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*THE CONCENTRATION OF CADMIUM IN URINE  
THE INHABITANTS OF OSLO-NYDALEN AND SØRUMSAND  
AS A FUNCTION OF AIR CADMIUM AND OTHER  
CONCOMITANT FACTORS*

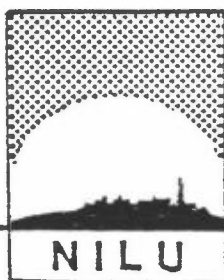
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**FOREWORD**

This report describes work done within the content of a larger investigation "Lead in blood in inhabitants of Oslo-Nydalen exposed to air lead both from industrial and vehicular sources". The main report of this study (Clench-Aas, et al., 1985) contains a detailed description of methodology used.

Urinary cadmium concentrations were also measured in the inhabitants of Holmestrand and Sørumsand in May 1984. When analysis of the later study is completed a summary report will be issued including Oslo-Nydalen, Sørumsand and Holmestrand that will include detailed methodology.

## SUMMARY

Cadmium concentrations in the urines of men, women and children living in an industrialized area of Oslo, Nydalen, were measured together with amounts of ambient cadmium in January-February 1984. These values were compared to those values measured in a control area Sørumsand, in May 1984. Ambient concentrations of cadmium in Oslo-Nydalen (mean values at the four stations varied from 1.4 to 6.3 ng/m<sup>3</sup>) were lower than those values measured in industrialized areas in other countries or in Sulitjelma. The control area Sørumsand had ambient cadmium concentrations that were slightly higher than other Norwegian background stations (0.65 ng/m<sup>3</sup>). Despite higher ambient values of cadmium in Oslo-Nydalen than in the control area of Sørumsand, no significant differences were measured between the two sites in concentrations of cadmium in the urine. In addition, concentrations of urinary cadmium compared well with values measured in Stockholm, Sweden. These values do not give reason to suspect that the body burden of cadmium in the population living in Oslo-Nydalen is too high.

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## *THE CONCENTRATION OF CADMIUM IN URINE IN THE INHABITANTS OF OSLO-NYDALEN AND SØRUMSAND AS A FUNCTION OF AIR CADMIUM AND OTHER CONCOMITANT FACTORS*

### **1 INTRODUCTION**

Information is generally available on the concentration of cadmium in the urine of occupationally exposed individuals. However, very little information is available on typical concentrations of urinary cadmium in the general population of Norway. Thus in 1984, the Norwegian Institute for Air Research (NILU) in cooperation with the Institute of Occupational Health and the City Health Department, Oslo decided to expand an investigation of blood lead concentrations in populations exposed to air lead to include urinary and ambient cadmium. Some cadmium is released into the air from industrial sources in the Oslo region. Therefore a control area, Sørumsand, having no industrial sources, was included for comparison.

Cadmium slowly builds up in the kidneys of exposed individuals over a lifetime, therefore urinary cadmium, reflects long-term exposure, not recent exposure.

### **2 METHODOLOGY**

#### **2.1 OVERALL DESIGN**

The overall design of this series of investigations is described in detail in the reports covering exposure to lead in air in Holmestrand and Oslo-Nydalen (Clench-Aas, et. al., 1984, and Clench-Aas et al., 1986). This study attempts to examine the relationship of ambient cadmium concentrations on urinary cadmium in adults and children exposed to moderate to low ambient cadmium, taking into account confounding factors such as age, sex, social class, smoking habits, etc.

## 2.2 EXPOSURE TO AIR CADMIUM

Ambient cadmium was measured using low-volume samplers placed in four areas in the experimental area and one in downtown Oslo. In order to compare these values with a control area, we include values from samples measured at two stations in Sørumsand. Cadmium was measured by electrothermal atomic absorption spectrometry.

Individual air cadmium exposure was estimated by combining information on weekly activity patterns from a self-administered questionnaire with both measured and estimated ambient cadmium concentrations. Ambient cadmium concentrations were measured for at least a 30 day period, and the values entered into a model that allows exposure to the previous two weeks ambient cadmium to be estimated taking into account time spent indoors, outdoors, jogging etc. Even though urinary cadmium reflects long-term and not short-term exposure, it was felt that this exposure estimate should reflect general trends of cadmium exposure in the population.

## 2.3 BIOLOGICAL VARIABLES

Urinary cadmium was measured by electrothermal atomic absorption spectrometry. Urinary creatinine was also measured in order to standardize the urinary cadmium values for urine concentration. All values where measured creatinine were under 5 (strongly diluted urine), or over 25 mmol/l (strongly concentrated urine) were excluded from data analysis.

