	C_m	$\bar{C}$	C_m	$\bar{C}$	C_m
Close to the factory			2.847	18.474	2.321	9.709	1.861	6.857
750 m SE	0.272	1.104	0.236	1.031	0.384	1.241	0.390	1.138
2000 m ESE	0.206	0.696	0.186	0.675	0.222	1.323	0.188	0.794
2750 m SE	0.202	0.604	0.164	0.722	0.243	1.082	0.231	1.151
5500 m SSE	0.082	0.272	0.052	0.161	0.042	0.206	0.099	0.275
25 km WNW			0.029	0.083	0.041	0.141	0.024	0.084

TABLE 2. ANNUAL MEAN AND MAXIMUM CONCENTRATIONS OF SULFUR DIOXIDE IN THE AMBIENT AIR ($\mu g/m^3$)

Position of site in relation to ferroalloy factory	1972		1973		1974		1975	
	$\bar{C}$	C_m	$\bar{C}$	C_m	$\bar{C}$	C_m	$\bar{C}$	C_m
Close to the factory			25	86	23	122	18	57
750 M SE	18	73	16	72	15	59	11	52
2000 m ESE	19	63	27	65	27	108	19	54
2750 m SE	25	119	23	75	22	70	17	84
5500 m SSE	13	47	17	64	20	82	19	145
25 km WNW			7	41	14	65	11	51

TABLE 3. FREQUENCY DISTRIBUTION OF WEEKLY MANAGEMENT CONCENTRATIONS AT THREE SITES WITHIN 0.75 TO 2.75 km FROM THE FERROMANGANESE FACTORY, 1972-1975

Site	0.75 km SE					2.0 km ESE					2.75 km SE				
Concentration Range	1972	1973	1974	1975	1972-1975	1972	1973	1974	1975	1972-1975	1972	1973	1974	1975	1972-1975
0.0-0.1	16	14	2	7	39	20	21	17	15	73	22	21	14	18	75
0.1-0.2	10	9	12	10	41	12	13	16	16	57	11	12	20	10	53
0.2-0.3	8	5	15	7	35	9	6	8	4	27	6	8	8	8	30
0.3-0.4	5	5	8	10	28	6	3	4	6	19	1	7	1	11	20
0.4-0.5	4	6	3	5	18	1	3	2	1	7	8	1	3	-	12
0.5-0.6	3	1	4	3	11	3	1	-	1	5	3	-	1	2	6
0.6-0.7	3	3	1	1	8	2	3	1	-	6	1	-	1	1	3
0.7-0.8	1	1	1	2	5			-	2	2		1	1	-	2
0.8-0.9	1		3	2	6			-		-			1	-	1
0.9-1.0	-		1	-	1			1		1			1	-	1
1.0-1.1	-		-	3	3			-		-			1	-	1
1.1-1.2	1		-	1	2			1		1				1	1
1.2-1.3			2		2			-		-					
1.3-1.4								1		1					

TABLE 4. MANGANESE CONCENTRATIONS IN INDOOR AIR AT THE FERROALLOY PLANT (MEASUREMENTS IN APRIL 1972)

Measuring site	N*	Mn concentration in mg/m^3		
		Mean	Minimum	Maximum
Stoker	20	4.933†	0.151	47.767
Charging machine driver	18	0.856	0.080	5.612
Preparation of molds	17	0.600	0.122	4.165
Casting	8	0.442	0.069	1.959
Electric car driver	13	3.991	0.267	30.030
Craneman	11	0.301	0.104	0.584
Elevator operator	5	16.347	0.336	216.320
Electric furnace controller	6	2.025	0.103	16.417
Silo operator	2	1.056	0.356	1.569
Cleaner	2	1.897	0.539	4.368
Furnace foreman	2	0.391	0.144	0.722
Sinter transport	1	0.421	0.421	0.421
Raw material mixer	1	20.442	5.076	41.250
Belt-conveyer	1	9.480	6.660	12.183
Silo stoker	1	0.469	0.469	0.469
Sinter mixer	1	11.062	5.647	17.409
Cyclone	1	2.386	1.537	3.223
Sintering pan operator	5	3.004	1.710	5.774

*N - number of samples per work place; at the time of measurements three out of four furnaces producing manganese alloys were in operation.

†Underlined results represent values exceeding maximum allowable concentrations (2 mg/m^3).

TABLE 5. MANGANESE, COBALT, CHROMIUM, AND NICKEL CONCENTRATIONS IN TOTAL AND RESPIRABLE DUST IN INDOOR AIR AT THE ELECTRODE PLANT (MEASUREMENTS IN APRIL 1972)

Measuring site	Total dust in mg/m^3	Total dust in mg/m^3				Respirable dust in mg/m^3				%*			
		Mn	Co	Cr	Ni	Mn	Co	Cr	Ni	Mn	Co	Cr	Ni
Mass preparation	62.830	0.302	0.001	0	0	0.005	0	0	0	1.66	0	0	0
Electrode graphitizing	20.415	0.002	0	0	0	0.002	0	0	0	100.00	0	0	9
Electrode burning	42.960	0.125	0.002	0.028	0.003	0.004	0.001	0.001	0.001	3.20	50.00	3.57	33.33
Mechanical electrode processing	190.321	0.016	0.001	0.004	0.002	0.003	0	0.001	0	18.75	0	25.00	0
Pressing	46.925	0.025	0	0.029	0.001								
Ball mills	93.385	0.042	0.001	0.044	0.001	0.004	0.001	0.008	0	9.52	100.00	18.18	0
Furnace	34.622	0.033	0.002	0.061	0.002	0.002	0.001	0.004	0.001	6.06	50.00	6.56	50.00

*% Mn, Co, Cr, and Ni in respirable dust in relation to Mn, Co, Cr, and Ni in total dust.

TABLE 6. MANGANESE CONCENTRATIONS IN INDOOR AIR AT THE FERROALLOY PLANT (MEASUREMENTS IN JULY 1974)*

Measuring site	Concentration mg/m³			
	N[†]	Mean	Minimum	Maximum
Stoker	6	0.634	0.143	1.010
Charging machine driver	11	0.280	0.079	1.645
Preparation of molds	12	0.404	0.067	1.536
Casting	18	0.373	0.091	1.521
Electric car driver	7	0.708	0.163	2.188[#]
Craneman	1	0.147	0.147	0.147
Elevator operator	2	1.099	1.081	1.117
Electric furnace controller	1	0.707	0.707	0.707
Conveyer and mixer operator	11	1.251	0.216	2.994
Sintering pan operator	4	1.753	0.191	4.377
Crusher Si-Mn (waste and slag)	4	1.737	0.535	1.025
Preparation of raw material	6	0.205	0.140	0.310
Furnace II electrode cleaning	1	3.504[§]	3.504[§]	3.504[§]
Cleaner	2	6.069	0.407	11.732

*At the time of measurements only one out of four furances producing manganese alloys was in operation.

[†]N - number of samples per work place.

[#]Results exceeding MAC values (2 mg/m³) are underlined.

[§]Stationary sample (workers did not wear pumps because of difficulties in cleaning).

TABLE 7. MANGANESE CONCENTRATIONS IN TOTAL AND RESPIRABLE DUST IN AIR AT THE ELECTRODE PLANT (MEASUREMENTS IN JULY 1974)

Measuring site	Concentration mg/m^3			%*
	Total dust	Manganese in total dust	Manganese in respirable dust	
Chamber furnace	3.9	0.010	0.002	20.0
Electrode graphitizing	14.6	0.008	0.003	37.5
Mass preparation	36.0	0.005	0.004	80.0
Mechanical electrode processing	52.1	0.014	0.003	21.4
Electrode burning	30.5	0.043	0.007	16.3
Ball mills	463.0	0.009	0.007	77.8

*% - manganese in respirable dust vs manganese in total dust.

TABLE 8. FREQUENCY DISTRIBUTION OF MANGANESE CONCENTRATIONS IN URINE (SAMPLES FROM APRIL-MAY 1972)

	N*	Concentration of manganese in urine μg/1					
		0-5	6-10	11-15	16-20	21-25	26-
Production of manganese alloys	37	7	17	7	2	2	2
Electrode production	11	3	2	4	1	-	1
Light metal plant	24	13	7	-	-	3	1

*N - number of workers (samples).

TABLE 9. ARITHMETIC MEANS AND STANDARD DEVIATIONS OF MANGANESE CONCENTRATIONS IN URINE (SAMPLES FROM APRIL-MAY 1972)

	N*	Concentration of manganese in urine µg/1	
		$\overline{X}$	SD
a)[†] Production of manganese alloys	37	11.5	10.2
b) Electrode production	11	12.4	8.0
c) Light metal plant	24	6.7	6.7

*N - number of workers (samples).

[†]a-c $P<0.05$

b-c $P<0.05$

TABLE 10. COMPARISON OF MANGANESE CONCENTRATIONS IN HIGH-VOLUME (HV) AND LOW-VOLUME (LV) SAMPLES

Period April-June	Type of sampler	Average manganese concentrations $\mu g/m^3$		
		Position of site in relation to the ferroalloy plant		
		Close to the factory	750 m SE	2750 m SE
1973	LV	3.30	0.38	0.24
1974	LV	3.81	0.26	0.16
1975	LV	3.42	0.47	0.11
1976	HV	7.80	1.20	1.00

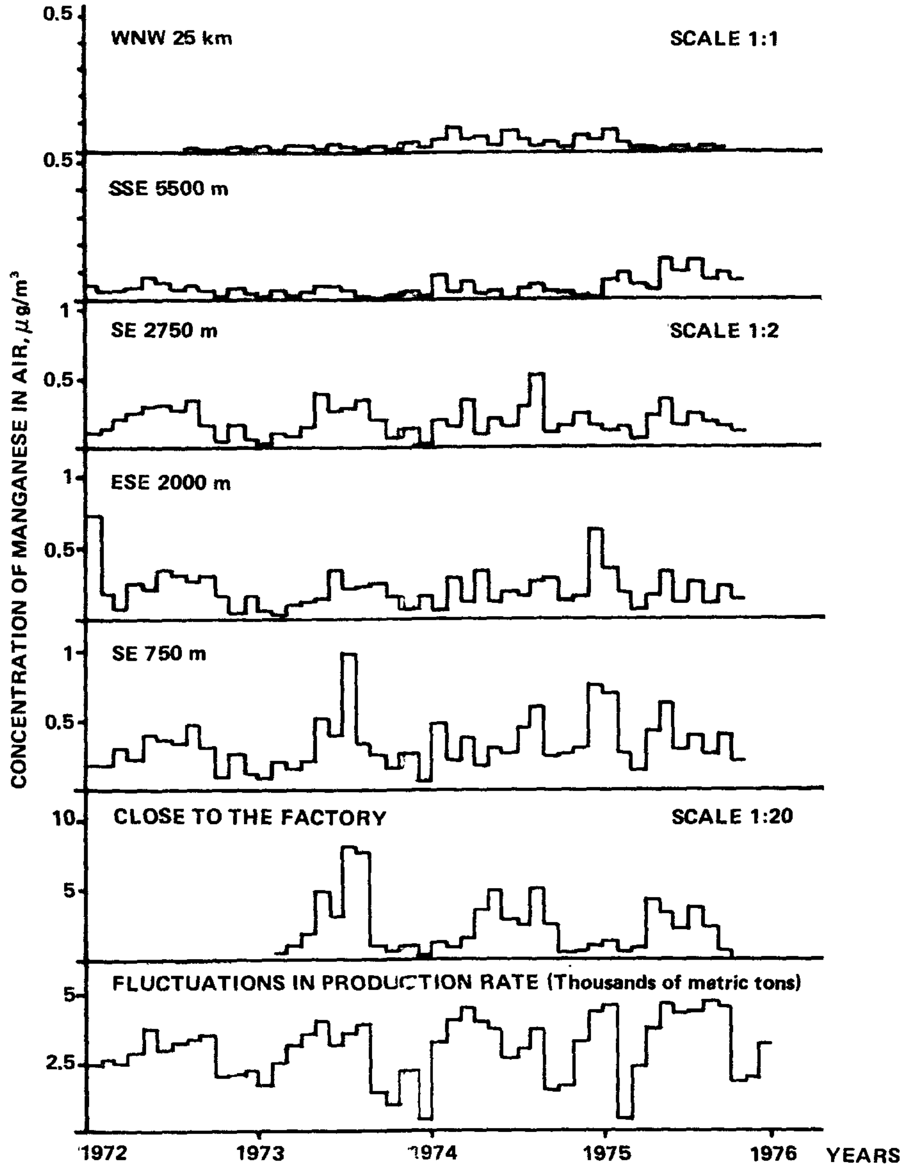

Figure 1. Yearly cycles of monthly mean manganese concentrations in the ambient air at six measuring sites compared with monthly production rate of ferroalloys for 1972 - 1975.

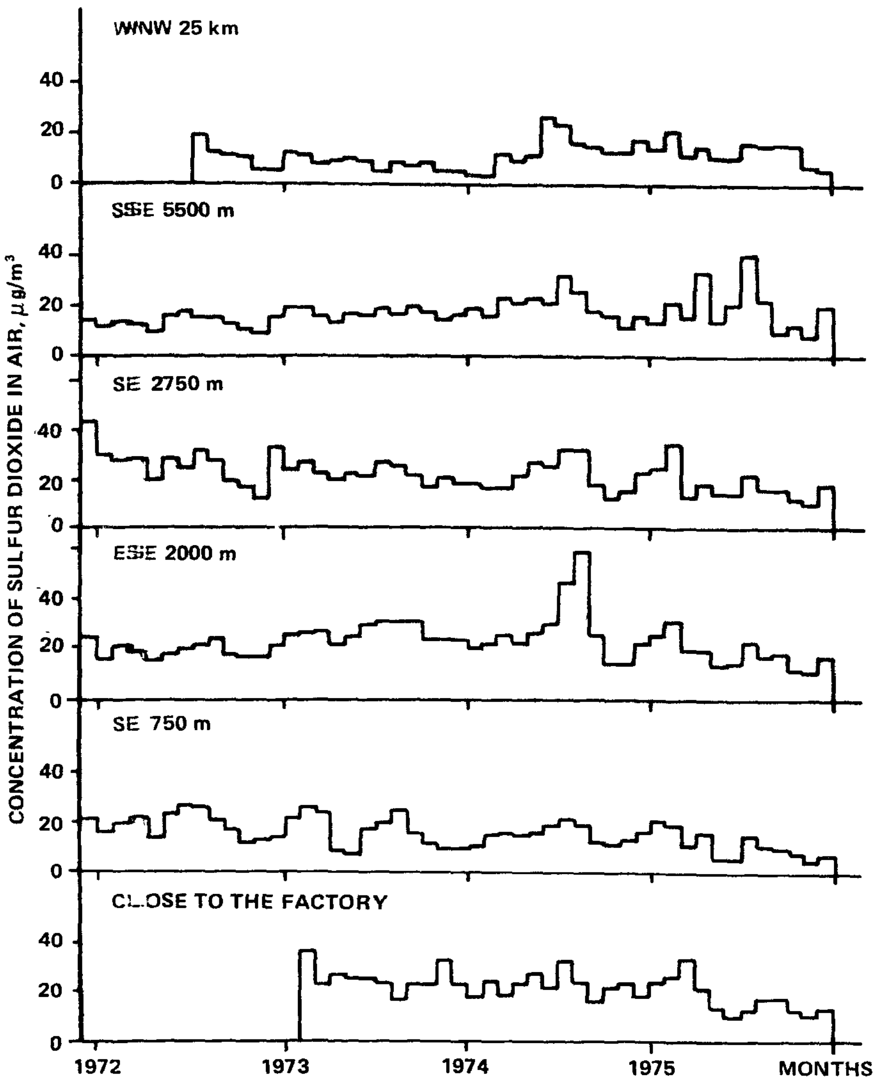

Figure 2. Yearly cycles of monthly mean sulphur dioxide concentrations in the ambient air at six measuring sites for 1972 - 1975.

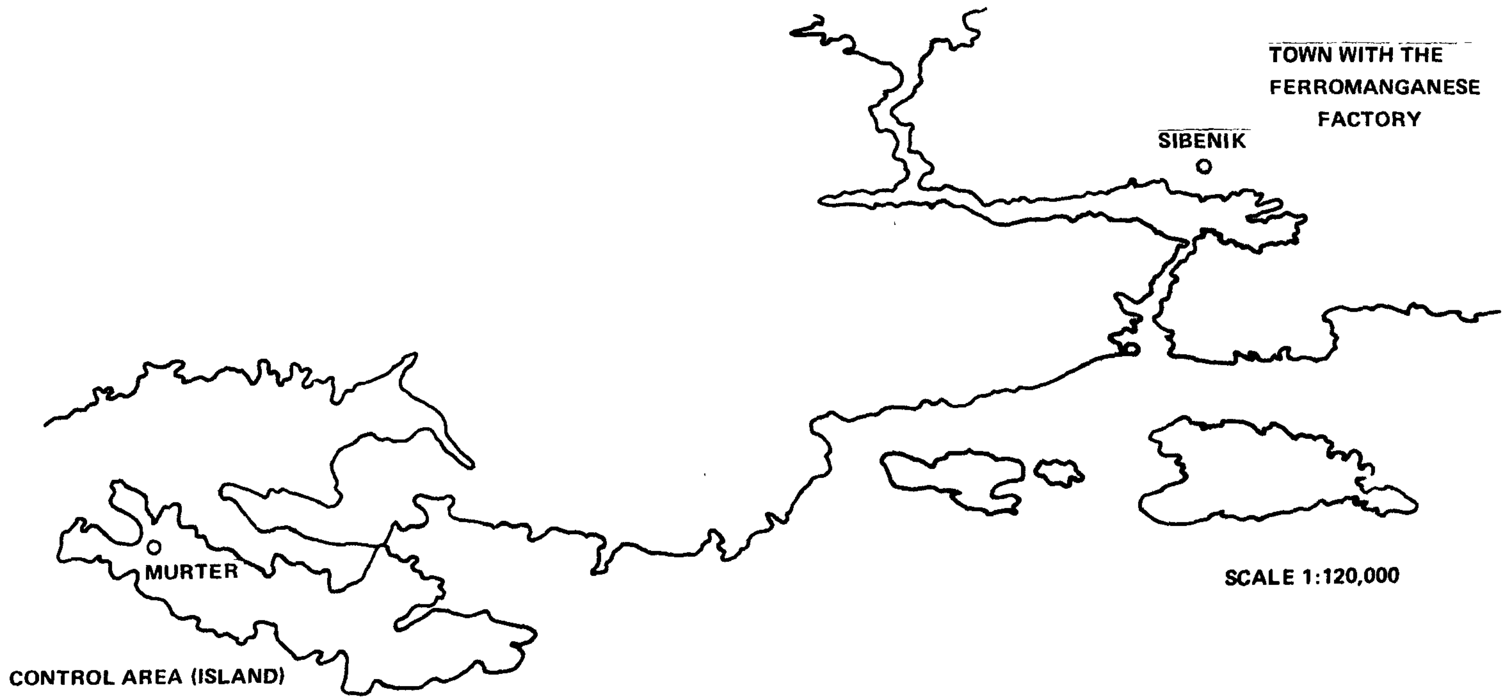

Figure 3. The map of the area under study.

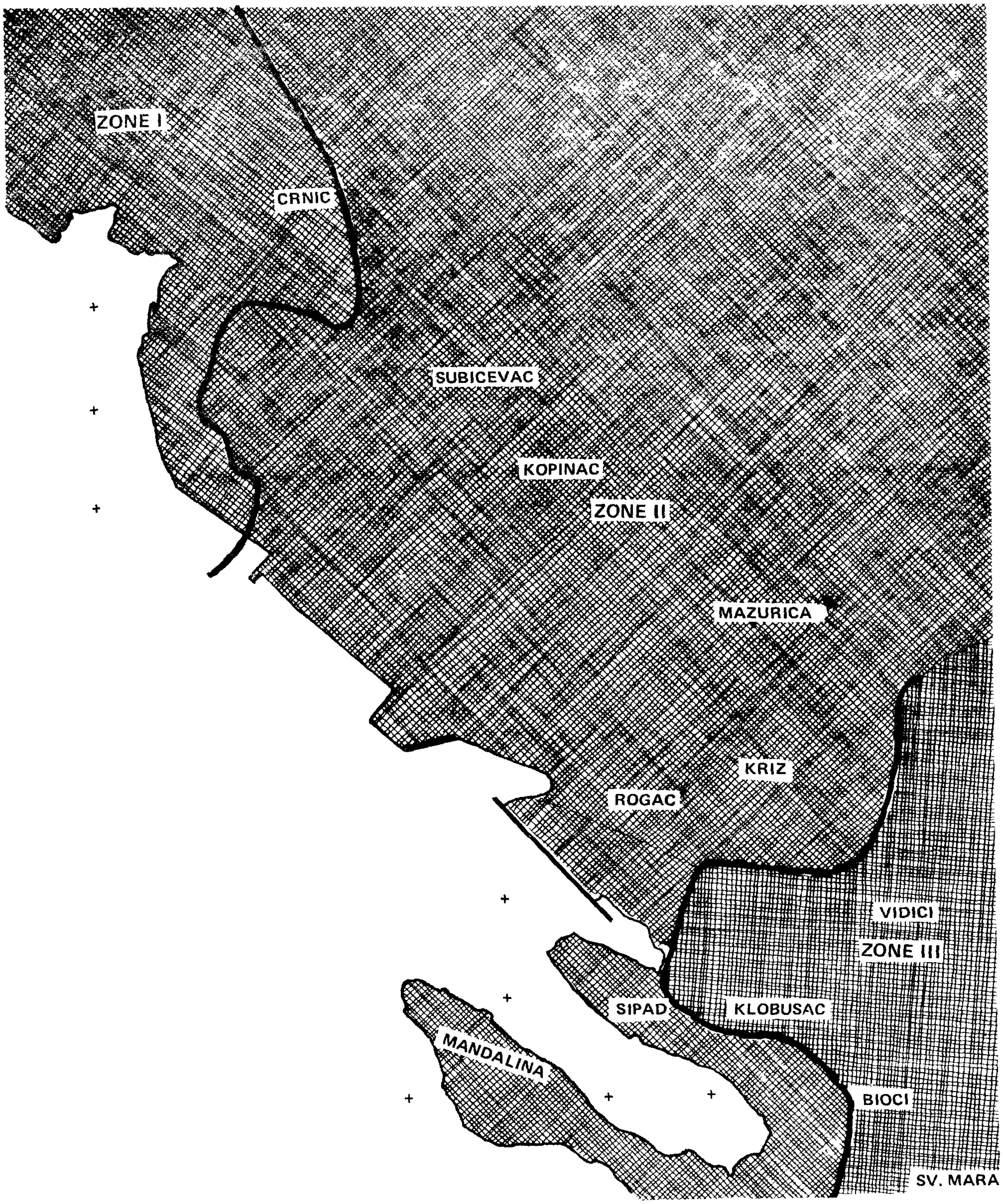

Figure 4. Zoning of the town area according to the measured concentrations of manganese in the air.

SECTION 5

WORK ABSENTEEISM CAUSED BY PNEUMONIA AND BRONCHITIS

MATERIAL AND METHODS

The data were taken from the workers' medical files in the factory producing manganese alloys and electrodes, first for the 1959-1971 period and then for the 1972-1975 period. Workers from an aluminum processing factory which is situated about 5 km away served as controls. Both factories have a health unit with a physician who monitors the health of the employees.

In the factory of manganese alloys and electrodes, the workers were divided into two groups: (a) those employed in the production of manganese alloys and (b) those employed in the production of electrodes, in workshops, or in other places without a direct occupational exposure to manganese. In both factories only male workers and only those who were employed in the factories during the whole period of analysis were subject to observation.

For the first study (1959-1971) sinter workers as well as the workers from maintenance workshops and all other services were grouped under the heading "Production of electrodes and other." For the second study (1972-1975) sinter workers were excluded from the group "Production of electrodes and other" and included in the group labeled "Production of manganese alloys." From the group "Production of electrodes and other" were also excluded those from other services. So, for the second study this particular group consisted of workers from the production of electrodes and from the maintenance workshops.

At the beginning of 1974 a new plant for the electrolytic extraction of aluminum began operation with 303 workers in the light metal factory.

The cumulative incidence of analyzed diseases was calculated for the first study by the number of workers in September 1971, and for the second study, by the number of workers in September 1975.

RESULTS OF THE STUDY FOR THE 1959-1971 PERIOD

The number of male workers in direct production in the compared groups is shown in Table 11. The cumulative number of workers with diagnosed pneumonia and bronchitis for the period 1959-1971 is presented in Table 12. Tables 13 and 14 show the number of absences due to pneumonia and bronchitis for the same period by years. Tables 15 and 16 show the number of cases of pneumonia and of acute and not specifically defined bronchitis, respectively, per ill worker during the 1959-1971 period.

RESULTS OF THE STUDY FOR THE 1972-1975 PERIOD

The number of workers in the compared groups for this study is shown in Table 17. The results of the retrospective analysis of work absenteeism due to pneumonia and bronchitis for the period 1972-1975 are shown in Tables 18-22.

DISCUSSION

From the presented data it appears that the rate of pneumonia and bronchitis in the first study (1959-1971) was highest in workers directly employed in the production of manganese alloys. The other two compared groups differed little in this respect, except in the case of bronchitis--acute and not specifically defined--which had a higher rate in workers from the production of electrodes than in workers from the light metal plant.

The second study (1972-1975) is not completely comparable with the first one because of the previously-described differences in the composition of the compared groups. However, the rate of pneumonia again showed a tendency to be highest in the production of manganese alloys. But the differences were not statistically significant. The number of those with bronchitis--acute and not specifically defined--remained slightly higher among manganese alloy workers compared with those engaged in the production of electrodes (Table 18). The accumulated incidence of bronchitis became highest in workers from the light metal plant. Table 20 shows that the rate of absenteeism due to this disease began to increase in that factory in 1974 and was particularly pronounced in 1975. This increase coincides with the opening of a new production, electrolytic extraction of aluminum, within the light metal plant at the beginning of 1974.

The process of electrolytic extraction of aluminum involves the exposure to fluorine and sulfur dioxide. The anlaysis of data collected in the light metal plant showed that a considerable number of sick leaves due to bronchitis, particularly acute bronchitis, relates to workers employed in the electrolytic extraction of aluminum. In 1975, 43 out of 97 sick leaves due to acute and not specifically defined bronchitis were taken by workers in the electrolytic extraction of aluminum. So it seems that the new production directly influenced the rate of bronchitis in workers from the light metal plant, particularly in 1975.

From the results of the retrospective analysis, it is assumed that the differences in the incidence of absenteeism caused by respiratory diseases are not due to the differences in socio-econommic conditions. Although medical documentation on which the retrospective analysis was based did not contain information about smoking habits, from the data collected in the course of subsequent epidemiological study presented in Table 27, Section 6, it is assumed that there were no significant differences between the compared groups with regard to smoking habits.

Medical records from which data about sick leave caused by respiratory diseases were taken were kept in the same manner in both compared plants. In each plant an industrial physician was in complete charge of workers' health, including the provision of necessary treatment. All diseases, particularly those which caused absences from work were, therefore, recorded in the worker's file, even in the case of workers who became ill at home and were granted sick leave by general practitioners. Naturally, the question as to what extent the criteria of industrial physicians in granting sick leaves were uniform remains open. This question is pertinent mainly to the cases of bronchitis.

As mentioned earlier, the analysis was based on cumulative data about absences from work due to respiratory diseases for only those workers who were continuously employed during the entire observation period. Because a number of workers left the plant during the observation period, a question arises, as to whether a selection took place which might have influenced the rate of analyzed diseases. To check this, we analyzed for 1972-1975, the rate of absences because of the same diseases in workers who had left the plants. The pattern of absences in these workers was lower than that in workers from the study. For pneumonia the cumulative rate was 0.8 in the ferroalloy plant, 1.1 in the electrode plant, and 0.7 in the light metal plant. For bronchitis the cumulative rate was 8.9 in the ferroalloy, 9.4 in the electrode, and 16.3 in the light metal plant.

The lower cumulative rates of absences due to pneumonia and bronchitis in workers who left the plant than in those continuously employed is obviously the result of the fact that the observation period for workers who left the plant was shorter: 1.4 years in the ferroalloy plant, 2 years in the electrode plant, and 1.5 years in the light metal plant. It appears accordingly that the rates of absences due to analyzed diseases in workers who left the plant were similar to the rates recorded in workers who were included in the study. The higher rate of absences due to bronchitis in workers who left the light metal plant relates mainly to those who were employed in the electrolytic extraction of aluminum. Some of these left the plant because of the workers' increased susceptibility to exposure at their working places.

TABLE 11. NUMBER OF WORKERS IN COMPARED GROUPS (1971 DATA)

Years of work	Production of manganese alloys	Production of electrodes and other*	Light metal plant
<5 years	87	243	283
6-10 years	52	148	229
11-15 years	74	187	389
16-20 years	55	202	287
>20 years	61	132	3
Total	329	912	1191

*100 sinter workers are included as well as those working in maintenance workshops and other services.

TABLE 12. NUMBER OF WORKERS WITH PNEUMONIA AND BRONCHITIS DURING 1959-1971

Disease	No. of ill workers			
	1. Production of manganese alloys	2. Production of electrodes and other	3. Light metal plant	Significance of difference
Pneumonia	60 (18.2)*	97 (10.6)	119 (10.0)	1-2 $P<0.01$ 1-3 $P<0.01$
Bronchitis--acute and not specifically defined	117 (35.6)	271 (29.7)	291 (24.4)	1-3 $P<0.01$ 2-3 $P<0.01$
Bronchitis--chronic	79 (24.0)	145 (15.9)	213 (17.9)	1-2 $P<0.01$ 1-3 $P<0.05$

*The numbers in parentheses are percentages of the total number of workers in each group.

TABLE 13. NUMBER OF ABSENCES DUE TO PNEUMONIA BY YEARS (1959 to 1971)

Year	No. of absences due to pneumonia*		
	1. Production of manganese alloys	2. Production of electrodes and other	3. Light metal plant
1959	4	8	19
1960	6	5	15
1961	2	10	8
1962	6	10	2
1963	3	13	11
1964	6	11	5
1965	12	16	13
1966	5	10	17
1967	9	9	9
1968	7	15	9
1969	4	7	12
1970	9	13	10
1971	8	8	17
Total	81 (24.6)[†]	135 (14.8)	147 (12.3)

*Significance of difference: 1-2 $P<0.01$; 1-3 $P<0.01$

[†] Numbers in parentheses denote the accumulated rate of sick leaves due to pneumonia per 100 workers from 1959 to 1971.

TABLE 14. NUMBER OF ABSENCES DUE TO ALL FORMS OF BRONCHITIS BY YEARS (1959 to 1971)

Year	No. of absences due to bronchitis (all forms)*		
	1. Production of manganese alloys	2. Production of electrodes and other	3. Light metal plant
1959	5	25	79
1960	11	23	87
1961	11	27	64
1962	20	39	54
1963	22	45	72
1964	19	49	64
1965	33	59	52
1966	30	56	53
1967	34	72	59
1968	69	112	81
1969	57	107	90
1970	53	95	94
1971	57	103	77
Total	421 (128.0)†	812 (89.0)	926 (77.7)

*Significance of difference: 1-2 $P<0.01$; 1-3 $P<0.01$; 2-3 $P<0.01$

†Numbers in parentheses denote the accumulated rate of sick leaves due to bronchitis (all forms) per 100 workers from 1959 to 1971.

TABLE 15. NUMBER OF PNEUMONIA ATTACKS PER ILL WORKER DURING 1959-1971

No. of illnesses per ill worker	1. Production of manganese alloys	2. Production of electrodes and other	3. Light metal plant	Significance of difference
1	46 (76.7)*	70 (72.2)	98 (82.4)	NS
2	9 (15.0)	19 (19.6)	16 (13.4)	NS
3 or more	5 (8.3)	8 (8.2)	5 (4.2)	NS
Total No. of ill persons	60	97	119	

*Numbers in parentheses denote percents of the total number of ill persons with one or more attacks of pneumonia.

TABLE 16. NUMBER OF ACUTE AND NOT SPECIFICALLY DEFINED BRONCHITIS PER ILL WORKER DURING 1959-1971

No. of illnesses per ill worker	1. Production of manganese alloys	2. Production of electrodes and other	3. Light metal plant	Significance of difference
1	58 (49.6)*	145 (53.5)	150 (51.5)	NS
2	29 (24.8)	77 (28.4)	86 (29.6)	NS
3 or more	30 (25.6)	49 (18.1)	55 (18.9)	NS
Total No. of ill persons	117	271	291	

*Numbers in parentheses denote percents of the total number of ill persons with one or more attacks of bronchitis.

TABLE 17. NUMBER OF MALE WORKERS FROM DIRECT PRODUCTION IN THE COMPARED GROUPS (SEPTEMBER 1975)

Years of work	Production of manganese alloys*	Production of electrode and maintenance	Light metal plant†
< 5	95	143	
6-10	80	83	
11-15	70	99	
16-20	88	85	
>20	106	165	
Total	439	575	1265

*90 Sinter workers are included

†Data about years of work were not included; 303 workers out of 1265 have been employed since 1974 in the electrolytic extraction of aluminium.

TABLE 18. NUMBER OF WORKERS WITH PNEUMONIA AND BRONCHITIS DURING 1972-1975

Disease	No. of ill workers			Significance of difference
	1. Production of manganese alloys	2. Production of electrodes and other	3. Light metal plant	
Pneumonia	16 (3.6)*	11 (1.9)	30 (2.4)	NS
Bronchitis-acute not specifically defined	37 (8.4)	39 (6.8)	190 (15.0)	3-1 P<0.01 3-2 P<0.01
Bronchitis chronic	42 (9.6)	57 (9.9)	75 (5.9)	1-3 P<0.01 2-3 P<0.01

*The numbers in parentheses are percentages of the total number of workers in each group.

TABLE 19. NUMBER OF ABSENCES DUE TO PNEUMONIA BY YEARS (1972 TO 1975)

Year	No. of absences due to pneumonia		
	1. Production of manganese alloys	2. Production of electrodes and others	3. Light metal plant
1972	3	5	6
1973	9	-	6
1974	3	4	10
1975	2	3	10
Total	17 (3.8)*	12 (2.1)	32 (2.5)

*Numbers in parentheses denote the accumulated rate of sick leaves due to pneumonia per 100 workers from 1972 to 1975.

TABLE 20. NUMBER OF ABSENCES DUE TO ALL FORMS OF BRONCHITIS BY YEARS (1972 TO 1975)

Year	No. of absences due to bronchitis (all forms)		
	1. Production of manganese alloys	2. Production of electrodes and others	3. Light metal plant
1972	30	29	52
1973	37	59	59
1974	30	45	124
1975	32	44	193
Total	129 (29.4)*	177 (30.8)	428 (33.8)

*Numbers in parentheses denote the accumulated rate of sick leaves due to all forms of bronchitis per 100 workers from 1972 to 1975.

TABLE 21. NUMBER OF PNEUMONIA ATTACKS PER ILL WORKER DURING 1972-1975

No. of illnesses per ill worker	1. Production of manganese alloys	2. Production of electrodes and other	3. Light metal plant	Significance of difference
1	15 (93.8)*	10 (90.9)	28 (93.3)	NS
2	1 (6.2)	1 (9.1)	2 (6.7)	NS
3 or more	-	-	-	-
Total No. of ill persons	16	11	30	

*Numbers in parentheses denote percents of the total number of ill persons with one or more attacks of pneumonia.

TABLE 22. NUMBER OF ACUTE AND NOT SPECIFICALLY DEFINED BRONCHITIS PER ILL WORKER DURING 1972-1975

No. of illnesses per ill worker	1. Production of manganese alloys	2. Production of electrodes and other	3. Light metal plant	Significance of difference
1	31 (83.8)*	34 (87.2)	164 (86.3)	NS
2	6 (16.2)	3 (7.7)	19 (10.0)	NS
3 or more	-	2 (5.1)	7 (3.7)	NS
Total No. of ill persons	37	39	190	

*Numbers in parentheses denote percents of the total number of ill persons with one or more attacks of bronchitis.

SECTION 6

EPIDEMIOLOGICAL SURVEY OF CERTAIN EFFECTS OF OCCUPATIONAL EXPOSURE TO MANGANESE

MATERIALS AND METHODS

The study was carried out in a group of 369 workers employed in the production of manganese alloys, in a group of 190 workers engaged in electrode production, and in a group of 204 workers from the aluminum rolling mill (light metal plant). Therefore, the study was conducted in the same factories as the retrospective study described in the previous section.

The examination was performed with the standard epidemiological technique. The study used the questionnaire on respiratory symptoms of the Committee on the Etiology of Chronic Bronchitis of the British Medical Research Council (1965) supplemented with questions relating to symptoms of manganism; forced expiratory volumes were measured, consistency and volume of the early morning sputum were determined, clinical and radiographical examinations of the lungs were performed as well as the conduct of a neurological examination. Arterial blood pressure measurements were also taken.

The workers were divided into the following smoking habit categories:

1. nonsmokers who never smoked or smoked not more than one cigarette a day,
2. past smokers who had smoked more than one cigarette a day but had stopped smoking at least one month prior to examination, and
3. present smokers divided into three groups according to the number of of cigarettes smoked in their lifetime using the criteria employed by Brinkman and Coates (1963):
    a) light smokers if the product of the average number of cigarettes smoked per day and the number of years of smoking was less than 200,
    b) moderate smokers if the product was between 200 and 600, and
    c) heavy smokers if the product was higher than 600.

In connection with the study of chronic nonspecific lung disease in exposure to manganese, reasons for disability retirement of workers in the manganese alloy and electrode plants were also analyzed for a 5-year period and compared to those from the light metal plant and to the total working population of the town area.

RESULTS AND DISCUSSION

Tables 23 and 24 show the general characteristics and smoking habit of workers in the study.

Chronic Nonspecific Lung Disease in Manganese Exposure

Table 25 shows the prevalence of phlegm part-day in compared groups of workers categorized by smoking habit. Phlegm part-day is defined as expectoration in the morning or during the day on most days for as much as three winter months each year.

The prevalence of regular wheezing in the chest is given in Table 26.

Table 27 shows the prevalence of chronic bronchitis. A person was considered to have the disease if phlegm production was present in the morning and during the day and/or night for at least three winter months than had been present during the past two years.

Table 28 shows the values of forced expiratory volumes in compared groups of workers. The obtained values of forced expiratory volumes are expressed as percentage of the values expected with regard to age and height of subjects (Morris et al., 1971).

Table 29 shows the values of forced expiratory volumes, expressed in the same way as in the previous table, for workers in manganese alloy production categorized by the duration of exposure and smoking habit.

The prevalence of symptoms of chronic bronchitis in combination with certain objective findings according to smoking habits is shown in Table 30.

The rate of disability retirement over the 5-year period 1968-1972, in the manganese alloy and electrode plants as well as in the town area is presented in Table 31.

As shown in the tables, the prevalence of respiratory symptoms was higher among those engaged in the production of manganese alloys compared with two other groups of workers. However, the differences were not statistically significant.

A more detailed analysis of data shows that the compared groups of nonsmoking workers did not significantly differ with regard to the prevalence of respiratory symptoms. In previous smokers the differences were also negligible.

Among smokers, the rate of respiratory symptoms was higher in the manganese alloy production than in the electrode production, while in the aluminum rolling mill it was usually lowest. The prevalence had a tendency to increase with categories of smokers (light, moderate, heavy). The tendency of the rate of symptoms to rise with the extent of the smoking habit was most pronounced in the group of workers in the production of manganese alloys.

As far as a combination of the symptoms of chronic bronchitis and certain objective findings is concerned, it is also interesting that differences between compared groups with regard to exposure were again more pronounced in smokers, the syndromes being more frequent in smokers from the ferroalloy group than from the other two groups of workers. Because of relatively low rates, it has not been possible to elaborate the differences in the prevalence of these syndromes statistically or to analyze them from the point of view of smoking categories. Since other relevant factors under control in compared groups of workers were more or less uniform, the results may even indicate a synergistic action of manganese exposure and smoking habits in the occurrence and rate of respiratory symptoms.

The analysis of forced expiratory volumes expressed as the mean percentage of the predicted values did not show any difference between the manganese alloy workers and two other compared groups. In all three groups of workers, the values of forced expiratory volumes were within the normal range. Analyzed by the length of exposure to manganese (in the manganese alloy group) the forced expiratory volumes appeared to be relatively lower (compared with the predicted values) in those exposed over 10 years. However, the difference was statistically significant only for $FEV_{1.0}$ values in nonsmokers.

In the interpretation of these results, a "normal" fall in ventilatory volumes with time has to be taken into consideration. As the duration of exposure is usually paralleled by age, an age factor might be also involved in the observed fall of the forced expiratory volumes. On the other hand, it is posisble that a certain number of workers who had developed respiratory impairment had left the factory and obtained a disability pension. As they were not included in the study, the obtained ventilatory indices may be partly biased showing better results than if those workers had also been examined.

The presented analysis of the rate of disability retirement demonstrates that the rate of retirement due to chronic nonspecific lung disease was significantly higher in the manganese alloy (and electrode) plant than in the light metal plant and in the overall working population in the town area. This finding speaks in favor of the assumption that the exposure to manganese may be a factor of importance in the development and occurrence of chronic respiratory impairment.

Neurological Disturbances and Manganese Exposure

The prevalence of recorded subjective symptoms in the compared groups is shown in Table 32. The groups did not greatly differ in the rate of symptoms. In the "ferroalloy" group there were significantly more workers in "bad moods" than in the two other groups. On the other hand, in the group with the lowest exposure to manganese, those with the symptoms of sleepiness, irritability, fatigue, tremor, tiredness, and stiffness in legs were also numerous--the prevalence of these symptoms was similar to that of the "ferroalloy" group. In the "electrode" group the rate of symptoms was lowest.

Tables 33-35 show the prevalence of some of the symptoms according to the degree of exposure to manganese and smoking habit. Moderate and heavy smokers in the "ferroalloy" group had a significantly higher rate of "fatigue" and "irritability" than light smokers. Symptoms of cramps in arms and legs were significantly more frequent in moderate and heavy smokers than in light smokers and in nonsmokers. In the "electrode" group the symptoms were almost equally frequent in nonsmokers and in smokers with the exception of "fatigue" which was more frequent in nonsmokers than in light smokers. In the group from the aluminum rolling mill, there was no statistical difference in the prevalence of symptoms by smoking habits with only one exception: a "bad mood" was more frequent not only in moderate and heavy smokers than in light smokers, but also more frequent in nonsmokers than in light smokers.

If moderate and heavy smokers in all the three groups of workers (ferroalloy plant, electrode plant, aluminum rolling mill) are compared, it appears that the rate of fatigue and cramps in arms and legs was significantly higher in the "ferroalloy" group than in the "electrode" group ($P<0.01$). "Bad mood" was more frequent in moderate and heavy smokers from the "ferroalloy" group than in those from the aluminum rolling mill ($P<0.05$). Light smokers from the "ferroalloy" group had a higher rate of "fatigue" than light smokers from the "electrode" group ($P<0.05$).

Table 36 shows the prevalence of neurological findings in the compared groups of workers. Such signs were recorded only in the group of workers from the productions of manganese alloys and electrodes. They were more frequent in the "manganese alloy" group. No regularity was observed with regard to smoking habit.

Table 37 shows the rate of neurological findings in the "manganese alloy" group in relation to the level of manganese exposure. The rate of neurological signs seems to be higher in the most exposed group, but the difference was not statistically significant. On the other hand, in the least exposed group the number of neurological signs was also rather numerous.

Epidemiological and clinical studies showed three phases in the development of manganism: a subclinical stage with a general vague symptomatology; the initial period in which the psychic or neurological symptoms are predominantly acute psychomotor disturbances, dysarthria, disturbances of the gait, and sialorrhea; and the fully developed stage which can be associated with the acute manic or depressive psychosis but is most often linked with a picture of parkinsonism with neurological disorders (Ansola et al., 1944).