## 2.4 SOCIO-ECONOMIC VARIABLES

The self-administered questionnaire also included information on additional cadmium exposure via hobbies and occupation, and other socio-economic parameters such as smoking (both active and passive), alcohol consumption, use of vitamins and iron supplements, eating of snow in children, sex, age, occupation, etc.



### 3 RESULTS

#### 3.1 AMBIENT CADMIUM CONCENTRATIONS

Table 1 gives means and standard deviations in addition to minimum and maximum values measured at each of the outdoor stations. During the Oslo-Nydalen investigation that took place in the winter of 1984, measurements were also made in downtown Oslo (St. Olavs gate). Sørumsand was chosen as a control area, having no local sources of ambient cadmium.

It is evident looking at Table 1 that ambient concentrations of cadmium in the Nydalen area are higher than those measured in Sørumsand. Maximum values are 2.3 and 5.7 ng/m<sup>3</sup> in Sørumsand, whereas they are between 6.7 and 29.9 ng/m<sup>3</sup> in Oslo. It should be pointed out that values in Sørumsand were measured in May, whereas those in Oslo-Nydalen were measured in January and February. Meteorological conditions lead to seasonal variations in ambient concentrations of cadmium. Differences in annual means of the two locations are most likely not as large as these values indicate. The four stations in the Nydalen area are placed to the north, south, east and west of an industrial area that releases some cadmium into ambient air. Examination of the values in Table 1, indicates that the stations to the south and west of the complex have the highest values. Thus it is possible that the high values measured further south in downtown Oslo (highs of 12.7 ng/m<sup>3</sup>) reflect in part, transport from the industrial zone into the center of town.

Table 2 shows selected values measured in February 1971 at sites relatively near the ones used in this study in the Oslo-Nydalen area. These values thus represent concentrations measured before bag-filters were installed in one of the factories. The pattern is very similar to the one seen in this study. The dates were selected to represent various meteorological conditions in the month of February. The values in Table 2 are only for a few selected dates and therefore do not represent mean values for the month of February. They are probably higher than average values. The highest values, 24 and 28 ng/m<sup>3</sup>, were measured to the south and to the west of the industrial complex. These values are similar to the maximums measured in this study.

Table 1: 24-Hour ambient cadmium concentrations ( $\text{ng}/\text{m}^3$ ) in Oslo, January-February 1984 and Sørumsand, May 1984.

	Oslo-Nydalen * <sup>1</sup>					Sørumsand* <sup>2</sup>	
	W * <sup>3</sup>	S	E	N	Down-town	St. 1	St. 2
Mean	2.45	6.32	1.37	2.07	2.08	0.64	0.86
Standard deviation	4.89	7.71	1.52	2.90	2.45	0.47	1.17
No.	42	40	33	39	29	22	29
Min.	0.07	0.10	0.13	0.22	<0.05	<0.26	<0.26
Max.	29.9	25.5	6.73	10.87	12.7	2.26	5.74

\*1 All values were measured in January-February 1984.

\*2 All values were measured in May 1984. Sørumsand is a control town with no local sources of ambient cadmium.

\*3 Directions, refer to direction of sites with respect to the industrial sources.

Table 2: 24-Hour ambient cadmium ( $\text{ng}/\text{m}^3$ ) measured in Oslo in February 1971, before bag filters were installed in one of the factories. Stations were relatively near the ones in this study.

Station Date	Ullevål sykehus	Sagene	Grefsen	St. Olavs plass
Closest study site in this study	W	S	E	Downtown
Dates * <sup>1</sup> 4-5/2	7	11	7	9
10-11/2	11	8	4	7
11-12/2	7	4	4	1
24-25/2	4	13	3	3
7-8/3	24	28	6	8

\*<sup>1</sup> Dates were selected to reflect different meteorological conditions.  
Source: Joranger et al., 1977.

Table 3 attempts to relate the ambient cadmium values measured in this study with those measured elsewhere in Norway and in the Common Market. The values measured in Sørumsand are equivalent or slightly higher than Norwegian background values whereas they are substantially lower than European rural values. The downtown Oslo values are slightly higher than most smaller Norwegian towns. The values measured at Oslo-Nydalen are below those measured at Sulitjelma or Sauda. They are also lower than the European industrial sites, being more comparable to European urban values.

Table 3: Ambient levels of cadmium (ng/m<sup>3</sup>) in Norway and in the Common Market.