The results of the study do not indicate any advanced forms of disease in the production of manganese alloys. However, a certain number of neurological findings which might be connected with manganese effects were recorded. Sixty-two workers out of 369 or 16.8 percent had some neurological signs. In most cases the sign was tremor (47 workers). Tremor which usually appears during rest and increases with movement is frequently observed, particularly in the tongue, arms, and legs (Penalver, 1955). In the group of workers occupationally exposed to manganese, neurological signs were more frequent than in those employed in the adjoining electrode plant who were not occupationally exposed to manganese. The difference concerned the number of pathological reflexes, which in the electrode group were found only in one worker, as well as the combination of neurological signs (pathological reflexes or cogwheel phenomenon and tremor at rest). The finding of the tremor at rest was also statistically significant more frequently in occupationally exposed workers.

In one worker from the "manganese alloy" group, a subsequent detailed clinical examination showed a picture of manganism (initial period with extrapyramidal symptoms). This worker was exposed to manganese concentrations estimated to be about 5-16 mg/m^3 for over 20 years.

The analysis according to level of exposure of other workers with some neurological signs did not show a good correlation between the measured mean manganese concentrations at working places and the rate of the disorders. This might be due partly to the fact that the concentrations of manganese in the air to which the workers were exposed were not always the same. Some of the workers changed their working places from time to time, which again may have influenced the exposure level. On the other hand, it is known that there are marked differences in individual susceptibility to manganese. Only a small percentage of those who are exposed to manganese dusts develop symptoms and signs of chronic manganese poisoning. This finding may be due to variations in the excretory capacity of the liver and kidney which may lead to accumulation of toxic levels of manganese in some and not in others (Rodier, 1955).

Horiguchi and collaborators (1974) reported the presence of disturbances of the central nervous system in four refinery workers. Fifteen others out of 79 workers who were exposed to manganese concentrations of 1.9-21.1 mg/m^3 were suspected of having some neurological signs. In the group which was exposed to manganese concentrations of 3.1 to 8.1 mg/m^3, 7 workers out of a total of 55 were suspected of having some neurological findings.

The recorded subjective symptoms are not specific. They were found in a relatively high percentage of workers, even in the control group which had a minimal exposure to manganese. However, in the ferroalloy group some of the recorded subjective symptoms which might be the symptoms of the subclinical phase of manganism were more frequent in moderate and heavy smokers than in light smokers or in nonsmokers. Smokers from the ferroalloy production showed some of the subjective symptoms more often than the smokers from the other two groups.

Exposure to Manganese and Arterial Blood Pressure

Tables 38 and 39 show the mean values of systolic and diastolic blood pressure by age in the examined group of workers. The mean values of systolic and diastolic blood pressure, not including hypertonics, are shown in Table 40. The results show that there is an association between exposure to manganese and lower values of systolic blood pressure. The lowest mean values of systolic blood pressure were found in workers with occupationally exposure to manganese, although this group was comparatively the oldest. These findings point to a possibility that the airborne manganese in the working environment acts by reducing the systolic pressure values. The mean values of diastolic blood pressure did not follow those of systolic pressure. The lowest mean diastolic pressure values were found in workers from the light metal plant, i.e., those with the lowest manganese exposure.

There are very few data available on the effect of manganese on blood pressure after the first observations of Kobert, dated as early as 1883, that some manganese salts can induce a fall in blood pressure. Schroeder and collaborators (1955) showed that manganese and chelating agents may inactivate pherentasine, which is a factor instrumental in hypertension. In humans intoxicated by or exposed to manganese, no such changes have been reported.

The differences found in our study in the behavior of systolic and diastolic blood pressures in the group occupationally exposed to manganese may indicate an action of manganese ions on the myocardium. This remains, of course, just an hypothesis. However, there is a recent experimental study by Kamiyama and Saeki (1974) on myocardial action potentials in the canine ventricle and effects of manganese ions which indicates that Mn^{++} decreases the contractile tension of the muscle.

TABLE 23. GENERAL CHARACTERISTICS OF COMPARED WORKERS

		Age (years)		Height (cm)		Weight (kg)	
	No.	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
1. Manganese production	369	37.8	8.8	173.3	6.6	76.6	10.4
2. Electrode production	190	35.8	9.4	172.8	7.1	75.2	11.3
3. Aluminum rolling mill	204	36.8	8.7	173.6	6.3	75.2	10.4

Age: 1-2 $P<0.01$

TABLE 24. DISTRIBUTION OF COMPARED WORKERS ACCORDING TO SMOKING HABITS

	Manganese alloy production		Electrode production		Aluminum rolling mill	
	No.	%	No.	%	No.	%
1. Nonsmokers	169	45.8	102	53.7	81	39.7
2. Past smokers	57	15.4	19	10.0	29	14.2
3. Light smokers	51	13.8	35	18.4	41	20.1
4. Moderate smokers	73	19.8	25	13.2	42	20.6
5. Heavy smokers	19	5.1	9	4.7	11	5.4
6. Smokers, total	143	38.8	69	36.3	94	46.1

TABLE 25. PREVALENCE OF PHLEGM (PART-DAY) IN COMPARED GROUPS OF WORKERS CATEGORIZED BY SMOKING HABITS

	Manganese alloy production		Electrode production		Aluminum rolling mill		Significance of difference
	f	%	f	%	f	%	
1. Nonsmokers	10	5.9	11	10.8	6	7.4	NS
2. Past smokers	2	3.5	3	15.8	1	3.4	NS
3. Light smokers	9	17.6	4	11.4	1	2.4	NS
4. Moderate smokers	11	15.1	6	24.0	7	16.7	NS
5. Heavy smokers	3	15.8	2	22.2	0	-	NS
6. Smokers, total	23	16.1	12	17.4	8	8.5	NS
Total	35	9.5	26	13.7	15	7.4	
Significance of difference	1-3 $P<0.05$ 1-4 $P<0.05$ 1-6 $P<0.05$		NS		NS		

TABLE 26. PREVALENCE OF REGULAR CHEST WHEEZING IN COMPARED GROUPS OF WORKERS CATEGORIZED BY SMOKING HABITS

	Manganese alloy production		Electrode production		Aluminum rolling mill		Significance of difference
	f	%	f	%	f	%	
1. Nonsmokers	9	5.3	6	5.9	5	6.2	NS
2. Past smokers	2	3.5	4	21.1	2	6.9	NS
3. Light smokers	3	5.9	0	-	3	7.3	NS
4. Moderate smokers	15	20.5	3	12.0	9	21.4	NS
5. Heavy smokers	7	36.8	0	-	2	18.2	NS
6. Smokers, total	25	17.5	3	4.3	14	14.9	I-II P<0.01 I-III P<0.05
Total	36	9.8	13	6.8	21	10.3	
Significance of difference	1-4 P<0.01 1-5 P<0.01 1-6 P<0.01		NS		NS		

TABLE 27. PREVALENCE OF CHRONIC BRONCHITIS IN COMPARED GROUPS OF WORKERS CATEGORIZED BY SMOKING HABITS

	Manganese alloy production		Electrode production		Aluminum rolling mill		Significance of difference
	f	%	f	%	f	%	
1. Nonsmokers	14	8.3	11	10.8	4	4.9	NS
2. Past smokers	4	7.0	3	15.8	4	13.8	NS
3. Light smokers	6	11.8	5	14.3	5	12.2	NS
4. Moderate smokers	29	39.7	8	32.0	9	21.4	I-III $P<0.05$
5. Heavy smokers	11	57.9	1	11.1	3	27.3	NS
6. Smokers, total	46	32.2	14	20.3	17	18.1	I-III $P<0.05$
Total	64	17.3	28	14.7	25	12.3	
Significance of difference	1-4 $P<0.01$ 1-5 $P<0.01$ 1-6 $P<0.01$ 3-4 $P<0.01$ 3-5 $P<0.01$ 4-5 $P<0.01$		1-4 $P<0.01$		NS		

TABLE 28. FORCED EXPIRATORY VOLUMES IN COMPARED GROUPS OF WORKERS

	Manganese alloy production		Electrode production		Aluminum rolling mill	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
FVC%*	98.1	11.7	97.0	10.9	97.0	12.3
$FEV_{1.0}$%*	101.5	14.1	99.0	13.3	100.8	15.2
$FEV_{0.1}$/FEV(%)	80.0	7.6	79.7	7.7	80.3	8.6

*Values are expressed as the percentage of expected (Morris et al., 1971).

TABLE 29. FORCED EXPIRATORY VOLUMES IN MANGANESE ALLOY WORKERS CATEGORIZED BY LENGTHS OF EXPOSURE AND SMOKING HABITS

	Length of exposure	Nonsmoker			Past smokers			Current smokers		
		N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD
FVC%*	<10 years	97	99.0	11.4	24	102.6	10.2	74	100.0	11.6
	10 years or more	72	96.4	13.1	33	95.6	12.9	68	97.1	11.2
$FEV_{1.0}$%*	<10 years	97	105.0	13.2	24	107.9	11.8	74	101.8	13.2
	10 years or more	72	99.7	14.6	33	99.0	16.8	68	98.5	15.3
$FEV_{1.0}$/FVC(%)	<10 years	97	83.6	6.6	24	81.4	6.5	74	80.0	8.2
	10 years or more	72	79.6	5.9	33	79.0	7.4	68	77.3	7.7
$FEV_{1.0}$ - nonsmokers	$P<0.05$									

*Values are expressed as the percentage of expected (Morris et al., 1971).

TABLE 28. FORCED EXPIRATORY VOLUMES IN COMPARED GROUPS OF WORKERS

	Manganese alloy production		Electrode production		Aluminum rolling mill	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
FVC%*	98.1	11.7	97.0	10.9	97.0	12.3
$FEV_{1.0}$%*	101.5	14.1	99.0	13.3	100.8	15.2
$FEV_{0.1}$/FEV(%)	80.0	7.6	79.7	7.7	80.3	8.6

*Values are expressed as the percentage of expected (Morris et al., 1971).

TABLE 29. FORCED EXPIRATORY VOLUMES IN MANGANESE ALLOY WORKERS CATEGORIZED BY LENGTHS OF EXPOSURE AND SMOKING HABITS

	Length of exposure	Nonsmoker			Past smokers			Current smokers		
		N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD
FVC%*	<10 years	97	99.0	11.4	24	102.6	10.2	74	100.0	11.6
	10 years or more	72	96.4	13.1	33	95.6	12.9	68	97.1	11.2
$FEV_{1.0}$%*	<10 years	97	105.0	13.2	24	107.9	11.8	74	101.8	13.2
	10 years or more	72	99.7	14.6	33	99.0	16.8	68	98.5	15.3
$FEV_{1.0}$/FVC(%)	<10 years	97	83.6	6.6	24	81.4	6.5	74	80.0	8.2
	10 years or more	72	79.6	5.9	33	79.0	7.4	68	77.3	7.7
$FEV_{1.0}$ - nonsmokers	$P<0.05$									

*Values are expressed as the percentage of expected (Morris et al., 1971).

TABLE 30. PREVALENCE OF CHRONIC BRONCHITIS IN COMBINATION WITH CERTAIN OBJECTIVE FINDINGS IN COMPARED GROUPS OF WORKERS CATEGORIZED BY SMOKING HABITS

	Manganese alloy production		Electrode production		Aluminum rolling mill	
	Nonsmokers N=169	Smokers N=143	Nonsmokers N=102	Smokers N=69	Nonsmokers N=81	Smokers N=94
Chronic bronchitis with mucopurulent or purulent sputum	2 (1.2)*	15 (10.5)	3	6 (8.7)	2	6 (6.4)
Chronic bronchitis with physical signs of bronchitis	7 (4.1)	28 (19.6)	4	4 (5.8)	0	7 (7.4)
Chronic bronchitis with reduced FVC% (79% or less)	0 -	7 (4.9)	0	1 (1.4)	1	1 (1.1)
Chronic bronchitis with reduced $FEV_{1.0}$% (79% or less)	0 -	7 (4.9)	2	1 (1.4)	1	4 (4.3)

*The numbers in parentheses are percents. The obtained values of forced expiratory volumes are expressed as percentage of the values expected with regard to age and height of subjects (Morris et al., 1971).

TABLE 31. DISABILITY RETIREMENT RATE FOR 1968-1972 IN THE TOWN AREA, FERROALLOY AND ELECTRODE, AND LIGHT METAL FACTORIES*

	Mean number of employed per year over a 5-year period	Retired regardless of diagnosis	Retired with diagnosis of chronic obstructive lung disease
Town area	20,000	982 (1.3%)[†]	260 (26.5%)[§]
Light metal plant	2,600	127 (2.5%)[†]	65 (51.2%)[§]
Manganese alloys and electrode plant	1,400	49 (2.6%)[†]	36 (73.5%)[§]

*Data of the Health Insurance Society, 1973.

†Percentage of the total number of employed.

§Percentage of the total number of retired regardless of diagnosis.

TABLE 32. PREVALENCE OF SUBJECTIVE SYMPTOMS IN COMPARED GROUPS OF WORKERS

Symptoms	Ferroalloy plant (N=369)		Electrode plant (N=190)		Aluminum rolling mill (N=204)		Significance of difference	
	f	%	f	%	f	%		
Fatigue	152	41.2	55	28.9	76	37.3	a-b	P<0.01
Bad mood	68	19.0	18	9.5	22	10.8	a-b a-c	P<0.01 P<0.01
Sleepiness	77	20.9	29	15.3	54	26.5	b-c	P<0.01
Irritability	161	43.6	63	33.2	89	43.6	a-b b-c	P<0.01 P<0.05
Hypersalivation	38	10.3	17	8.9	20	9.8		
Tiredness, stiffness, heaviness in legs	105	31.2	51	26.8	77	37.7	b-c	P<0.05
Trembling of hands	89	24.1	21	11.1	52	25.5	a-b b-c	P<0.01 P<0.01
Cramps in arms and legs (recurring)	45	12.2	17	8.9	16	7.8		

TABLE 33. PREVALENCE OF CERTAIN SUBJECTIVE SYMPTOMS IN WORKERS FROM FERROALLOY PLANT CATEGORIZED BY SMOKING HABITS

Symptoms	1. Moderate & heavy smokers (N=92)		2. Light smokers (N=51)		3. Nonsmokers (N=169)		Significance of difference	
	f	%	f	%	f	%		
Fatigue	48	52.2	19	37.3	61	36.1	1:3	P<0.05
Bad mood	24	26.1	4	7.8	26	15.4		
Irritability	47	51.1	13	25.5	66	39.1	1:2	P<0.01
Cramps in arms and legs (recurring)	20	21.7	1	2.0	19	11.2	1:2 1:3 2:3	P<0.01 P<0.05 P<0.01

TABLE 34. PREVALENCE OF CERTAIN SUBJECTIVE SYMPTOMS IN WORKERS FROM ELECTRODE PLANT CATEGORIZED BY SMOKING HABITS

Symptoms	1. Moderate & heavy smokers (N=34)		2. Light smokers (N=35)		3. Nonsmokers (N=69)		Significance of difference	
	f	%	f	%	f	%		
Fatigue	11	32.4	5	14.3	33	32.4	2:3	P<0.05
Bad mood	6	17.6	1	2.9	9	8.8	1:2	P<0.05
Irritability	13	38.2	8	22.9	37	36.3		
Cramps in arms and legs (recurring)	2	5.9	1	2.9	12	11.8		

TABLE 35. PREVALENCE OF CERTAIN SUBJECTIVE SYMPTOMS IN WORKERS FROM ALUMINUM ROLLING MILL CATEGORIZED BY SMOKING HABITS

Symptoms	1. Moderate & heavy smokers (N=53)		2. Light smokers (N=41)		3. Nonsmokers (N=81)		Significance of difference	
	f	%	f	%	f	%		
Fatigue	21	39.6	12	29.3	28	34.6		
Bad mood	7	13.2	1	2.4	10	11.5	1:2 2:3	P<0.05 P<0.05
Irritability	27	50.9	14	34.1	32	39.5		
Cramps in arms and legs (recurring)	6	11.3	1	2.4	3	3.7		

TABLE 36. PREVALENCE OF NEUROLOGICAL SIGNS IN COMPARED GROUPS OF WORKERS

Signs	Ferroalloy plant		Electrode plant		Aluminum rolling mill	
	Nonsmokers	Smokers*	Nonsmokers	Smokers*	Nonsmokers	Smokers*
	(N=169)	(N=200)	(N=102)	(N=88)	(N=81)	(N=123)
Cogwheel phenomenon		1 (0.5)[†]				
Tremor at rest	24 (14.2)	23 (11.5)	2 (2.0)	8 (9.1)		
Difficult starting of voluntary movements		1 (0.5)				
Pathological reflexes	4 (2.4)	4 (2.0)		1 (1.1)		
Cogwheel phenomenon & tremor at rest		1 (0.5)				
Cogwheel phenomenon pathological reflexes		1 (0.5)				
Pathological reflexes & tremor at rest[#]	1 (0.6)	2 (1.0)				

*Present and past smokers.

†Numbers in parentheses are percentages.

#The difference between the number of symptoms of tremor at rest in ferroalloy and electrode plant is statistically significant (P<0.01).

TABLE 37. FERROALLOY WORKERS WITH NEUROLOGICAL SIGNS BY LEVEL OF EXPOSURE TO MANGANESE

Signs	Mean manganese concentrations at working places mg/m^3 0.301-4.933 (N=268)	9.480-11.062 (N=17)	16.347-20.442 (N=18)
Cogwheel phenomenon	1		
Difficult starting of voluntary movements	2		
Pathological reflexes	6	1	1
Tremor at rest	42	2	2
Pathological reflexes & tremor at rest	3		
Cogwhell phenomenon & tremor at rest			1
Cogwhell phenomenon & pathological reflexes			1
T o t a l	54 (20.1%)	3 (17.6%)	5 (27.8%)

TABLE 38. MEAN VALUES OF SYSTOLIC BLOOD PRESSURE IN WORKERS BY CATEGORIZED AGE GROUPS

	Group number	Ferroalloy plant I[*]			Electrode plant II[†]			Rolling mill (light metal plant) III[#]		
		N	$\overline{X}$	SD	N	$\overline{X}$	SD	N	$\overline{X}$	SD
20-29 yr	1[§]	60	134.3	13.3	43	134.5	10.3	42	143.8	14.7
30-39 yr	2[**]	144	136.2	11.4	80	142.1	13.0	82	145.5	14.0
40-49 yr	3[††]	133	143.4	14.7	52	146.7	15.0	63	149.9	15.2
50-59 yr	4	30	150.1	20.4	14	152.8	28.6	16	159.8	18.3
Totals and averages[§§]	5[##]	367	139.8	14.8	189	142.6	15.4	203	147.9	15.8

[*] 1-3 P<0.01, 1-4 P<0.01, 2-3 P<0.01, 2-4 P<0.01

[†] 1-2 P<0.01, 1-3 P<0.01, 1-4 P<0.01, 2-4 P<0.05

[#] 1-3 P<0.05, 1-4 P<0.01, 2-4 P<0.01, 3-4 P<0.05

[§] I-III P<0.01, II-III P<0.01

[**] I-III P<0.01, I-III P<0.01

[††] I-III P<0.01

[##] I-II P<0.05, I-III P<0.01, II-III P<0.01

[§§] In two workers from the ferroalloy plant, in one worker from the electrode plant, and in one worker from the light metal plant, the blood pressure was not measured.

TABLE 39. MEAN VALUES OF DIASTOLIC BLOOD PRESSURE IN WORKERS CATEGORIZED BY AGE GROUPS

Age	Group number	Ferroalloy plant I[*]			Electrode plant II[†]			Rolling mill (light metal plant) III[#]		
		N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD
20-29 yr	1[§]	60	91.0	10.5	43	92.6	8.4	42	86.4	10.3
30-39 yr	2[**]	144	93.5	9.8	80	97.5	11.4	82	92.5	10.9
40-49 yr	3[††]	133	97.6	10.5	52	98.4	11.3	63	92.3	10.5
50-59 yr	4	30	99.7	14.4	14	98.9	6.8	16	93.1	10.9
Totals and averages	5[##]	367	95.1	10.6	189	96.8	11.0	203	91.4	11.0

[*] 1-3 P<0.01, 1-4 P<0.01, 2-3 P<0.01, 2-4 P<0.05

[†] 1-2 P<0.01, 1-3 P<0.01, 1-4 P<0.01

[#] 1-2 P<0.01, 1-3 P<0.01, 1-4 P<0.01

[§] I-III P<0.05, II-III P<0.01

[**] I-II P<0.01, II-III P<0.01

[††] I-III P<0.01, II-III P<0.01

[##] I-II P<0.01, II-III P<0.01

TABLE 40. MEAN VALUES OF SYSTOLIC AND DIASTOLIC BLOOD PRESSURE IN WORKERS NOT INCLUDING HYPERTONICS*

	Group number	N	Systolic pressure I†		Diastolic pressure II#	
			$\bar{X}$	SD	$\bar{X}$	SD
Ferroalloy plant	1	191	130.8	10.4	86.5	5.0
Electrode plant	2	102	133.6	9.2	87.9	5.9
Rolling mill (light metal plant)	3	132	138.7	9.6	84.7	7.4

*Hypertonics are persons with systolic blood pressure of 160mm Hg or higher and diastolic pressure of 95mm Hg and higher, as well as those having a combination of these values.

†1-2 $P<0.05$, 1-3 $P<0.01$, 2-3 $P<0.01$

#1-2 $P<0.05$, 1-3 $P<0.05$, 2-3 $P<0.01$

SECTION 7

ACUTE RESPIRATORY DISEASES IN A MANGANESE-CONTAMINATED TOWN AREA

MATERIAL AND METHODS

A 4-year study of the incidence of acute bronchitis, peribronchitis and pneumonia was conducted in the town whose atmosphere is polluted with emissions from a manganese alloy plant. Data about acute respiratory diseases were available through the local Chest Disease Clinic. Considering the current organization of the local health service, the collected data can be considered to reflect actual conditions. The incidence of the respiratory diseases studied was analyzed by zones of manganese exposure, by age and sex of the ill, and by seasonal factor (summer: April-September; winter: October-March).

As described earlier (see Section 4), Zone I was defined as the part of the town nearest to the ferromanganese plant. The central part of the town was defined as Zone II. Zone III was the part of the town 3.5-6 km from the ferromanganese plant. Table 41 shows the structure of the population by zones of manganese concentrations in air.

RESULTS AND DISCUSSION

Tables 42-45 show the incidence of acute bronchitis and peribronchitis and pneumonia by zones and season for the years 1972 through 1975.

Table 46 shows the accumulated incidence (1972-1974) of the same diseases. Tables 47 and 48 also show the accumulated incidence but present the data separately for males and females.

Table 49 shows the accumulated incidence (1972-1974) of acute bronchitis, peribronchitis, and pneumonia by age.

The presented results reveal that acute bronchitis and peribronchitis occurred more frequently among the inhabitants living in the parts of the town defined as Zone I and Zone II than among the inhabitants of Zone III. In addition, the results show that the incidence of these diseases was higher in the winter than in the summer periods. However, it is interesting to note that the incidence of these diseases was usually a little higher in Zone II, which represents the central part of the town, than in Zone I, which is nearest to the ferroalloy factory and which usually had slightly higher mean and maximum concentrations of manganese in air compared with Zone II. However, on some occasions, particularly in 1974, maximum weekly concentrations of manganese were higher in Zone II than in Zone I (see frequency distribution of the weekly concentrations of manganese presented in Table 3). A slight difference in the incidence of acute bronchitis and peribronchitis between the two zones might be partly connected with a higher population density in the central part of the town, i.e., in Zone II. On the other hand, because of the configuration of the town, it might be that the number of measuring sites was not sufficient and that the locations do not best represent the real situation as far as air pollution with manganese is concerned.

There is another factor which should be considered. As shown in Table 96, the concentrations of total suspended particulates seem to be higher, on the average, in the central part of the town than in the part nearest to the ferroalloy factory. This situation is true for the sulfate concentrations.

Pneumonia incidence does not differ consistently in relation to the pollution zones. It was never the highest in Zone III which is the zone with the lowest manganese in air concentrations; on the other hand, it tends to be slightly higher in Zone II compared with Zone I. In general, the incidence of pneumonia did not seem to exceed significantly the predicted figures, nor did it differ in relation to season. As it was expected that the rate of pneumonia would be higher in the winter than in the summer period, a question arises whether this finding might not be associated with usually higher summer concentrations of manganese. Data on the incidence of pneumonia collected by the Institute of Public Health of Croatia (1975) show that in the costal area, as well in other parts of the country, it is usually higher in the winter than in the summer period.

A separate analysis by sex shows that acute bronchitis and peribronchitis occur more frequently in men than in women. In both sexes their incidence is higher in winter than in summer. As concerns the zones of living, the incidence for both sexes was lowest in the zone with the lowest manganese concentration. Pneumonia incidence was usually slightly higher in men than in women. The observed lack of seasonal difference in pneumonia rate was seen in males and females alike.

A detailed analysis of acute bronchitis and peribronchitis with regard to age shows, as expected, a higher incidence at the ages of 0-4 and 5-9 years. In these, as in almost all other age groups, the incidence also tends to be higher in winter than in summer. The same is true for more polluted zones. The difference in the incidence of acute bronchitis and peribronchitis in zones I and II compared with Zone III is particularly evident in the 0-4-year age group. Pneumonia was also more frequent in the 9-year age group, but its rate was not consistently higher in the zones with higher manganese concentrations. No significant difference was observed in the rate of studied diseases by years of followup. As shown in Table 1 and Figure 1, no greater difference in this respect was noticeable in manganese concentrations either.

It has to be mentioned that sulfur dioxide concentrations had an annual mean below 30 $\mu g/m^3$. Also there was no information indicating the presence of any other pollutants which might be of importance for the occurrence and rate of respiratory disease. However, it also has to be mentioned that within the light metal plant, which is (according to manganese in air concentrations) located in Zone III of the town area, a new facility for the electrolytic extraction of aluminum began operation in the beginning of 1974. This facility has created a problem of potential fluorine pollution, not only in the working atmosphere but also in the outer atmosphere, mainly affecting people living in the close vicinity of the factory, i.e., in the zone of the town with the lowest manganese exposure. It is possible that fluorine as a respiratory irritant had a certain influence on the incidence of the followup diseases in Zone III in 1974 and 1975.

The presented results need some additional comments regarding the reliability of the data used. The local clinic for lung diseases through which the data were collected has been operating for years. It began as a clinic for tuberculosis and expanded later to treat other diseases of the lungs and respiratory system.

The number of inhabitants in the town is not greater than 30,000, and because of the good reputation of the clinic, it soon became customary for general practitioners, pediatricians, school physicians, and industrial physicians to consult the clinic in all matters regarding respiratory diseases including their acute forms. Among other examinations, X-rays of the lungs are performed at the clinic. The town inhabitants are also free to consult the clinic directly. Thus, we can assume that practically all cases of acute respiratory diseases are registered at the clinic. Besides, the clinic is conveniently located and easily accessible. It should also be mentioned that health insurance entitles the members of the population to avail themselves of the clinic's services on an equal basis. The data presented in this study can, therefore, be considered reliable.

Although it is not possible to say that some relevant factors in addition to those mentioned earlier may not have been under adequate control, the results of the study indicate that an exposure to manganese which is of the order of magnitude of 1 $\mu g/m^3$ might have an adverse effect on health. As a matter of fact, the measured annual mean manganese in air concentrations in the area of higher incidence of acute respiratory illnesses were between 0.164 and 0.390 $\mu g/m^3$. Due to the sampling techniques described earlier (see Section 4), only particles of approximately respirable size have been collected and, therefore, it can be assumed that the total manganese concentrations in the air were considerably higher.

If the observed characteristics in the incidence of acute respiratory diseases are partly due to manganese pollution, a possible mechanism of manganese action could be that it disturbs some protective functions in the lung, thus making the organism more susceptible to respiratory infection. On the other hand, a possible catalytic effect of manganese on the oxidation of sulfur dioxide and of the potential synergistic action of manganese aerosol and the sulfuric acid and sulfates adsorbed on its surface also have to be considered.

TABLE 41. STRUCTURE OF THE POPULATION OF THE TOWN BY ZONES ACCORDING TO MANGANESE CONCENTRATIONS IN AIR

Zone	Age	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-	Total
I	Total	669	695	721	799	843	619	782	851	730	487	287	321	304	235	182	165	8,690
Sex	m	349	357	370	405	394	304	381	442	374	213	123	146	132	105	67	56	4,218
	f	320	338	351	394	449	315	401	409	356	274	164	175	172	130	115	109	4,474
II	Total	1,163	1,215	1,266	1,454	1,488	1,163	1,317	1,488	1,369	992	650	889	838	684	616	513	17,105
Sex	m	606	623	649	737	695	571	641	772	702	433	280	404	365	306	228	174	8,186
	f	557	592	617	717	793	592	676	716	667	559	370	485	473	378	388	339	8,919
III	Total	413	429	445	492	519	381	482	524	450	297	169	191	180	138	101	85	5,296
Sex	m	215	220	228	249	242	187	235	272	231	130	73	87	78	62	37	29	2,575
	f	198	209	217	243	277	194	247	252	219	167	96	104	102	76	64	56	2,721
Total																		31,091

TABLE 42. INCIDENCE OF ACUTE RESPIRATORY DISEASES IN 1972

		Zones according to manganese concentrations in air			Significance of difference
		I	II	III	
Acute bronchitis and peribronchitis	W*	158 (1.8)†	349 (2.0)	67 (1.3)	I-III P<0.05 II-III P<0.01
	S*	83 (1.0)	178 (1.0)	30 (0.6)	I-III P<0.01 II-III P<0.01
Pneumonia	W	15 (0.1)	7 (0.04)	3 (0.06)	NS
	S	5 (0.06)	13 (0.08)	5 (0.09)	NS

*W = winter; S = summer

†Numbers in parentheses denote percents of the total number of inhabitants in particular zones or in particular age groups.

TABLE 43. INCIDENCE OF ACUTE RESPIRATORY DISEASES IN 1973

		Zones according to manganese concentrations in air I	II	III	Significance of difference
Acute bronchitis and peribronchitis	W*	142 (1.6)†	368 (2.2)	63 (1.2)	I-II P<0.01 I-III P<0.05 II-III P<0.01
	S*	77 (0.9)	199 (1.2)	40 (0.8)	I-II P<0.05 II-III P<0.01
Pneumonia	W	21 (0.2)	35 (0.2)	2 (0.04)	I-III P<0.01 II-III P<0.01
	S	7 (0.08)	16 (0.09)	1 (0.02)	II-III P<0.05

*W = winter; S = summer

†Numbers in parentheses denote percents of the total number of inhabitants in particular zones or in particular age groups.

TABLE 44. INCIDENCE OF ACUTE RESPIRATORY DISEASES IN 1974

		Zones according to manganese concentrations in air			Significance of difference
		I	II	III	
Acute bronchitis and peribronchitis	W*	176 (2.0)†	408 (2.4)	96 (1.8)	I-II P<0.05 II-III P<0.01
	S*	136 (1.6)	322 (1.9)	71 (1.3)	II-III P<0.01
Pneumonia	W	11 (0.1)	42 (0.2)	12 (0.2)	I-II P<0.05
	S	27 (0.3)	64 (0.4)	13 (0.2)	II-III P<0.05

*W = winter; S = summer

†Numbers in parentheses denote percents of the total number of inhabitants in particular zones or in particular age groups.

TABLE 45. INCIDENCE OF ACUTE RESPIRATORY DISEASES IN 1975

		Zones according to manganese concentrations in air			Significance of difference
		I	II	III	
Acute bronchitis and peribronchitis	W*	114 (1.3)†	352 (2.1)	85 (1.6)	I-II P<0.01 II-III P<0.05
	S*	74 (0.9)	182 (1.1)	50 (0.9)	NS
Pneumonia	W	17 (0.2)	49 (0.3)	17 (0.3)	NS
	S	9 (0.1)	55 (0.3)	6 (0.1)	I-II P<0.01 II-III P<0.01

*W = winter; S = summer

†Numbers in parentheses denote percents of the total number of inhabitants in particular zones or in particular age groups.

TABLE 46. ACCUMULATED INCIDENCE OF ACUTE RESPIRATORY DISEASES DURING 1972-1975

		Zones according to manganese concentrations in air			Significance of difference
		I	II	III	
Acute bronchitis and peribronchitis	W*	588 (6.8)†	1477 (8.6)	301 (5.7)	I-II P<0.01 I-III P<0.01 II-III P<0.01
	S*	370 (4.3)	880 (5.1)	191 (3.6)	I-II P<0.01 I-III P<0.05 II-III P<0.01
Pneumonia	W	64 (0.7)	133 (0.8)	34 (0.6)	NS
	S	48 (0.6)	148 (0.9)	25 (0.5)	I-II P<0.01 II-III P<0.01

*W = winter; S = summer

†Numbers in parentheses denote percents of the total number of inhabitants in particular zones or in particular age groups.

TABLE 47. ACCUMULATED INCIDENCE OF ACUTE RESPIRATORY DISEASES DURING 1972-1975 - MALES

		Zones according to manganese concentrations in air			Significance of difference
		I	II	III	
Acute bronchitis and peribronchitis	W*	315 (7.5)†	795 (9.7)	172 (6.7)	I-II P<0.01 II-III P<0.01
	S*	226 (5.4)	508 (6.2)	111 (4.3)	I-III P<0.05 II-III P<0.01
Pneumonia	W	33 (0.8)	73 (0.9)	21 (0.8)	NS
	S	32 (0.8)	84 (1.0)	15 (0.6)	II-III P<0.05

*W = winter; S = summer

†Numbers in parentheses denote percents of the total number of inhabitants in particular zones or in particular age groups.

TABLE 48. ACCUMULATED INCIDENCE OF ACUTE RESPIRATORY DISEASES DURING 1972-1975 - FEMALES

		Zones according to manganese concentrations in air I	II	III	Significance of difference
Acute bronchitis and peribronchitis	W*	273 (6.1)†	682 (7.6)	139 (5.1)	I-II P<0.01 II-III P<0.01
	S*	144 (3.2)	372 (4.2)	80 (3.9)	I-II P<0.01
Pneumonia	W	31 (0.7)	60 (0.7)	13 (0.5)	NS
	S	16 (0.4)	64 (0.7)	10 (0.4)	I-II P<0.05 II-III P<0.05

*W = winter; S = summer

†Numbers in parentheses denote percents of the total number of inhabitants in particular zones or in particular age groups.

TABLE 49. ACCUMULATED INCIDENCE OF ACUTE RESPIRATORY DISEASES DURING 1972-1975 BY AGE

			0-4	5-9	10-19	20-39	40-59	60 or more	Total
Acute bronchitis and peribronchitis	I	W*	139 (20.8)†	94 (13.5)	61 (4.0)	106 (3.4)	127 (7.0)	61 (6.9)	588
		S*	79 (11.8)	57 (8.2)	29 (1.9)	80 (2.6)	79 (4.3)	46 (5.2)	370
	II	W	271 (23.3)	237 (19.5)	155 (5.7)	309 (5.7)	322 (8.3)	183 (6.9)	1477
		S	130 (11.2)	104 (8.6)	90 (3.3)	213 (3.9)	213 (5.5)	130 (4.9)	880
	III	W	61 (14.8)	65 (15.2)	28 (3.0)	70 (3.7)	71 (6.4)	16 (3.2)	311
		S	28 (6.8)	45 (10.5)	24 (2.6)	32 (1.7)	42 (3.8)	20 (4.0)	191
Significance of difference		W	I-III P<0.05 II-III P<0.01	I-II P<0.01 II-III P<0.05	I-II P<0.05 II-III P<0.01	I-II P<0.01 II-III P<0.01	II-III P<0.05	I-III P<0.01 II-III P<0.01	
		S	I-III P<0.01 II-III P<0.01		I-II P<0.01	I-II P<0.01 I-III P<0.05 II-III P<0.01	I-II P<0.05 II-III P<0.05		
Pneumonia	I	W	10 (1.5)	12 (0.7)	11 (0.7)	17 (0.5)	6 (0.3)	8 (0.9)	64
		S	4 (0.6)	10 (0.5)	8 (0.5)	9 (0.3)	10 (0.5)	7 (0.8)	58
	II	W	22 (1.9)	22 (1.8)	20 (0.7)	34 (0.6)	23 (0.6)	12 (0.5)	133
		S	14 (1.2)	31 (2.6)	36 (1.3)	25 (0.5)	24 (0.6)	18 (0.7)	148
	III	W	4 (1.0)	14 (3.3)	1 (0.1)	10 (0.5)	2 (0.2)	3 (0.6)	34
		S	2 (0.5)	11 (2.6)	2 (0.2)	4 (0.2)	2 (0.2)	4 (0.8)	25
Significance of difference		W			I-III P<0.05 II-III P<0.05		II-III P<0.05		
		S		I-II P<0.01 I-III P<0.01	I-II P<0.01 II-III P<0.01	II-III P<0.05	II-III P<0.05		

*W = winter; S = summer

†Numbers in parentheses denote percents of the total number of inhabitants in particular zones or in particular age groups.

SECTION 8

RESPIRATORY DISEASES IN SCHOOL CHILDREN AND THEIR FAMILIES IN A MANGANESE-CONTAMINATED TOWN AREA

MATERIALS AND METHODS

From the 1st of November 1972 until the 30th of April 1973, the rate of acute respiratory diseases was studied in groups of 288 children (2nd graders)* from three schools, at three different locations in the town contaminated by manganese from the ferroalloy factory, and in 44 children from a town on an island situated about 25 kilometers southwest.

The study was repeated during the period from the 1st of November 1974 until the 30th of April 1975, in another group of school children of the same age. In this later study 356 children were included: 296 from the town contaminated by emissions of the ferroalloy factory and 60 from the same island as in the first study. Among the children from the later group, 26 were 3rd graders.†

The studies included:

1. Measurements of forced expiratory volume at the beginning (November) and before the end (March) of the study.
2. Follow-up of acute respiratory diseases in the children and in members of their families during the entire period of 6 months.
3. Medical examinations of the parents of children chosen for the first study in 1972/73.

*The average 2nd grader is 8 years of age.

†The average 3rd grader is 9 years of age.

Three-quarter-second and one-second forced expiratory volumes ($FEV_{0.75}$ and $FEV_{1.0}$) were performed by each volunteer child once weekly during the months of November and March of the respective years. Ventilatory tests with "Pulmonor" spirometers were conducted by a physician in both studies. In addition to ventilatory tests, the standing height of each child was measured once in November and once in March.

In the first study of 1972/1973, forced expiratory volumes were measured in 273 children from the town contaminated by manganese and in 41 children from the island which served as the control group. In the second study of 1974/1975, 298 children from the town were included in the ventilatory measurements. Twenty-six children from the island were excluded from the testing because as 3rd graders they were slightly older than the others.

All members of the household of each participating pupil were asked to volunteer for the assessment of the frequency of acute respiratory disease. At biweekly intervals from November through April, a post card was sent to each household. A simple "yes" or "no" response to the question "Did anyone in your household have a new cold or sore throat in the past two weeks?" was requested, and a return envelope was provided. Households giving an affirmative response to the post card and all nonrespondents were visited by a nurse within a two-week interval and questioned about age, sex, and severity of illness of household members. Severity indices included the presence of fever, length of home confinement, and consultation of a physician for treatment.

At the time of the first contact, the nurse recorded on a census list age, sex, family position, and selected data on socioeconomic level of the household and profession of the father. Questions were also asked about the presence of asthma, bronchitis, or other chronic disease in volunteer children, duration of residence at current address, number of rooms in the house (apartment), type of heating used, and whether there was a cigarette smoker in the household. The method described is practically the same as used by Shy and collaborators (1970) in the Chattanooga School Children Study.

Medical examinations of the parents of children who participated in the first study were performed in April 1973. The examination included the MRC questionnaire on respiratory symptoms, determination of forced expiratory volumes, analysis of the early morning sputum, clinical examination, and an X-ray of the lungs.

RESULTS

Forced Expiratory Volumes of the Children

Study of 1972-1973--

Tables 50 and 51 show the mean age and the standing height of the compared groups of children.

The mean age and height did not differ in the compared groups of children. There was only one exception: children from the island were slightly older than children from the town contaminated by emissions from the ferroalloy factory. Girls from the island were also taller, on the average, than the boys and girls at all locations.

Table 52 compares the mean $FEV_{0.75}$ values for boys obtained in November 1972 and March 1973. Table 53 shows the same for girls. In Tables 54 and 55 are the mean $FEV_{1.0}$ values for boys and girls expressed as percentages of the predicted (nomograms by Bjure et al., 1963). Mean $FEV_{0.75}$ values obtained in March 1973 were slightly higher than those obtained in November 1972 both for boys and girls. It is most likely that the observed increase was due to the normal growth of the children during that period.

The children from the island had higher volumes than the children from the town with the ferroalloy factory. The differences were not statistically significant except in boys from the island compared with the boys from the school nearest to the ferroalloy factory.

The $FEV_{1.0}$ values show a relative increase in March 1973 compared with November 1972, with the exception of boys from the island and boys and girls from the school farthest from the ferroalloy factory.

In November 1972, the highest $FEV_{1.0}$ percent values were found in the boys from the island and the lowest in the boys from the school nearest to the ferroalloy plant. In March, the observed differences in volumes for boys were not statistically significant.

In girls, both in November 1972 and in March 1973, those from the school in the central part of the town with the ferroalloy plant had highest $FEV_{1.0}$ percent volume.

As shown in Figure 1, the mean monthly concentrations of manganese in air in the town with the ferroalloy plant were slightly lower in March 1973 compared with November 1972, and varied between 0.105-0.147 $\mu g/m^3$ in Zones I and II. In Zone III they were at a level of about 0.040 $\mu g/m^3$.

Study of 1974-1975--

Tables 56 and 57 show the mean age and the standing height of the compared groups of school children. Boys and girls from the school in the central part of the town contaminated by ferroalloy emissions were slightly shorter than boys and girls from other groups.

Tables 58 and 59 compare the mean $FEV_{0.75}$ values (November 1974-March 1975) for boys and girls respectively. In Tables 60 and 61 the same is presented for $FEV_{1.0}$ percent values. $FEV_{0.75}$ values did not statistically differ among groups. However, it is interesting that in children from the island, $FEV_{0.75}$ had a slight tendency to decrease in March 1975 compared with November 1974, while in other groups this was not observed.

$FEV_{1.0}$ percent values in all groups of children showed a decrease in March 1975 compared with November 1974. In November 1974 the boys from the school in the central part of the town had statistically higher $FEV_{1.0}$ percent values than the boys from the school nearest to the ferroalloy factory. In November 1974 as well as in March 1975, the girls from the school in the central part of the town had higher $FEV_{1.0}$ percent volumes than the girls from the school nearest to the ferroalloy factory, and also higher than the girls from the island.

In November 1974 the mean monthly and maximum weekly manganese concentrations of air in the town with the ferroalloy plant were higher than in March 1975 (Figure 1) except in Zone III. Mean manganese concentration in November 1974 were also higher compared with those in November 1972 (first study). Concentrations in March 1974 and 1972 did not differ practically.

Incidence of Acute Respiratory Disease

Study of 1972-1973--

General characteristics of compared 2nd graders and their families are presented in Tables 61-66. Table 62 shows the structure of families (based on the location of school of 2nd graders). Table 63 shows the structure of families by location in the zones according to manganese concentrations in air. This table shows that 25 familes of 2nd graders attending schools in Zone II live in Zone III, i.e., in the area with the lowest manganese concentrations in the air.

Table 64 shows the number of families with children under the age of 10 by zones according to the location of schools of 2nd graders. Table 65 shows data about socioeconomic status of the families in the study by schools of 2nd graders. Table 66 shows the density rate (number of members of the families per one room) in the compared groups. Table 67 shows the smoking habits of the children's parents on the same basis as in the previous table. Table 68 shows the number of ill (November 1972-April 1973) out of the total number of subjects in particular segments of the family. The comparison is based on the location of schools of 2nd graders. Distribution of ill by the rate of disease is presented in Table 69. Table 70 shows the incidence of acute respiratory illnesses, and Table 71 shows the structure of "other diseases" in the category "Acute respiratory disease with elevated temperature and staying in bed, physician consulted" from the previous table.

The results in these tables indicate that the incidence of acute respiratory illnesses (all compared grades and categories taken together) was higher in 2nd graders from the town contaminated by emissions from the ferroalloy factory than in 2nd graders from the island. The same relates to other members of the compared families.

However, it is interesting to note that the percentage of those with acute respiratory disease who stayed in bed and consulted a physician was highest in children and families living on the island, probably because of the fact that in the actual conditions of a small town on the island, home visits made by a local physician are generally more frequent than in a larger town.

Pneumonia also appeared to be more frequent in the town with the ferroalloy factory than on the island, although the total number of pneumonia cases was rather low.

A comparison of the incidence of acute respiratory illnesses in the town contaminated by ferroalloy emissions shows that the group of 2nd graders from one of the schools which is in Zone II, but not far from Zone III (so that some children attending this school live in Zone III with the lower manganese concentrations), had the highest rate of illnesses. The same was observed in other members of the families of these children except in grandfathers and grandmothers. It is true, however, that this relates mainly to the category "acute respiratory disease" and not to other categories (acute respiratory disease with elevated temperature, staying in bed, or physician consulted).

One of the explanations for this finding could be that more families in this group had children under the age of 10 than in the other two groups from the town with the ferroalloy factory. The number of members of the family per one room (density rate) was also slightly higher in that group compared with two others (Tables 64 and 66).

Study of 1974-1975--

General characteristics of compared 2nd graders and their families are presented in Tables 70-74. Table 72 shows the structure of the familes (based on the location of schools of 2nd graders). Table 73 shows the structure of the families by home location in zones according to measured manganese in air concentrations. This table demonstrates that out of 114 pupils attending the school, which is situated in Zone II but is not far from Zone III, 51 live in Zone III. A number of pupils attending the second-grade classes of the two schools from Zone II live in Zone I, and a rather small percentage of pupils attending the school situated in Zone I live in Zone II.

Table 74 shows the number of families with children under the age of 10. Table 75 shows data about socioeconomic status of the families compared by schools of 2nd graders. Table 76 shows the density rate (number of members of the families per one room) in the compared groups. Table 77 shows the smoking habits of the children's parents. Table 78 shows the number of ill (November 1972-April 1973) out of the total number of subjects in particular segments of the families. Data are based on the location of schools of 2nd graders. Table 79 shows the distribution of ill by the rate of disease. Table 80 demonstrates the incidence of acute respiratory illnesses by categories. Table 81 shows the structure of "other diseases" in the category

"Acute respiratory disease with elevated temperature and staying in bed - physician consulted" from Table 80.

This study shows that the incidence of acute respiratory illnesses was again higher in the school children, and members of their families, from the town contaminated by emissions from the ferroalloy factory than in the school children, and members of their families, from the island chosen as control. Compared with the first study (1972-1973), this time the difference relates also to the rate of "other disease" in the category "acute respiratory disease with elevated temperature and staying in bed, physician consulted". Here, it should be mentioned that the general practitioner who used to work on the island left his position just before the second study started. The physician who replaced him took the job on a temporary basis. This might have influenced to some extent the practice and the frequency of home visits on the island.

The analysis of incidence of acute respiratory illnesses within the town with the ferroalloy plant indicated again, a slightly higher rate of diseases in those from Zone II but near Zone III. As shown in Table 71, 45 percent of the children attending this school live in Zone III with the lowest atmospheric pollution with manganese. As in the first study (1972-1973), this related mainly to the category "acute respiratory disease," i.e., symptoms of cold or sore throat without elevated temperature or staying in bed. Brothers and sisters of the examined school children did not show the same tendency as far as the rate of the followed-up diseases is concerned. In their case, the incidence of the diseases was higher in the families from two other schools.

In fathers and mothers, the incidence was approximately the same in all compared families. The groups of grandfathers and grandmothers, as well as the rates of diseases in this segment of the families, were small and for that reason inadequate for comparison.

In this study, in contrast to the first one, the number of families with children under the age of 10 was lower in the group connected with the school nearest the zone with the lowest manganese air pollution than in two other compared groups of families.

As far as other characteristics are concerned, the compared families did not greatly differ.

However, the potential exposure to fluorine from the new plant for the electrolytic extraction of aluminium which, as already mentioned in Section 7, started to operate from the beginning of 1974, also has to be considered in the evaluation of the results of this study. It is possible that a certain number of cases with acute respiratory illness in the area around the factory was due to exposure to fluorine emitted in the air.

Respiratory Examination of Parents of Subjects of the First Respiratory Study--

Tables 82-84 show the main characteristics of the examined parents. Respiratory symptoms and forced expiratory volumes in men smokers by zones according to manganese concentrations in air are presented in Table 80. Table 81 shows the same for men nonsmokers. In Tables 82 and 83 respiratory symptoms and forced expiratory volumes are shown for women smokers and nonsmokers, respectively.

The results in the above tables indicate a certain difference in the rate of respiratory symptoms in men and women according to the zones of living. In practically all smoking-habit subgroups, the prevalence of respiratory symptoms was higher in those living in more polluted zones of the town.

Forced expiratory volumes also showed higher relative values (compared with the predicted) in fathers and mothers living in the less polluted part of the town. However, only in a few instances were the differences statistically significant.

A comparison between the study group of men and women in the town with the ferroalloy factory and the controls from the island is difficult because of a small number of subjects in the latter group. There was a lower rate of respiratory symptoms in women from the island, compared with women from the town polluted by manganese. In men, the rate of symptoms was practically the same in both groups. It is interesting that men nonsmokers from the island had lower FVC percent and $FEV_{1.0}$ percent values than men nonsmokers from the town contaminated by emissions of the ferroalloy plant.

TABLE 50. AGE AND HEIGHT COMPARISONS OF BOYS (1972-1973)

Location of school	N	November 1972				March 1973	
		Age*		Standing height		Standing height	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
a) Elementary school - Zone I - 0.75 km from ferroalloy plant	35	7.8	0.5	131.9	5.7	133.9	6.5
b) Elementary school - Zone II - 2 km from ferroalloy plant	42	7.9	0.5	132.5	6.4	134.6	6.4
c) Elementary school - Zone II - 2.75 km from ferroalloy plant	50	7.9	0.4	132.4	6.7	135.9	6.4
d) Elementary school - island	23	8.3	1.0	132.9	6.4	135.7	6.1

*Age: a-d $P<0.05$

b-d $P<0.05$

c-d $P<0.05$

TABLE 51. AGE AND HEIGHT COMPARISONS OF GIRLS (1972-1973)

Location of school	N	November 1972				March 1973	
		Age		Standing height*		Standing height†	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
a) Elementary school - Zone I - 0.75 km from ferroalloy plant	55	8.0	0.5	130.9	6.2	133.2	6.2
b) Elementary school - Zone II - 2 km from ferroalloy plant	34	7.9	0.9	129.8	5.1	131.8	6.8
c) Elementary school - Zone II - 2.75 km from ferroalloy plant	57	7.9	0.8	130.7	6.2	134.2	5.1
d) Elementary school - island	18	8.2	1.0	135.1	4.9	136.4	7.8

*Standing height: November 1972: a-d $P<0.01$
b-d $P<0.01$
c-d $P<0.05$

†Standing height: March 1973: a-b $P<0.05$
a-d $P<0.05$
b-d $P<0.01$
c-d $P<0.01$

TABLE 52. $FEV_{0.75}$ IN COMPARED GROUPS OF BOYS (1972-1973)

Location of school	N	November 1972*		March 1973	
		$\overline{X}$	SD	$\overline{X}$	SD
a) Elementary school - Zone I - 0.75 km from ferroalloy plant	35	1503	213	1563	219
b) Elementary school - Zone II - 2 km from ferroalloy plant	42	1577	213	1618	243
c) Elementary school - Zone II - 2.75 km from ferroalloy plant	50	1545	226	1623	260
d) Elementary school - island	23	1636	268	1651	280

*November, 1972: c-d $P<0.05$

TABLE 53. $FEV_{0.75}$ IN COMPARED GROUPS OF GIRLS (1972-1973)

Location of school	N	November 1972		March 1973	
		$\bar{X}$	SD	$\bar{X}$	SD
a) Elementary school - Zone I - 0.75 km from ferroalloy plant	55	1449	268	1523	244
b) Elementary school - Zone II - 2 km from ferroalloy plant	34	1480	188	1542	179
c) Elementary school - Zone II - 2.75 km from ferroalloy plant	57	1441	196	1485	214
d) Elementary school - island	18	1540	245	1571	245

TABLE 56. AGE AND HEIGHT COMPARISONS OF BOYS (1974-1975)

Location of school	N	November 1974				March 1975	
		Age		Standing height*		Standing height†	
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
a) Elementary school - Zone I - 0.75 km from ferroalloy plant	53	8.0	0.3	131.2	5.2	133.1	5.3
b) Elementary school - Zone II - 2 km from ferroalloy plant	32	8.1	0.3	129.5	5.8	132.0	5.7
c) Elementary school - Zone II - 2.75 km from ferroalloy plant	69	8.0	0.3	132.6	5.8	134.5	6.0
d) Elementary school - island	21	8.0	0.3	131.5	5.3	133.7	5.6

*November, 1974: a-b $P<0.05$

†March, 1975: a-b $P<0.05$
b-c $P<0.01$
b-d $P<0.01$

TABLE 57. AGE AND HEIGHT COMPARISON OF GIRLS (1974-1975)

Location of school	N	November 1974				March 1975	
		Age		Standing height*		Standing height†	
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
a) Elementary school - Zone I - 0.75 km from ferroalloy plant	46	8.0	0.4	130.2	5.2	132.0	5.0
b) Elementary school - Zone II - 2 km from ferroalloy plant	52	8.0	0.5	127.3	5.1	130.0	5.1
c) Elementary school - Zone II - 2.75 km from ferroalloy plant	46	8.0	0.2	129.5	5.7	131.7	5.7
d) Elementary school - island	13	8.1	0.3	132.1	4.5	133.8	4.7

*November, 1974: a-b $P<0.05$
b-c $P<0.01$
b-d $P<0.01$

†March, 1975: b-c $P<0.05$
b-d $P<0.05$

TABLE 58. $FEV_{0.75}$ IN COMPARED GROUPS OF BOYS (1974-1975)

Location of school	N	November 1974		March 1975	
		$\overline{X}$	SD	$\overline{X}$	SD
a) Elementary school - Zone I - 0.75 km from ferroalloy plant	53	1613	218	1631	216
b) Elementary school - Zone II - 2 km from ferroalloy plant	32	1640	258	1644	269
c) Elementary school - Zone II - 2.75 km from ferroalloy plant	69	1645	218	1657	221
d) Elementary school - island	21	1710	245	1683	266

TABLE 59. $FEV_{0.75}$ IN COMPARED GROUPS OF GIRLS (1974-1975)

Location of school	N	November 1974		March 1975	
		$\overline{X}$	SD	$\overline{X}$	SD
a) Elementary school - Zone I - 0.75 km from ferroalloy plant	46	1509	198	1525	184
b) Elementary school - Zone II - 2 km from ferroalloy plant	52	1535	171	1563	184
c) Elementary school - Zone II - 2.75 km from ferroalloy plant	46	1534	209	1543	203
d) Elementary school - island	13	1576	240	1553	269

TABLE 60. $FEV_{1.0}$ PERCENT IN COMPARED GROUPS OF BOYS (1974-1975)*

Location of school	N	November 1974†		March 1975	
		$\bar{X}$	SD	$\bar{X}$	SD
a) Elementary school - Zone I - 0.75 km from ferroalloy plant	53	100.2	9.6	96.4	9.4
b) Elementary school - Zone II - 2 km from ferroalloy plant	32	104.6	10.8	98.6	11.3
c) Elementary school - Zone II - 2.75 km from ferroalloy plant	69	97.9	9.0	94.3	9.6
d) Elementary school - island	21	103.2	8.7	97.9	7.3

*$FEV_{1.0}$ values are expressed as percentages of predicted values. (Bjure, 1963).

†November, 1974: a-b $P<0.01$

TABLE 61. $FEV_{1.0}$ PERCENT IN COMPARED GROUPS OF GIRLS (1974-1975)*

Location of school	N	November 1974†		March 1975#	
		$\bar{X}$	SD	$\bar{X}$	SD
a) Elementary school - Zone I - 0.75 km from ferroalloy plant	46	94.2	9.2	91.9	8.3
b) Elementary school - Zone II - 2 km from ferroalloy plant	52	100.6	9.5	97.4	8.8
c) Elementary school - Zone II - 2.75 km from ferroalloy plant	46	97.1	8.6	94.2	8.5
d) Elementary school - island	13	94.8	8.7	90.3	9.3

*$FEV_{1.0}$ values are expressed as percentages of predicted values. (Bjure, 1963).

†November, 1974: b-c $P<0.01$
b-d $P<0.05$

#March, 1975: b-c $P<0.01$
b-d $P<0.05$

TABLE 62. STRUCTURE OF COMPARED FAMILIES BY SCHOOL LOCATION OF 2nd GRADERS (1972-1973)

Location of school of 2nd graders	2nd graders	Fathers	Mothers	Brothers & sisters	Grandfathers & grandmothers
a) Elementary school - Zone I - 0.75 km from ferroalloy plant	94	91	94	103	22
b) Elementary school - Zone II - 2 km from ferroalloy plant	79	76	79	85	11
c) Elementary school - Zone II - 2.75 km from ferroalloy plant	115	114	114	120	21
d) Elementary school - island	44	29	41	58	35
TOTAL	332	310	328	366	89

TABLE 63. STRUCTURE OF COMPARED FAMILIES BY ZONES OF LIVING (1972-1973)

Zones of living (according to manganese concentrations in air)	2nd graders	Fathers	Mothers	Brothers & sisters	Grandfathers grandmothers
Zone I	94	91	94	103	22
Zone II	169	165	168	182	27
Zone III	25	25	25	23	5
Island	44	29	41	58	35
TOTAL	332	310	328	366	89

TABLE 64. FAMILIES WITH CHILDREN BELOW 10 YEARS* BY LOCATION OF SCHOOLS (1972-1973)

School	Families with children under the age of 10
Elementary school - Zone I - 0.75 km from ferroalloy plant	41 (43.6%)
Elementary school - Zone II - 2 km from ferroalloy plant	39 (49.4%)
Elementary school - Zone II - 2.75 km from ferroalloy plant	59 (51.8%)
Elementary school - island	19 (43.2%)

*These children do not include 2nd graders

TABLE 65. SOCIOECONOMIC DATA ON FAMILIES BY SCHOOL LOCATION OF 2nd GRADERS (1972-1973)

		Elementary school-Zone I-0.75 km from ferroalloy plant N=94		Elementary school-Zone II-2 km from ferroalloy plant N=79		Elementary school-Zone II-2.75 km from ferroalloy plant N=114		Elementary school-island N=44	
Number of family members	3 members	14	(14.9)*	10	(12.7)	20	(17.6)	6	(13.6)
	4 members	57	(60.6)	50	(63.3)	61	(53.5)	12	(27.3)
	5 members	23	(24.5)	19	(24.0)	33	(28.9)	26	(59.1)
Housing conditions	one-room apartment	11	(11.7)	10	(12.7)	13	(11.4)	3	(6.8)
	two-room apartment	30	(31.9)	31	(39.2)	53	(46.5)	13	(29.5)
	three-room or larger apartment	53	(56.4)	38	(48.1)	48	(42.1)	28	(63.6)
Father's occupation	worker	68	(72.3)	44	(55.7)	61	(53.5)	34	(77.3)
	office worker	19	(20.2)	25	(31.6)	28	(24.6)	4	(9.1)
	other	7	(7.5)	10	(12.7)	25	(21.9)	6	(13.6)
Apartment heating	heating: kitchen only	77	(81.9)	54	(68.4)	66	(57.9)	39	(88.6)
	other premises too	17	(18.1)	25	(31.6)	48	(42.1)	5	(11.4)

*The numbers in parentheses denote percents of the total number of families.

TABLE 66. MEMBERS OF FAMILY PER ONE ROOM BY SCHOOL LOCATION OF 2nd GRADERS (1972-1973)

Location of school of 2nd graders	Density rate
Elementary school - Zone I - 0.75 km from ferroalloy plant	1.65
Elementary school - Zone II - 2 km from ferroalloy plant	1.72
Elementary school - Zone III - 2.75 km from ferroalloy plant	1.78
Elementary school - island	1.67

TABLE 67. PARENTS' SMOKING HABITS BY SCHOOL LOCATION OF 2nd GRADERS (1972-1973)

Smoking habit of parents	Elementary school-Zone I-0.75 km from ferroalloy plant		Elementary school-Zone II-2 km from ferroalloy plant		Elementary school-Zone II-2.75 km from ferroalloy plant		Elementary school-island	
Both parents smoke	3	(1.6)*	5	(3.0)	10	(4.4)	4	(5.7)
Father or mother smokes	38	(20.5)	45	(27.3)	69	(30.3)	20	(28.6)
TOTAL	41	(22.1)	50	(30.3)	79	(34.7)	24	(34.3)

*The numbers in parentheses denote percentages of the total number of parents (fathers and mothers)

TABLE 68. NUMBER OF ILL PERSONS IN FAMILIES BY SCHOOL LOCATION OF 2nd GRADERS (1972-1973)

Location of school of 2nd graders	2nd graders	Fathers	Mothers	Brothers and sisters	Grand-fathers and grand-mothers
Elementary school - Zone I - 0.75 km from ferroalloy plant	49 (52.1)*	26 (28.6)	35 (37.2)	50 (48.5)	8 (36.4)
Elementary school - Zone II - 2 km from ferroalloy plant	42 (53.2)	19 (25.0)	34 (43.0)	31 (36.5)	4 (36.4)
Elementary school - Zone II - 2.75 km from ferroalloy plant	69 (60.0)	51 (44.7)	62 (54.4)	66 (55.0)	7 (33.3)
Elementary school - island	23 (52.3)	5 (17.2)	13 (31.7)	29 (50.0)	8 (22.8)

*The numbers in parentheses denote percents of the total number of persons in particular subgroups of the family.

TABLE 69. DISTRIBUTION OF ILL BY DISEASE RATE (BY SCHOOL LOCATION OF 2nd GRADERS); (1972-1973)

Location of school of 2nd graders	Number of the ill by rate of disease	2nd graders		Fathers		Mothers		Brothers and sisters		Grand-fathers and grand-mothers	
Elementary school - Zone I - 0.75 km from ferroalloy plant	once	29	(59.2)*	24	(92.3)	28	(80.0)	36	(72.0)	5	(62.5)
	twice	16	(32.6)	2	(7.7)	4	(11.4)	10	(20.0)	2	(25.0)
	three times	3	(6.1)	0	-	3	(8.6)	4	(8.0)	1	(12.5)
	four times	1	(2.0)	0	-	0	-	0	-	0	-
Elementary - Zone II - 2 km from ferroalloy plant	once	24	(57.1)	16	(84.2)	22	(64.7)	21	(67.7)	2	(50.0)
	twice	16	(38.1)	3	(15.8)	11	(32.4)	6	(19.4)	1	(25.0)
	three times	2	(4.8)	0	-	1	(2.9)	3	(9.7)	1	(25.0)
	four times	0	-	0	-	0	-	1	(3.2)	0	-
Elementary school Zone II - 2.75 km from ferroalloy plant	once	40	(58.0)	42	(82.4)	46	(74.2)	45	(68.2)	7	(100.0)
	twice	22	(31.9)	8	(15.7)	15	(24.2)	19	(28.8)	0	-
	three times	6	(8.7)	1	(2.0)	1	(1.6)	2	(3.0)	0	-
	four times	1	(1.4)	0	-	0	-	0	-	0	-
Elementary school - island	once	13	(56.5)	5	(100.0)	11	(84.6)	23	(79.3)	6	(75.0)
	twice	9	(39.1)	0	-	2	(15.4)	5	(17.2)	1	(12.5)
	three times	1	(4.3)	0	-	0	-	1	(3.4)	1	(12.5)
	four times	0	-	0	-	0	-	0	-	0	-

*The numbers in parentheses denote percents of the total number of the ill in each group.

TABLE 70. ACUTE RESPIRATORY DISEASES IN FAMILIES BY CATEGORIES; BY SCHOOL LOCATION OF 2nd GRADERS (1972-1973)

	Location of school of 2nd graders	Acute respiratory disease	Acute respiratory disease with elevated temperature	Acute respiratory disease with elevated temperature and staying in bed	Acute respiratory disease with elevated temperature and staying in bed. Physician consulted.		Total
					Pneumonia	Other diseases	
2nd graders	Elementary school - Zone I-0.75 km from ferroalloy plant	40 (42.6)*	7 (7.4)	2 (2.1)	3 (3.2)	27 (28.7)	79 (84.0)
	Elementary school - Zone II-2 km from ferroalloy plant	25 (31.6)	3 (3.8)	12 (15.2)	0 -	35 (44.3)	75 (94.9)
	Elementary school - Zone II-2.75 km from ferroalloy plant	59 (51.3)	7 (6.1)	20 (17.4)	2 (1.7)	28 (24.3)	116 (100.9)
	Elementary school - island	5 (11.4)	0 -	4 (9.1)	0 -	25 (56.8)	34 (77.3)
Fathers	Elementary school - Zone I-0.75 km from ferroalloy plant	14 (15.4)	4 (4.4)	1 (1.1)	0 -	10 (11.0)	29 (31.9)
	Elementary school - Zone II-2 km from ferroalloy plant	8 (10.5)	2 (2.6)	5 (6.6)	0 -	8 (10.5)	23 (30.3)
	Elementary school - Zone II-2.75 km from ferroalloy plant	36 (31.6)	4 (3.5)	9 (7.8)	1 (0.9)	12 (10.5)	62 (54.4)
	Elementary school - island	0 -	0 -	2 (6.9)	0 -	3 (10.3)	5 (17.2)

(continued)

TABLE 70. (continued)

	Location of school of 2nd graders	Acute respiratory disease	Acute respiratory disease with elevated temperature	Acute respiratory disease with elevated temperature and staying in bed	Acute respiratory disease with elevated temperature and staying in bed. Physician consulted.		Total
					Pneumonia	Other diseases	
Mothers	Elementary school - Zone I-0.75 km from ferroalloy plant	27 (28.7)	6 (6.4)	1 (1.1)	0 -	6 (6.4)	40 (42.6)
	Elementary school - Zone II-2 km from ferroalloy plant	21 (26.6)	6 (7.6)	6 (7.6)	0 -	14 (17.7)	47 (59.5)
	Elementary school - Zone II-2.75 km from ferroalloy plant	57 (44.7)	12 (10.5)	9 (7.9)	0 -	9 (7.9)	81 (71.1)
	Elementary school - island	3 (7.3)	1 (2.4)	1 (2.4)	1 (2.4)	9 (22.0)	15 (36.6)
Brothers and sisters	Elementary school - Zone I-0.75 km from ferroalloy plant	24 (23.3)	7 (6.8)	6 (5.8)	2 (1.9)	27 (26.2)	66 (64.1)
	Elementary school - Zone II-2 km from ferroalloy plant	16 (18.8)	3 (3.5)	5 (5.9)	0 -	19 (22.4)	43 (50.6)
	Elementary school - Zone II-2.75 km from ferroalloy plant	34 (28.3)	12 (10.0)	15 (12.5)	2 (1.7)	27 (22.5)	90 (75.0)
	Elementary school - island	2 (3.4)	1 (1.7)	3 (5.2)	0 -	32 (55.2)	38 (65.5)

(continued)

TABLE 70. (continued)

	Location of school of 2nd graders	Acute respiratory disease	Acute respiratory disease with elevated temperature	Acute respiratory disease with elevated temperature and staying in bed	Acute respiratory disease with elevated temperature and staying in bed. Physician consulted.		Total
					Pneumonia	Other diseases	
Grandfathers and grandmothers	Elementary school - Zone I-0.75 km from ferroalloy plant	7 (31.8)	3 (13.6)	0 -	1 (4.5)	1 (4.5)	12 (54.5)
	Elementary school - Zone II-2 km from ferroalloy plant	4 (36.4)	0 -	0 -	0 -	4 (36.4)	8 (72.7)
	Elementary school - Zone II-2.75 km from ferroalloy plant	5 (23.8)	1 (4.8)	1 (4.8)	0 -	0 -	7 (33.3)
	Elementary school -	1 (2.9)	0 -	2 (5.7)	0 -	7 (20.0)	10 (28.6)

*The numbers in parentheses denote percents of the total number of persons inparticular groups.

TABLE 71. ACUTE RESPIRATORY DISEASE, BEDRIDDEN, WITH ELEVATED TEMPERATURE - PHYSICIAN CONSULTED; BY SCHOOL LOCATION OF 2ND GRADERS (1972-1973)

Location of school of 2nd graders	Disease	2nd graders	Fathers	Mothers	Brothers and sisters	Grand-fathers and Grand-mothers
Elementary school - Zone I-0.75 km from ferroalloy plant	Diseases of the upper respiratory tract	18 (19.1)*	7 (7.7)	5 (5.3)	21 (20.4)	0 -
	Diseases of the lower respiratory tract	9 (9.6)	3 (3.3)	1 (1.1)	6 (5.8)	1 (4.5)
	Influenza	0 -	0 -	0 -	0 -	0 -
Elementary school - Zone II-2 km from ferroalloy plant	Diseases of the upper respiratory tract	19 (24.0)	3 (3.9)	8 (10.1)	12 (11.6)	2 (20.1)
	Diseases of the lower respiratory tract	13 (16.4)	0 -	1 (1.3)	4 (3.9)	2 (20.1)
	Influenza	3 (3.8)	5 (6.6)	5 (6.3)	3 (3.5)	0 -
Elementary school - Zone II-2.75 km from ferroalloy plant	Diseases of the upper respiratory tract	19 (16.5)	10 (8.8)	7 (6.1)	19 (15.8)	0 -
	Diseases of the lower respiratory tract	9 (7.8)	2 (1.8)	2 (1.8)	8 (6.7)	0 -
	Influenza	0 -	0 -	0 -	0 -	0 -
Elementary school - island	Diseases of the upper respiratory tract	11 (25.0)	1 (3.5)	4 (9.8)	12 (20.7)	0 -
	Diseases of the lower respiratory tract	14 (31.8)	2 (6.9)	5 (12.2)	20 (34.5)	7 (20.0)
	Influenza	0 -	0 -	0 -	0 -	0 -

*The numbers in parentheses denote percents of the total number of persons in particular groups.

TABLE 72. STRUCTURE OF COMPARED FAMILIES BY SCHOOL LOCATION OF 2ND GRADERS (1974-1975)

Location of schools of 2nd graders	2nd graders	Fathers	Mothers	Brothers & sisters	Grandfathers & grandmothers
Elementary school - Zone I - 0.75 km from ferroalloy plant	98	91	95	100	22
Elementary school - Zone II - 2 km from ferroalloy plant	84	78	81	75	14
Elementary school - Zone II - 2.75 km from ferroalloy plant	114	109	111	101	18
Elementary school - island	60	51	57	116	45
Total	356	329	344	392	99

TABLE 73. STRUCTURE OF COMPARED FAMILIES BY ZONES OF RESIDENCE (1974-1975)

Zones of living (according to manganese concentrations in air)	2nd graders	Fathers	Mothers	Brothers & sisters	Grandfathers & grandmothers
Zone I	98	91	95	100	22
Zone II	147	139	142	134	28
Zone III	51	48	50	42	4
Island	60	51	57	116	45
Total	356	329	344	392	99

TABLE 74. FAMILIES WITH CHILDREN UNDER AGE 10* BY SCHOOL LOCATION OF 2ND GRADERS (1974-1975)

Location of schools	No. of families with children under age of 10
Elementary school - Zone I - 0.75 km from ferroalloy plant	56 (57.1%)
Elementary school - Zone II - 2 km from ferroalloy plant	42 (50.0%)
Elementary school - Zone II - 2.75 km from ferroalloy plant	51 (44.7%)
Elementary school - island	37 (61.7%)

*These children do not include 2nd graders.

TABLE 75. SOCIOECONOMIC DATA OF FAMILIES BY SCHOOL LOCATION OF 2ND GRADERS (1974-1975)

		Elementary school - Zone I-0.75 km from ferroalloy plant	Elementary school - Zone II-2 km from ferroalloy plant	Elementary school - Zone II-2.75 km from ferroalloy plant	Elementary school - island
Number of family members	3 members	15 (15.5)*	16 (19.3)	20 (18.0)	2 (3.3)
	4 members	52 (53.6)	46 (55.4)	64 (57.7)	10 (16.7)
	5 members	30 (30.9)	21 (25.3)	27 (24.3)	48 (80.0)
Housing conditions	one-room apartment	23 (23.7)	13 (15.7)	9 (8.1)	2 (3.4)
	two-room apartment	24 (24.7)	34 (41.0)	64 (57.7)	11 (18.3)
	three-room or larger apartment	50 (51.6)	36 (43.3)	38 (34.2)	47 (78.3)
Father's occupation	worker	58 (61.1)	41 (49.4)	57 (51.4)	43 (71.7)
	office worker	33 (34.7)	32 (38.6)	39 (35.1)	7 (11.7)
	other	4 (4.2)	10 (12.0)	15 (13.5)	10 (16.7)
Apartment heating	heating: kitchen only	72 (74.2)	56 (67.5)	72 (64.9)	45 (75.0)
	other premises too	25 (25.8)	27 (32.5)	39 (35.1)	15 (25.0)

*Numbers in parentheses denote percents of the total number of families.

TABLE 76. MEMBERS OF THE FAMILY PER ONE ROOM BY SCHOOL LOCATION OF 2ND GRADERS (1974-1975)

Location of school of 2nd graders	Density rate
Elementary school - Zone II - 2.75 km from ferroalloy plant	1.78
Elementary school - Zone II - 2 km from ferroalloy plant	1.77
Elementary school - Zone I - 0.75 km from ferroalloy plant	1.81
Elementary school - island	1.63

TABLE 77. SMOKING HABIT OF PARENTS BY SCHOOL LOCATION OF 2ND GRADERS (1974-1975)

Smoking habit of parents	Elementary school - Zone I-0.75 km from ferroalloy plant	Elementary school - Zone II-2 km from ferroalloy plant	Elemenetary school - Zone II-2.75 km from ferroalloy plant	Elementary school - island
Both parents smoke	3 (1.6)*	5 (3.1)	11 (5.0)	26 (24.1)
Father or mother smokes	52 (27.9)	49 (30.8)	58 (26.4)	0 -
Total	55 (29.5)	54 (33.9)	69 (31.4)	26 (24.1)

*The numbers in parentheses denote percentages of the total number of parents (fathers and mothers).

TABLE 78. NUMBER OF ILL IN FAMILIES BY SCHOOL LOCATION OF 2ND GRADERS (1974-1975)

Location of schools	2nd graders	Fathers	Mothers	Brothers & sisters	Grandfathers & grandmothers
Elementary school - Zone I - 0.75 km from ferroalloy plant	57 (58.2)*	26 (28.6)	49 (51.6)	53 (53.0)	2 (9.1)
Elementary school - Zone II - 2 km from ferroalloy plant	46 (54.8)	29 (37.2)	29 (35.8)	40 (53.3)	1 (7.1)
Elementary school - Zone II - 2.75 km from ferroalloy plant	63 (55.3)	45 (41.3)	57 (51.4)	51 (50.5)	3 (16.7)
Elementary school - island	22 (36.7)	10 (19.6)	12 (21.1)	29 (25.0)	6 (13.3)

*Numbers in parentheses are percentages of the total number of persons in particular segments of the family.

TABLE 79. DISTRIBUTION OF ILL BY DISEASE RATE AND SCHOOL LOCATION OF 2ND GRADERS (1974-1975)

	Number of the ill by rate of disease	2nd graders	Fathers	Mothers	Brothers & sisters	Grandmothers & grandfathers
Elementary school - Zone I - 0.75 km from ferroalloy plant	once	38 (66.7)*	17 (65.4)	30 (62.2)	26 (50.1)	2
	twice	14 (24.6)	9 (34.6)	13 (26.5)	20 (37.7)	0 -
	three times	3 (5.2)	0 -	5 (10.2)	5 (9.4)	0 -
	four times	2 (3.5)	0 -	1 (2.0)	2 (3.8)	0 -
Elementary school - Zone II - 2 km from ferroalloy plant	once	28 (61.9)	20 (69.0)	20 (69.0)	22 (55.0)	1
	twice	11 (23.9)	6 (20.7)	9 (31.0)	11 (27.5)	0 -
	three times	7 (15.2)	3 (10.3)	0 -	7 (17.5)	0 -
	four times	0 -	0 -	0 -	0 -	0 -
Elementary school - Zone II - 2.75 km from ferroalloy plant	once	37 (58.7)	34 (75.6)	36 (63.2)	28 (54.9)	2
	twice	19 (30.2)	8 (17.8)	14 (24.6)	13 (25.5)	1
	three times	4 (6.3)	2 (4.4)	4 (7.0)	6 (11.8)	0 -
	four times	3 (4.8)	1 (2.2)	3 (5.2)	4 (7.8)	0 -
Elementary school - island	once	17 (77.3)	10	10 (83.3)	25 (86.2)	6
	twice	4 (18.2)	0 -	2 (16.7)	3 (10.4)	0 -
	three times	1 (4.5)	0 -	0 -	1 (3.4)	0 -
	four times	0 -	0 -	0 -	0 -	0 -

*Numbers in parentheses are percentages of the total number of the ill in each group.

TABLE 80. CATEGORIES OF ACUTE RESPIRATORY DISEASES IN FAMILIES BY LOCATION OF SCHOOL OF 2nd GRADERS (1974-1975)

	Location of school of 2nd Graders	Acute respiratory disease	Acute respiratory disease with elevated temperature	Acute respiratory disease with elevated temperature and staying in bed	Acute respiratory disease with elevated temperature and staying in bed. Physician consulted.		Total
					Pneumonia	Other diseases	
2nd Graders	Elementary school-Zone I-0.75 km from ferroalloy plant	24 (24.5)*	5 (5.1)	2 (2.0)	3 (3.1)	44 (44.9)	78 (79.6)
	Elementary school-Zone II-2 km from ferroalloy plant	16 (19.0)	1 (1.2)	3 (3.6)	1 (1.2)	42 (50.0)	63 (75.0)
	Elementary school Zone II-2.75 km from ferroalloy plant	36 (31.6)	1 (0.9)	7 (6.1)	3 (2.6)	48 (42.1)	96 (84.2)
	Elementary school-island	0 -	0 -	2 (3.3)	2 (3.3)	23 (38.3)	27 (45.0)
Fathers	Elementary school-Zone I.0.75 km from ferroalloy plant	8 (8.8)	2 (2.2)	2 (2.2)	0 -	19 (20.9)	31 (34.1)
	Elementary school-Zone II-2 km from ferroalloy plant	15 (19.2)	0 -	0 -	1 (1.3)	23 (29.5)	39 (50.0)
	Elementary school-Zone II-2.75 km from ferroalloy plant	22 (20.2)	3 (2.8)	6 (5.5)	0 -	25 (22.9)	56 (51.4)
	Elementary School-island	2 (3.9)	0 -	0 -	2 (3.9)	7 (13.7)	11 (21.6)

(continued)

TABLE 80. (Continued)

	Location of school of 2nd Graders	Acute respiratory disease	Acute respiratory disease with elevated temperature	Acute respiratory disease with elevated temperature and staying in bed	Acute respiratory disease with elevated temperature and staying in bed. Physician consulted. Pneumonia	Other diseases	Total
Mothers	Elementary school-Zone I-0.75 km from ferroalloy plant	17 (17.9)	5 (5.3)	2 (2.1)	0 -	42 (44.2)	66 (69.5)
	Elementary school-Zone II-2 km from ferroalloy plant	17 (21.0)	1 (1.2)	0 -	0 -	19 (23.5)	37 (45.7)
	Elementary school-Zone II-2.75 km from ferroalloy plant	30 (27.0)	8 (7.2)	5 (4.5)	3 (2.7)	29 (26.1)	75 (67.6)
	Elementary school-island	0 -	0 -	0 -	0 -	14 (24.6)	14 (24.6)
Brothers and sisters	Elementary school-Zone I-0.75 km from ferroalloy plant	14 (14.0)	3 (3.0)	5 (5.0)	1 (1.0)	58 (58.0)	91 (91.0)
	Elementary school-Zone II-2 km from ferroalloy plant	13 (17.3)	4 (5.3)	3 (4.0)	1 (1.3)	42 (56.0)	63 (84.0)
	Elementary school-Zone II-2.75 km from ferroalloy plant	25 (24.5)	2 (2.0)	1 (1.0)	2 (2.0)	46 (45.5)	76 (75.2)
	Elemantary school-island	1 (0.9)	0 -	1 (0.9)	0 -	32 (27.6)	34 (29.3)

(continued)

TABLE 80. (Continued)

	Location of school of 2nd Graders	Acute respiratory disease	Acute respiratory disease with elevated temperature	Acute respiratory disease with elevated temperature and staying in bed	Acute respiratory disease with elevated temperature and staying in bed. Physician consulted. Pneumonia	Other diseases	Total
Grandfathers and grandmothers	Elementary school Zone I-0.75 km from ferroalloy plant	1 (4.5)*				1 (4.5)	2 (9.1)
	Elementary school-Zone II-2 km from ferroalloy plant	1 (7.1)					1 (7.1)
	Elementary school-Zone II-2.75 km from ferroalloy plant					3 (16.6)	3 (16.6)
	Elementary school-island						

*The numbers in parentheses denote percents of the total number of persons in particular groups.

TABLE 81. ACUTE RESPIRATORY DISEASE, BEDRIDDEN, ELEVATED TEMPERATURE - PHYSICIAN CONSULTED; BY SCHOOL LOCATION OF 2ND GRADERS (1974-1975)

Location of school of 2nd graders	Disease	2nd graders	Fathers	Mothers	Brothers and sisters	Grandfathers and grandmothers
Elementary school - Zone I-0.75 km from ferroalloy plant	Diseases of the upper respiratory tract	19 (19.4)*	5 (5.5)	14 (14.7)	26 (26.0)	0 -
	Diseases of the lower respiratory tract	18 (18.4)	5 (5.5)	15 (15.8)	22 (22.0)	0 -
	Influenza	7 (7.1)	9 (9.9)	13 (13.7)	10 (10.0)	1 (4.5)
Elementary school - Zone II-2 km from ferroalloy plant	Diseases of the upper respiratory tract	8 (9.5)	6 (7.7)	5 (6.2)	19 (25.3)	0 -
	Diseases of the lower respiratory tract	21 (25.0)	8 (10.3)	8 (9.9)	17 (22.7)	0 -
	Influenza	13 (15.5)	9 (11.5)	6 (7.4)	6 (8.0)	0 -
Elementary school - Zone II-2.75 km from ferroalloy plant	Diseases of the upper respiratory tract	19 (16.7)	9 (8.3)	12 (10.8)	17 (16.8)	1 (5.6)
	Diseases of the lower respiratory tract	24 (21.0)	8 (7.3)	13 (11.7)	22 (21.8)	1 (5.6)
	Influenza	5 (4.4)	8 (7.3)	4 (3.6)	7 (6.9)	1 (5.6)

(continued)

TABLE 81. (continued)

Location of school of 2nd graders	Disease	2nd graders	Fathers	Mothers	Brothers and sisters	Grandfathers and grandmothers
Elementary school - island	Diseases of the upper respiratory tract	11 (18.3)	0 -	4 (7.0)	10 (8.6)	1 (2.2)
	Diseases of the lower respiratory tract	10 (16.7)	7 (13.7)	5 (8.8)	17 (14.7)	4 (8.8)
	Influenza	2 (3.3)	0 -	5 (8.8)	5 (4.3)	1 (2.2)

*The numbers in parentheses denote percents of the total number of persons in particular groups.

TABLE 82. NUMBER OF FATHERS IN COMPARED GROUPS BY HOME LOCATION

Zones according to manganese concentrations in air	N	Mean age	Present & past smokers	Nonsmokers
Zone I	70	38.4 (SD=5.5)*	38 (54.3)	32 (45.7)
Zone II	120	39.0 (SD=6.6)	87 (72.5)	33 (27.5)
Zone III	21	38.7 (SD=5.1)	16 (76.2)	5 (23.8)
Island	21	40.2 (SD=7.7)	13 (61.9)	8 (38.1)

*The numbers in parentheses denote percents.

TABLE 83. NUMBER OF MOTHERS IN COMPARED GROUPS BY HOME LOCATION

Zones according to manganese concentrations in air	N	Mean age	Present & past smokers	Nonsmokers
Zone I	82	34.2 (SD=5.0)*	6 (7.3)	76 (92.7)
Zone II	148	34.6 (SD=5.3)	29 (19.6)	119 (80.4)
Zone III	27	33.6 (SD=4.5)	4 (14.8)	23 (85.2)
Island	39	36.5 (SD=6.3)	7 (25.9)	32 (82.1)

*The numbers in parentheses denote percents.

TABLE 84. RESPIRATORY SYMPTOMS AND FORCED EXPIRATORY VOLUMES IN MEN SMOKERS BY ZONES ACCORDING TO MANGANESE CONCENTRATIONS IN AIR

Zones according to manganese Concentrations in air	N	Phlegm per day		Chronic bronchitis		Regular wheezing in the chest		FVC %		$FEV_{1.0}$ %		$FEV_{1.0}/FVC$ %*	
		f	%	f	%	f	%	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
Zone I	38	6	15.8	7	18.4	2	5.3	94.2	12.2	96.1	17.9	78.5	9.8
Zone II	87	19	21.8	15	17.2	8	9.2	93.9	10.8	97.6	12.2	79.4	6.6
Zone III	16	1	6.3	1	6.3	2	12.5	96.0	10.8	101.4	12.3	81.0	4.2
Island	13	3	23.1	2	15.4	1	7.7	93.4	9.1	98.8	10.9	81.0	5.1

*$FEV_{1.0}/FVC$ (%) I - III $P<0.01$
II - III $P<0.05$

TABLE 85. RESPIRATORY SYMPTOMS AND FORCED EXPIRATORY VOLUMES IN MEN NONSMOKERS BY ZONES ACCORDING TO MANGANESE CONCENTRATIONS IN AIR

Zones according to manganese concentrations in air	N	Phlegm per day		Chronic bronchitis		Regular wheezing in the chest		FVC %		$FEV_{1.0}$ %		$FEV_{1.0}$/FVC %	
		f	%	f	%	f	%	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
Zone I	32	4	12.5	2	6.3	1	3.1	97.1	9.4	102.2	14.1	81.4	8.5
Zone II	33			1	3.0			94.2	14.5	102.5	15.6	83.7	4.6
Zone III	5							93.6	15.2	98.2	15.5	82.6	3.5
Island	8			1				87.8	13.8	94.2	16.4	81.5	8.5

TABLE 86. RESPIRATORY SYMPTOMS AND FORCED EXPIRATORY VOLUMES IN WOMEN SMOKERS BY ZONES ACCORDING TO MANGANESE CONCENTRATIONS IN AIR

Zones according to manganese concentrations in air	N	Phlegm per day		Chronic Bronchitis		Regular wheezing in the chest		FVC %		$FEV_{1.0}$ %		$FEV_{1.0}$/FVC	
		f	%	f	%	f	%	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
Zone I	6			2		1		95.8	7.8	97.4	9.6	81.2	3.1
Zone II	29	1	3.4	2	6.9	2	6.9	95.7	11.3	101.2	13.9	84.2	6.5
Zone III	4							102.7	6.1	107.0	4.5	83.5	2.7
Island	7	1		1				93.4	5.5	99.0	9.1	84.0	3.3

TABLE 87. RESIPRATORY SYMPTOMS AND FORCED EXPIRATORY VOLUMES IN WOMEN NONSMOKERS BY ZONES ACCORDING TO MANGANESE CONCENTRATIONS IN AIR

Zones according to manganese concentrations in air	N	Phlegm per day		Chronic Bronchitis		Regular wheezing in the chest		FVC %		$FEV_{1.0}$ %		$FEV_{1.0}/FVC$ %*	
		f	%	f	%	f	%	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
Zone I	76	1	1.3	3	3.9	1	1.3	92.2	12.0	97.9	13.7	83.9	5.9
Zone II	119	3	2.5	4	3.4	4	3.4	93.5	12.6	99.4	13.1	84.7	6.8
Zone III	23							92.2	10.6	102.3	11.6	88.3	3.2
Island	32							92.4	12.4	98.4	12.9	83.4	6.9

*$FEV_{1.0}/FVC$ (%) I - III $P<0.01$

II - III $P<0.05$

SECTION 9

POSSIBLE CATALYTIC EFFECT OF MANGANESE IN FLUE DUST ON SULFUR DIOXIDE

In order to clarify the possible catalytic effect of manganese containing flue dust on the conversion of sulfur dioxide in the air, this study examined differences in the relationship between sulfur dioxide and sulfur concentrations in a polluted environment and the relationship between the two in a control environment. In addition to manganese, other components in the airborne particulates, such as gaseous ammonia, ammonium ion, iron, lead, and copper, were simultaneously measured. In the first experiments, the temperature and humidity of the air were also recorded. A determination was made of the various relationships among the components in summer, in winter, and at various distances from the manganese source. In addition, the distribution of all the measured particulate components was determined.

At first, it was planned to determine sulfuric acid and sulfate separately. However, as there is no satisfactory method either for preserving sulfuric acid in the free form during the collection and handling of a sample or for separating free sulfuric acid from sulfate, only the total sulfate was determined.

Within another project, the sulfur dioxide/sulfate relationship was studied on other urban and industrial areas, and these data have also been compared in the final evaluation of results.

MATERIALS AND METHODS

Determination of Sulfur Dioxide and Ammonia in the Air

Samples of sulfur dioxide were collected in a 1-percent solution of hydrogen peroxide from 2 m^3 of air over 24 hours. The sulfate formed by oxidation of sulfur dioxide was determined by titration with barium perchlorate in the presence of thorin indicator by means of an EEL titrator (Methods for Measuring Air Pollution, OECD, 1964). Samples of ammonia were collected in a 0.01 percent solution of H_2SO_4 from 2 m^3 of air over 24 hours. The yellow color developed with the Nessler's reagent was measured at 440 μm with a spectrophotometer UNICAM SP 600.

Determination of the Total Suspended Particulate Matter (TSP)

The total suspended particulates were collected on glass fiber filters from about 250 m^3 of air over 24 hours. The filters were washed before use according to the procedure described by Scaringelli and Rehme (1969). Before and after the sampling, they were equilibrated to a relative humidity by a desiccator and weighed.

One quarter of the samples was extracted by distilled water in a Soxhlet apparatus, cations were removed by ion exchange, the solution was evaporated to a small volume, and the sulfate content was determined in the same way as in the sulfur dioxide determination.

From the second quarter of the samples, ammonia was liberated by distillation with 20-percent NaOH and collected in 0.01-percent H_2SO_4. The same method of analysis was applied as for the gaseous ammonia. The third quarter was extracted by nitric acid in a Soxhlet apparatus. The extract was evaporated to dryness in order to remove the acid, and the residue was dissolve in 1-percent EDTA and analyzed by atomic absorption spectrophotometry for manganese, lead, iron, and copper.

Determination of the Distribution of Suspended Particulates

The selective sampling of suspended particulates was measured by means of a modified Anderson cascade impactor on glass fiber filter media, from about 200 m^3 of air over 24 hours. Samples were analyzed in the same way as the TSP samples.

RESULTS

The first set of data was collected simultaneously in June 1974, over 20 consecutive days in an area polluted with manganese dust and in a comparable control area. The arithmetic means and standard deviations of all measured components in the two compared areas are shown in Table 88. The significance of difference between the arithmetic means of the same components in the two areas are presented in Table 89, and the correlation among various components in each area appears in Table 90. The mass median diameters of particulate components and the geometric standard deviations are shown in Table 91.

The second set of data was collected on 59 weekdays between April and September 1975, in the area polluted with manganese dust only. Arithmetic means, standard deviations, and range of results for all measured components are presented in Table 92, and correlation between the components is shown in Table 93. Variations in daily means of the measured components are shown in Figures 5, 6, and 7, and the relationships between sulfate and ammonium ion and sulfate and manganese concentration are illustrated in Figures 8 and 9. The third set of data was collected on 59 weekdays between October 1975 and January 1976. These data were compared with the summer results obtained earlier in 1975. Arithmetic means and standard deviations of both summer and winter results of all measured components are shown in Table 94 and the correlation between the components appears in Table 95.

The fourth set of data was collected simultaneously on 34 weekdays between April and June 1976 at three distances from the ferromanganese plant. Arithmetic means and range of results from all three sites are shown in Table 96 and the correlation between the measured components at each site is given in Table 97.

The results of the first set of data have shown that the correlation between sulfate and ammonium ion was high in the control area, while no correlation was found in the area polluted with manganese dust. In the latter area sulfate was in good correlation with manganese concentration. In both areas there was an excess of sulfate in TSP over the simultaneously present ammonium ion, but the excess was much higher in the polluted area.

It was observed that the sulfate concentration does not rise necessarily with the rising sulfur dioxide concentration, and that if it does, it rises at a much lower rate. Therefore, there is a negative correlation between the SO_4^{--}/SO_2 ratio and SO_2. In all calculations sulfate was expressed as equivalent SO_2 concentration and for simplicity reasons it will be called "sulfate S" in further text. The sum of SO_2 and sulfate (as SO_2) will be referred to as "total S".

The results of the second set of data have confirmed the first findings. As shown in Figures 8 and 9 again, no correlation was found between ammonium and sulfate ion, but a high correlation was observed between sulfate and manganese in the TSP. Both sulfate and manganese were in good correlation with the TSP, as were iron and lead, which may be an indication of their common origin. In contrast, ammonium ion was in no correlation with the TSP or any of the particulate components.

The distribution did not give more information on the possible mechanism of sulfate formation. The largest fraction of sulfate was found in the fourth separation stage, and the largest fraction of manganese in the first. The smaller sulfate particles seem to be combined with ammonium, while the larger probably come from sea salts. The distribution is similar in the polluted and in the control areas.

The seasonal differences in the relationship between sulfur dioxide and particulate components indicate that although lower concentrations of all measured components were found in winter (because of the local climate and a lower production rate in winter), a relatively larger part of the particulate pollution comes from other sources, such as heating, than in summer. In winter the correlation between sulfate and manganese or iron was lower, while between sulfate and ammonia, it was much higher than in summer. The percent of sulfate in the TSP and in the total S was, however, higher in summer (Table 94).

From the last set of data, it is noticeable that both relative and absolute contents of manganese in the TSP decrease with distance from the major source. TSP is the highest at site 1 and the lowest at site 2. The absolute sulfate content is the lowest at site 2, but since the TSP concentration is also the lowest at this site, it actually has the highest relative content of sulfate in the TSP of all three sites. Site 1 has the lowest absolute and relative content of ammonia, and site 2 the highest.

The correlations show that the SO_4^{--}/NH_4^+ relationship varies from practically no correlation at site 1 to a good and a very good correlation at sites 2 and 3 respectively. At the same time the correlation between sulfate and manganese decreases with the distance as does the correlation between manganese and the TSP. On the other hand, the correlation between ammonium ion and TSP increases with the distance from the source.

The results indicate that during transport, manganese particles are partly removed from the air (larger particles may settle down) and partly diluted by dispersion and mixing with dust of other origin. The increase in the relative sulfate content of the TSP from site 1 to site 2 may be due either to a further conversion of sulfur dioxide or to the contribution from other sources, for example, combustion of fuel for various purposes and sea salts.

Most striking in this investigation, as well as in the investigation carried out under another project which studied areas polluted by lead and cement dust and other urban areas, are the characteristic regression equations in urban and industrial areas for the relationship between absolute or relative concentrations of the sulfate S and the total S. The relationship obtained in various areas as well as from the 3-year averages of sulfate and sulfur dioxide concentrations at 15 urban sites in the USA (Altschuller, 1976) are presented in Table 98.

The relationship between the absolute concentrations of the sulfate S and the total S shows a very slow rise of the sulfate S with the total S in the three groups of urban data (slope I_{1-3}: 0.05). The two runs of data in the manganese polluted area show that a higher concentration of the sulfate S than in urban areas for the same total S concentration is obtained in the presence of manganese aerosol (slope $I_{5,6}$: 0.14-0.19). In the presence of cement dust, sulfate formation is further increased (slope I_7: 0.35).

As the slope of equation I increases, the slope of equation II decreases and so does the correlation between the relative portion of the sulfate S and the total S, ending with no correlation at all in the area polluted with cement dust.

These findings indicate that the limitation of sulfur dioxide conversion is significantly influenced by aerosol composition. The mechanisms of these processes could be associated with those occurring in water phase according to experimental data reviewed or obtained by Barrie (1976). These show that both sulfur dioxide absorption and oxidation are pH dependent and slow down below pH 6 unless catalysts like managanese salts are present. Alkaline substances keep both processes going simply by increasing the pH.

To what extent our findings can be attributed to the sulfur dioxide conversion at the relatively low concentrations of manganese and sulfur dioxide in the ambient air and to what extent they reflect the results of the processes within the plume is still to be answered.

TABLE 88. ARITHMETIC MEANS AND STANDARD DEVIATIONS OF ALL PARAMETERS AT TWO SITES

Parameter	Manganese polluted area		Control area	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
SO_2	22.9	11.4	24.6	14.3
SO_4^{--}	13.9	6.8	9.9	3.0
NH_3	5.5	2.0	4.8	1.6
NH_4	2.0	1.6	2.1	1.2
Pb	0.18	0.11	0.13	0.03
Fe	1.3	0.57	0.65	0.22
Mn	3.8	5.1	0.03	0.02
Cu	0.12	0.03	0.09	0.07
t °C	21.7	1.5	22.2	1.3
RH %	63	8.3	75	7.2

TABLE 89. SIGNIFICANCE OF DIFFERENCE BETWEEN THE MEANS OF DATA SHOWN IN TABLE 88

Parameter	$t_{obtained}$	$t_{critical}$	P
SO_2	0.42	2.02	>>0.05
SO_4^{--}	2.42	2.03	<0.05
NH_3	1.06	2.03	>0.05
NH_4^+	0.07	2.03	>>0.05
Pb	1.58	2.03	>0.05
Fe	5.07	2.03	<0.05
Mn	3.29	2.03	<0.05
Cu	2.13	2.03	<0.05
RH	4.95	2.03	<0.05

TABLE 90. CORRELATION BETWEEN SO_4^{--}, SO_4^{--}/SO_2 RATIO AND SO_2 AND OTHER PARAMETERS

Correlated parameters	Correlation coefficients	
	Manganese polluted area	Control area
SO_4^{--} and SO_2	0.00	-0.02
SO_4^{--} and NH_4^+	0.13	0.83
SO_4^{--} and Pb	0.45	-0.35
SO_4^{--} and Fe	0.14	0.36
SO_4^{--} and Mn	0.62	-0.03
SO_4^{--} and Cu	0.28	0.09
Sulfate S and Total S	0.37	0.12
Sulfate S and Total NH_3	0.13	0.54
SO_4^{--}/SO_2 and SO_2	-0.53	-0.63
SO_4^{--}/SO_2 and Mn	0.63	0.03
$\log \frac{\text{Sulfate S}}{\text{Total S}}$ and log Total S	-0.42	-0.73
SO_2 and RH	0.08	-0.26
SO_4^{--} and RH	0.06	0.13

TABLE 93. CORRELATION BETWEEN SO_2, RELATIVE HUMIDITY, AND PARTICULATE COMPONENTS

Correlated parameters	Linear correlation coefficient
SO_4^{--} and SO_2	-0.14
NH_4^+ and SO_2	0.48
SO_4^{--} and NH_4^+	-0.19
SO_4^{--} and Mn	0.77
SO_4^{--} and Pb	0.65
SO_4^{--} and Fe	0.56
SO_4^{--} and Cu	0.23
SO_4^{--}/SO_2 and SO_2	-0.43
SO_4^{--}/SO_2 and Mn	0.32
SO_2 and RH	-0.30
SO_4^{--}/SO_2 and RH	0.33
SO_4^{--} and total suspended particulates	0.84
Mn and total suspended particulates	0.86
NH_4^+ and total suspended particulates	-0.34

TABLE 94. ARITHMETIC MEANS AND STANDARD DEVIATIONS OF SO_2 AND SUSPENDED PARTICULATE COMPONENTS NEAR A FERROMANGANESE FACTORY

Component	Arithmetic mean $\mu g/m^3$		Standard deviation	
	Summer results N = 84	Winter results N = 59	Summer results	Winter results
SO_4^{--}	14.7	8.3	7.6	5.3
SO_2	18.5	13.9	11.1	7.2
NH_4^+	0.9	0.6	0.7	0.6
Mn	5.4	4.1	5.7	6.4
Pb	0.2	0.1	0.1	0.1
Fe	1.1	1.0	0.5	1.3
Cu	0.2	0.2	0.1	0.1
TSP	121.8	96.7	54.9	57.9
SO_4^{--} in % of TSP*	12.1	8.6		
Sulfate S in % of total S	34.6	28.4		

*TSP = Total suspended particulates

TABLE 95. CORRELATION DIFFERENCES BETWEEN SO_2 AND PARTICULATE COMPONENTS NEAR A FERROMANGANESE FACTORY

Correlated components	Linear correlation coefficient	
	Summer results	Winter results
SO_4^{--} and SO_2	-0.04	-0.06
NH_4^+ and SO_2	0.30	0.14
SO_4^{--} and NH_4^+	-0.03	0.64
SO_4^{--} and Mn	0.68	0.43
SO_4^{--} and Pb	0.58	0.75
SO_4^{--} and Fe	0.51	0.23
SO_4^{--} and TSP*	0.79	0.68
Mn and TSP	0.75	0.75

*TSP = Total suspended particulates

TABLE 96. AVERAGE CONCENTRATIONS ($\overline{X}$) AND RANGE OF SUSPENDED PARTICULATE COMPONENTS AT THREE SITES (N = 35 DAYS)

Component	Site 1*		Site 2†		Site 3#	
	$\overline{X}$ µg/m³	Range	$\overline{X}$ µg/m³	Range	$\overline{X}$ µg/m³	Range
SO_4^{--}	15.7	4.7 - 49.0	10.8	5.3 - 23.2	11.6	2.8 - 21.9
NH_4^+	1.2	0.04 - 3.0	1.3	0.1 - 2.3	1.3	0.2 - 3.0
Mn	7.8	0.2 - 46.1	1.2	0.04 - 6.2	1.0	0.03 - 3.9
Pb	0.2	0.03 - 0.3	0.1	0.01 - 0.2	0.1	0.03 - 0.3
Fe	1.9	0.6 - 4.2	0.6	0.0 - 1.5	0.9	0.3 - 2.5
Cu	0.2	0.04 - 1.2	0.01	0.0 - 0.03	0.1	0.02 - 0.7
TSP§	135.6	45.2 - 358.2	68.4	23.0 - 123.3	91.2	31.2 - 183.3
Mn in % TSP	4.4	0.1 - 17.2	1.6	0.1 - 9.3	1.0	0.4 - 6.1
SO_4^{--} in % of TSP	11.8	6.1 - 17.9	16.4	11.0 - 30.1	13.4	6.4 - 23.6

*Site 1 - close to a ferromanganese factory
†Site 2 - 0.75 km away from the factory
#Site 3 - 2.75 km away from the factory
§TSP = Total suspended particulates

TABLE 97. CORRELATION BETWEEN SO_4^{--} AND PARTICULATE COMPONENTS AT THREE SITES

Correlated components	Linear correlation coefficient (N = 35 days) Site 1*	Site 2†	Site 3#
SO_4^{--} and NH_4^+	- 0.08	0.61	0.85
SO_4^{--} and Mn	0.87	0.39	0.33
SO_4^{--} and Pb	0.60	0.26	0.26
SO_4^{--} and Fe	0.70	0.48	0.60
SO_4^{--} and TSP§	0.92	0.78	0.81
Mn and TSP	0.86	0.54	0.31
NH_4^+ and TSP	- 0.18	0.63	0.67

*Site 1 - close to a manganese factory
†Site 2 - 0.75 km away from the factory
#Site 3 - 2.75 km away from the factory
§TSP = Total suspended particulates

TABLE 98. RELATION BETWEEN SULFATE S AND TOTAL S IN VARIOUS AREAS

Area	N	Sulfate S against total S		Sulfate S in % of total S against total S	
		r_I*	Regression equation I	r_{II}	Regression equation II
1. Continental urban site	20	0.40	y=0.05x + 6.12	-0.87	$y = 316x^{-0.74}$
2. Coastal urban site	20	0.12	y=0.02x + 6.11	-0.73	$y = 355x^{-0.83}$
3. 15 urban sites in the USA†	67	0.80	y=0.02x + 7.60	-0.96	$y = 378x^{-0.78}$
4. Continental lead polluted site	20	0.74	y=0.05x + 4.64	-0.73	$y = 91x^{-0.49}$
5. Coastal manganese polluted site (1st run)	20	0.37	y=0.14x + 4.91	-0.42	$y = 107x^{-0.39}$
6. Coastal manganese polluted site (2nd run)	50	0.43	y=0.19x + 4.21	-0.31	$y = 98x^{-0.35}$
7. Coastal cement dust polluted area	50	0.65	y=0.35x - 2.54	0.014	

*r = correlation coefficient

†Calculated from 3-year moving averages reported by Altschuller (1976)

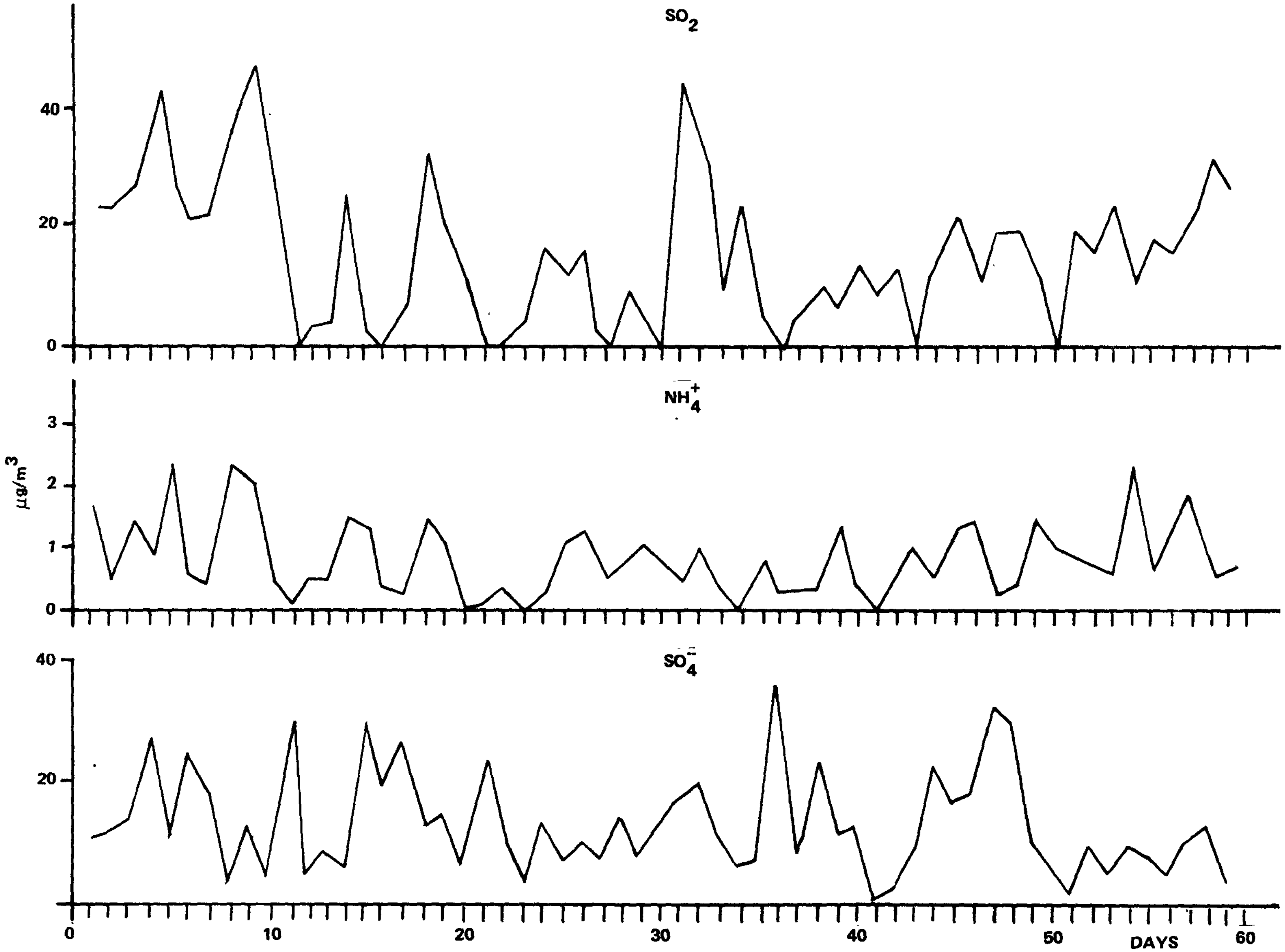

Figure 5. Variations in daily means.

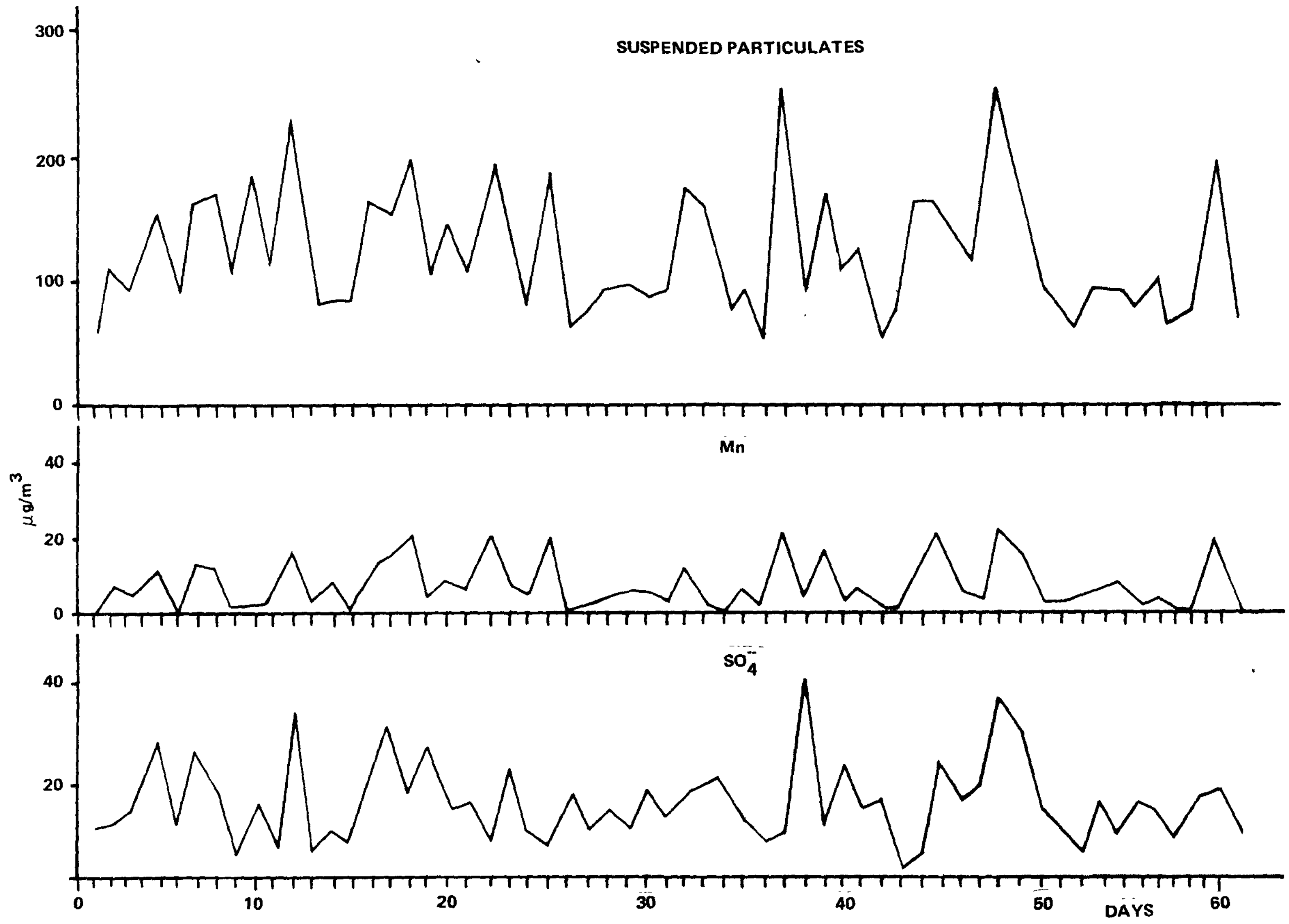

Figure 6. Variations in daily means.

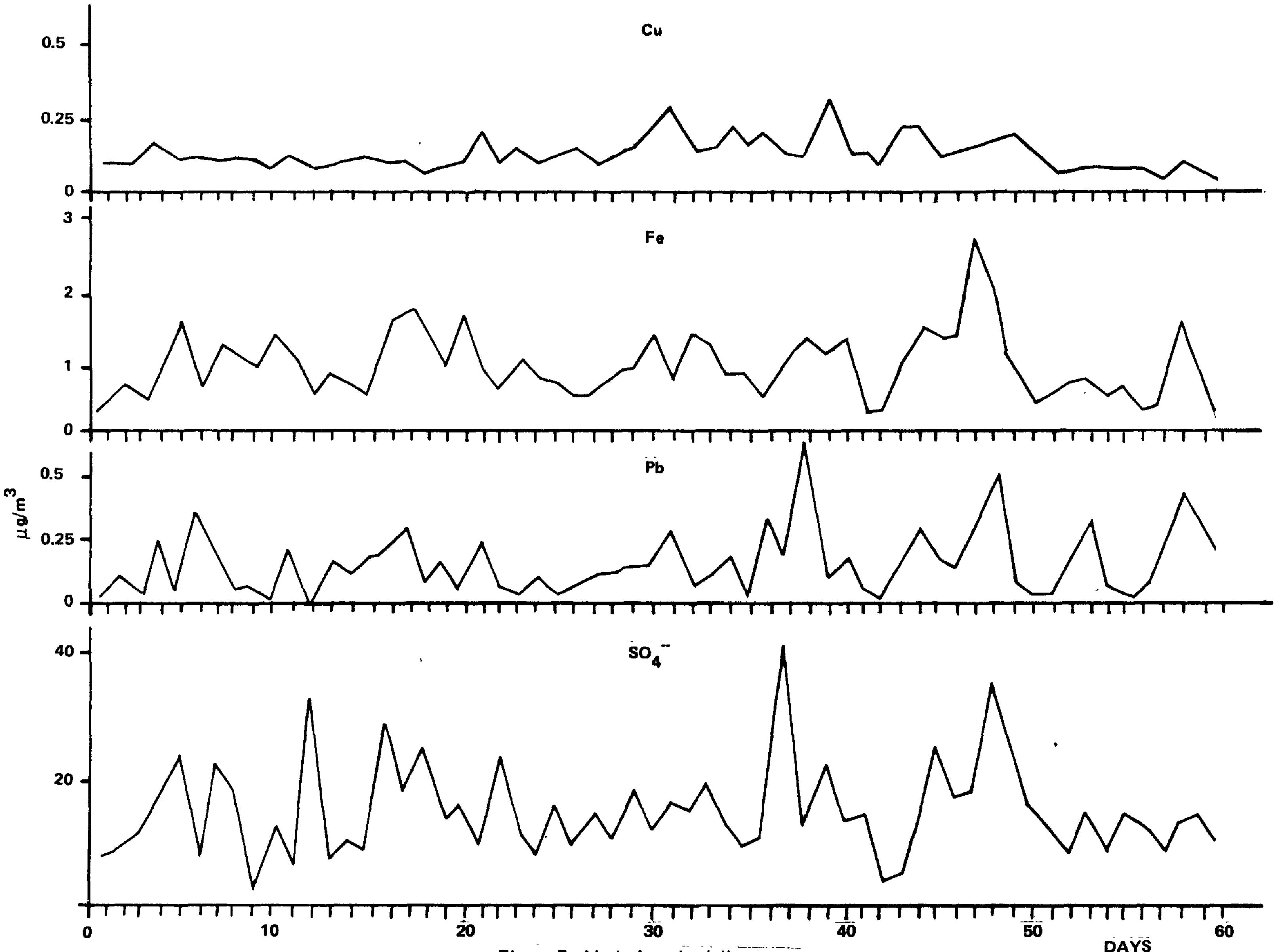

Figure 7. Variations in daily means.

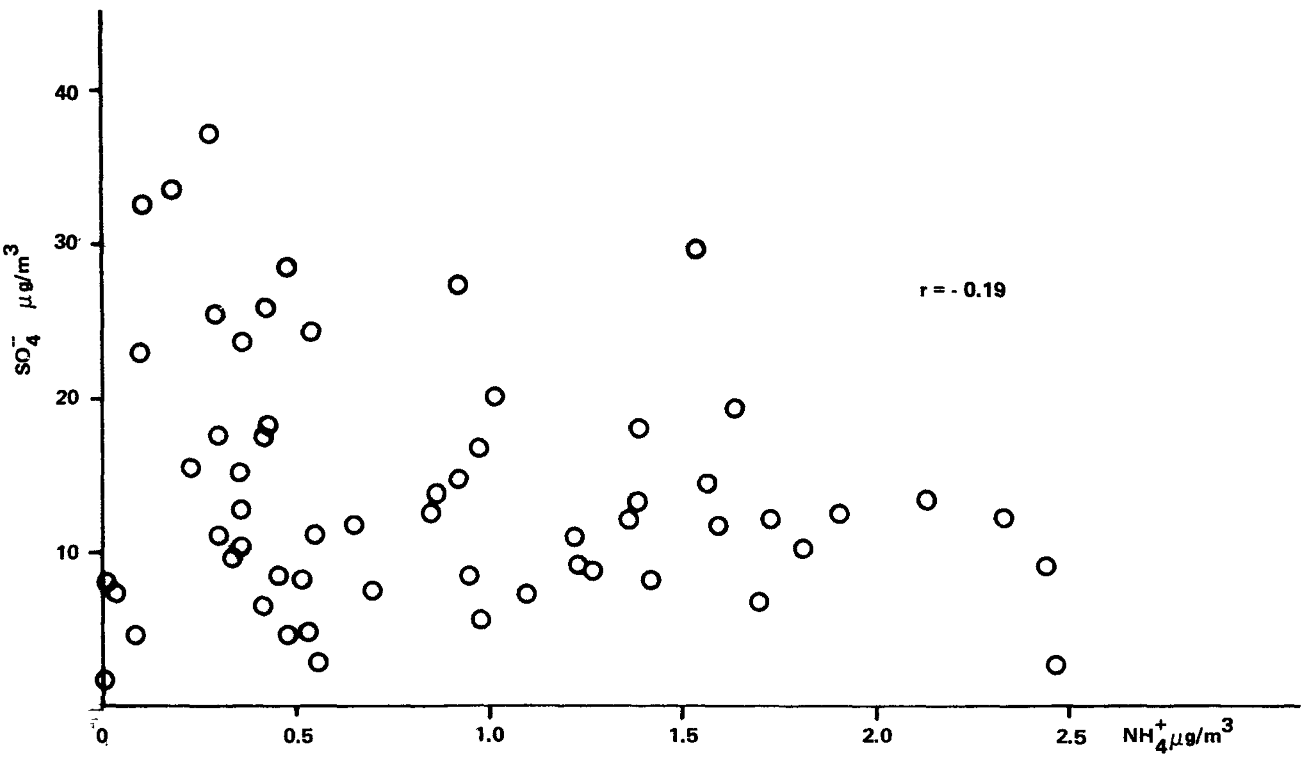

Figure 8. Relationship between sulfates and ammonium concentrations.

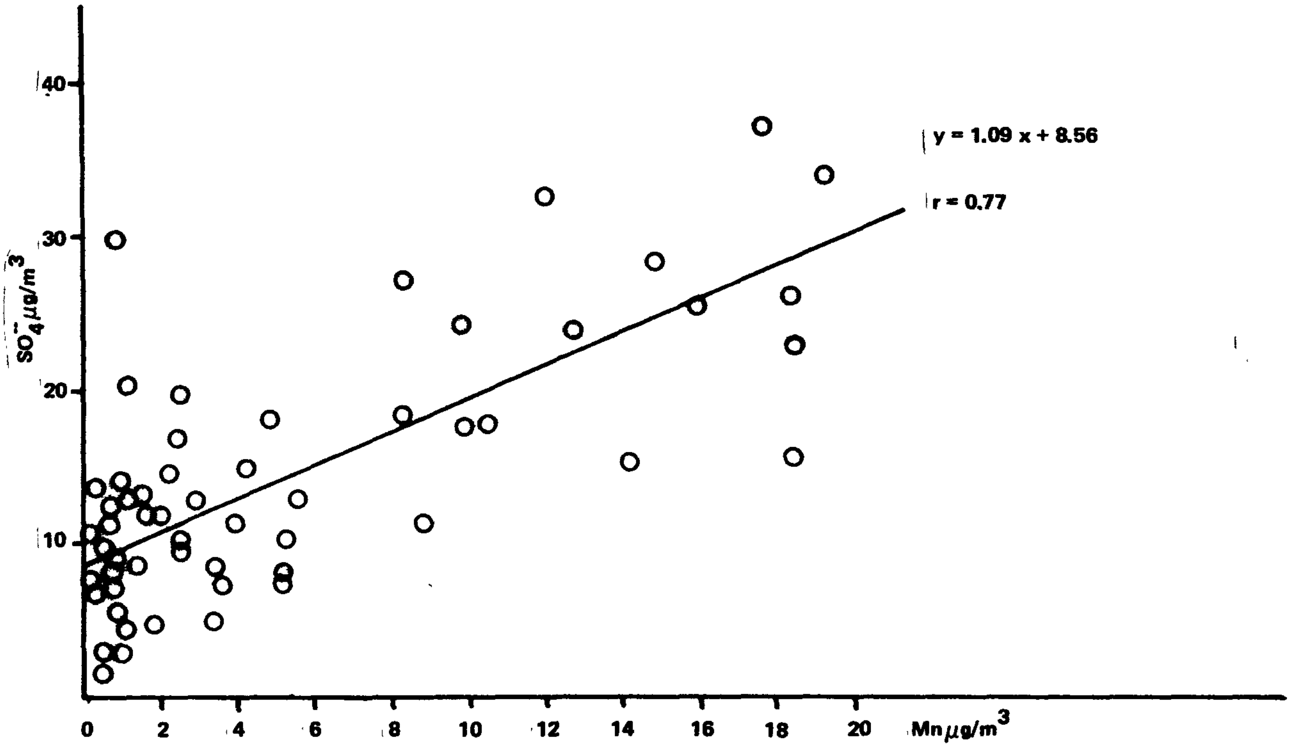

Figure 9. Relationship between sulfates and manganese concentrations.

SECTION 10

DISCUSSION

As early as 1837, John Cooper reported in England a case of occupational disease due to exposure to manganese. The description, however, remained forgotten for a whole century. Not before 1901 did Jaksch in Prague and Emleden in Hamburg provide an accurate clinical description of manganism.

Cases of manganese poisoning have been observed in mining and manganese ore processing industries. In manganese mines, particularly in the rich deposits, miners inhale a dust containing manganese dioxide. A large use of manganese in industry represents a potential source of occupational manganese poisoning. The use of manganese in metalurgy is particularly important, as nine-tenths of the entire manganese production represent the manufacture of manganese alloys which are of utmost importance in the steel industry. Besides occupational exposure of workers, an important problem relates to the exposure of the population residing in the vicinity of manganese processing factories. And organo-manganese fuel additives, though presently a minor source of exposure to manganese, could significantly increase exposure if they come into widespread use.

While the effect of manganese on the central nervous system has been quite well known, the action of manganese on the lung still remains to be explained definitely. The notion of "manganese pneumonia" (manganese pneumonitis) has been created mainly on the basis of epidemiological observations. The association between the exposure to manganese and a high rate of pneumonia was first suspected by Brezina (1921) and then described by Baader (1933). In 1939, Elstad reported a high rate of pneumonia among the residents of Sauda, a small Norwegian town, after the opening of a manganese ore smelting works. A high incidence of pneumonia in manganese exposure has also been reported by other authors (Povoleri, 1947; Rodier, 1955). In addition to these observations concerning "manganese pneumonia" in humans, Lloyd Davies (1946 and 1949) succeeded in inducing acute changes in the lungs of animals after inhalation of manganese dioxide.

Since the beginning of the era of sulfonamides and antibiotics, the possible toxic effect of manganese on the lungs has been overshadowed by its definitely much more important effect on the central nervous system. On the other hand, it is true that in the meantime, no increase in pneumonia incidence from exposure to manganese has been recorded. Only recently have there been once again some reports suggesting an influence of manganese on the rate of pneumonia and other respiratory ailments in groups of workers exposed to manganese and in inhabitants living in the vicinity of a factory manufacturing ferromanganese (Suzuki, 1970; Nogawa et al., 1973; Kagamimori et al., 1973).

The results of our investigations also indicate a higher rate of pneumonia in occupational exposure to manganese. In the ferroalloy plant which was included in our study, the level of exposure to manganese followed the fluctuations in the manufacture of ferromanganese. These fluctuations were primarily influenced by occasional restrictions in the supply of electricity. Manganese concentrations measured in the plants ranged from 0.147 to 20.442 mg/m^3 (mean values for 8-hour work). Although it is impossible to reconstruct exactly the level of exposure to manganese in the conditions of the study, and to compare it with fluctuations in the morbidity from pneumonia, the fact is that the average rate of pneumonia for the analyzed period was higher in the manufacture of ferromanganese than in two other groups of workers, one of which worked in the neighboring electrode plant with a measured exposure level from 0.002 to 0.302 mg/m^3. Morbidity from pneumonia in this group did not differ significantly from the morbidity in the other group with an average exposure to manganese below 0.1 µg/m^3.

The investigations performed over 4 years in the population of the town with the ferroalloy factory did not show the expected significantly higher rate of pneumonia. Nor was a more constant difference observed in the rate of pneumonia with regard to the level of ambient exposure to manganese in different residential areas of the town. While this level in two zones of the town was within mean yearly values, ranging from 0.164 to 0.390 µg/m^3, in the third zone it amounted to 0.042-0.099 µg/m^3, a range 4-5 times lower than in the other two zones. As pointed out in the description of measurements and sampling technique, the listed concentrations refer mainly to the particles which belong to the respirable fraction. This means that the values obtained must be multiplied by a factor of approximately 3-5 in order to obtain the total concentration of manganese in air.

It is interesting to note that the analysis of the rate of pneumonia in the population of the town did not show the expected difference between summer and winter periods. Since the concentrations of manganese in the ambient air were higher in the summer period than in winter, the question is raised of whether this finding might not be, to a certain extent, associated with observed seasonal variations in the level of manganese. This connection, however, is still an assumption without enough firm evidence to establish it as fact. Consequently, it is possible to conclude with comparative certainty that the rate of pneumonia is influenced only by the exposure to manganese which is at the level of occupational exposure in the production of manganese alloys.

A higher rate of acute bronchitis was recorded at a level of comparatively low ambient exposure to manganese of about 1 µg/m^3. Still, it is possible that some other factors, which had not been controlled, might have influenced the obtained results and relationships. Provided that a higher incidence of cute bronchitis is associated with the described exposure, the question remains as to whether this respiratory effect can be exclusively attributed to manganese or perhaps to the synergistic action of manganese aerosol and sulfuric acid, i.e., sulfates adsorbed on the surface of manganese particles.

It is generally known that sulfur dioxide reacts readily with manganese dioxide to form manganese sulfate. Data also exist about the catalytic action of Mn^{2+} ions on the oxidation of sulfur dioxide in aqueous solutions. (Bracewell and Gall, 1967). Accordingly, it might be assumed that in the fuel gases of the manganese processing industrial plants, a rapid oxidation of sulfur dioxide could occur, catalyzed by the manganese particles. The process might continue during the dispersion of emissions in the surrounding atmosphere, including in the reaction the sulfur dioxide emitted from other sources.

The results of the investigations performed within our study under natural conditions also indicate the catalytic action of manganese. The question still remains as to what extent our findings refer to the conversion of sulfur dioxide at comparatively low concentrations of manganese and sulfur dioxide in the ambient air.

At any rate, regardless of whether manganese produces a biological effect or acts in combination with sulfuric acid, the action seems to be primarily manifest by a disturbance of immunobiological properties of the organism (the effect on the ciliary epithelium, the inhibition of alveolar macrophages, etc.), and by a growing predisposition to infection. Most probably, a higher rate of pneumonia as it is associated with the exposure to manganese could be explained in the same way.

Two separate studies on the relationship between the incidence of acute respiratory diseases and exposure to manganese performed in groups of school children and their families did not give convincing results that these diseases depend on the level of the exposure to manganese.

Still, the data show that the incidence of respiratory diseases was somewhat higher in the town with a ferromanganese plant than in the control area. In the town with the ferroalloy plant, no consistent differences were found between the zones in which the school, attended by the children included in the studies, are located. However, there was a tendency towards a decrease in the rate of acute repiratory disease as well as towards a slight increase of forced expiratory volumes in children as one moves further from the ferroalloy plant. As methodologically sound and conscientiously performed as these studies may be, we are still confronted with the number of interfering factors that cannot be completely controlled. Consequently, the interpretation of results is rather complex. In view of other approaches applied in our investigations, the most important is that the results obtained in these two studies have not denied the results obtained by other methods. If we compare them with the results of a 4-year followup of the incidence of acute respiratory diseases in the popoulation of the town with the ferromanganese manufacture, it should be pointed out that the children living in the zone with the lowest ambient exposure to manganese attend school and spend a part of the day in the zone where the concentration of manganese in air is higher. The same applies, to a greater or lesser extent, to the members of their families. This situation also might have influenced the results.

In addition, it is worth noting that the concentrations of total suspended particulates, as well as of sulfate concentrations, seems to be higher in the central part of the town than in the part nearest to the ferroalloy plant.

The problem of chronic respiratory symptoms as associated with manganese exposure has never been studied separately. The results of our investigations indicate that a higher rate of chronic nonspecific lung disease can be expected from occupational exposure to manganese. A possible synergism between the exposure to manganese and smoking may enhance this effect.

Our investigation supports the results reported by other authors who have shown that a neurological effect of manganese is manifest in a relatively small number of subjects, even in conditions of a comparatively high level of exposure. More developed pictures of manganese poisoning are even more rarely found. The worker with a clinical diagnosis of manganese poisoning (initial period with extrapyramidal symptoms) in our investigation did not show, at the time of examination, any signs of anemia; that is, he did not have low values of serum iron, which are considered indicative of the degree of manganese absorption and toxicity (Mena et al., 1969).

A possible hypnotic effect of manganese on systolic blood pressure represents an interesting and original finding as well. It is suggested that such an effect of manganese might be produced through the heart muscle. This hypothesis, of course, needs verification, just as we need to investigate more precisely whether the observed hypnotic effect of manganese on systolic blood pressure is persistent or whether it is manifest only temporarily at a certain level of exposure.

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16. ABSTRACT

The biological effects of manganese were studied in a town on the coast of Dalmatia in which a ferromanganese plant has been operating since before World War II The study focused on the question of whether the exposure to manganese can cause a higher incidence of respiratory diseases and, if it can, at what exposure levels. The study also considered the effects of manganese on the central nervous system and on blood pressure as well as a possible catalytic effect of dust containing manganese on the conversion of sulfur dioxide in the air.

The results obtained show that the rate of pneumonia is influenced by the exposure to manganese at the level of occupational exposure in the production of manganese alloys. During a 4-year follow up a higher rate of acute bronchitis was recorded at an ambient exposure to manganese at a level of one microgram per cubic meter. The study also indicates that a higher rate of chronic nonspecific lung disease can be expected in occupational exposure at this level. The investigation supports the obaservations of other authors that a developed neurological effect of manganese is present in a very small number of subjects, even in conditions of a comparatively high exposure. At the level of occupational exposure a hypotonic effect on systolic blood pressure was observed.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Manganese Ferromanganese Absorption (biology) Toxicity Air pollution Biological surveys Exposure	Dalmatia Yugoslavia	06 C, F, T

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