NORWAY* <sup>1</sup>		INTERNATIONAL* <sup>2</sup>							
Location	Rural	Location	Urban	Location	Industrial	Location	Rural	Urban	Industrial
		THIS STUDY							
		Oslo	2.1	Oslo-Nydalen	1.37-6.32	U.K.	1-2.7	3.6-8.9	200-11000
		Sørumsand	0.7-0.9						16.5-40
Birkenes	.11-.34 <sup>1</sup>	Halden <sup>3</sup>	1-1.5 <sup>3</sup>	Sulitjelma	60-180 <sup>2</sup>	Belgium	4-6	8-15	18-54
Vasser	.30-.46 <sup>1</sup>	Askim	4 <sup>3</sup>	Notodden	5.4 <sup>3</sup>	FRG	2.1	6.1	
Svanvik	.49 <sup>4</sup>	Moss	1 <sup>3</sup>	Sauda	6-15 <sup>3</sup>	Netherlands	5		
Jergul	.13 <sup>4</sup>	Sarp./Fred.	0.5-1.0 <sup>3</sup>			France		20	
		Lillestrøm	1-8 <sup>3</sup>						
		Hamar	1-3 <sup>3</sup>						
		Kongsvinger	0.5 <sup>3</sup>						
		Gjøvik	2.5-6 <sup>3</sup>						
		Lillehammer	0.5-2 <sup>3</sup>						
		Slemmestad	0.5-1 <sup>3</sup>						
		Larvik	0.5 <sup>3</sup>						
		Sandefjord	0.5 <sup>3</sup>						
		Eydehavn	1.5-2.0 <sup>3</sup>						
		Kristiansand	1.0 <sup>3</sup>						
		Vennesla	0.5 <sup>3</sup>						
		Stavanger	1.5 <sup>3</sup>						
		Mongstad	1-4.5 <sup>3</sup>						
		Alvik	0.5-1.0 <sup>3</sup>						
		Høyanger	2-4 <sup>3</sup>						
		Svelgen	0.5-1.0 <sup>3</sup>						
		Årdal	2 <sup>3</sup>						
		Trondheim	0.5-1.0 <sup>3</sup>						
		Kopperå	1.0-1.5 <sup>3</sup>						
		Mosjøen	0.5-2.5 <sup>3</sup>						
		Narvik	0.5 <sup>3</sup>						
		Mo i Rana	0.5-1.0 <sup>3</sup>						
		Finnsnes	0.5-1.0 <sup>3</sup>						
		Tromsø	0.5 <sup>3</sup>						
		Honningsvåg	0.5 <sup>3</sup>						
		Kirkenes	0.5 <sup>3</sup>						

\*1 Values come from 1) Semb, 1978; 2) Sivertsen and Hanssen, 1983; 3) Hagen, 1977 and 4) Hagen, 1981 and represent 24-hour values.

\*2 Values are summarized in Hutton, 1982.

\*3 Values from Hagen, 1977 are from a few selected samples. These means are probably higher than a monthly mean for each area.

### 3.2 URINARY CADMIUM CONCENTRATIONS

Urinary cadmium concentrations were standardized for creatinine to facilitate comparison of individuals and population groups. Therefore, the parameter used for data analysis was urinary cadmium (nmol/l)/urinary creatinine (mmol/l). As mentioned earlier all values where creatinine was measured as under 5 or over 25 mmol/l were considered too dilute or too concentrated, and removed prior to data analysis. A step-wise multiple regression analysis of U-Cd/U-Cr as dependent variable was run with the following independent variables: age; passive smoking in children and smoking in adults; air cadmium exposure estimate; sex; social class; cadmium related hobbies in adults; and measuring site in Oslo-Nydalen and Sørumsand. The variables age, age squared and smoking were significantly correlated to U-Cd/U-Cr. Ambient cadmium, sex, social class, measuring site and cadmium related hobbies were not significantly correlated to U-Cd/U-Cr (Table 4). Because of the significance of age and smoking the values were tabulated by 10 year age groups and by smoking habits (Tables 5 and 6) for easier comprehension for both Oslo-Nydalen and Sørumsand. The results found by the step-wise multiple regression analysis are confirmed in these tables. The data is also visually presented in Figures 1 to 4. U-Cd/U-Cr values are not normally distributed, therefore median values were chosen for the graphs.

Examination of Table 5 reveals an interesting difference between the sexes in Oslo-Nydalen, where females have higher values than males between the ages of 30 and 70 that is non-existent or reversed in Sørumsand.

It is thus evident that despite higher ambient cadmium in Oslo-Nydalen, than in Sørumsand, urinary cadmium concentrations in the population are not higher in Oslo-Nydalen. The significant correlations of smoking and age in these populations are well-known findings.

#### 4 DISCUSSION

It is clear when comparing the results from Sørumsand with Oslo-Nydalen that, despite higher ambient values of cadmium in the Oslo-Nydalen area than in Sørumsand, no greater long-term accumulation of cadmium in the kidney occurred in the Oslo area that could be attributed to exposure to ambient concentration of cadmium. The significant correlations of smoking and age with U-Cd is a well-known phenomenon frequently reported in the literature.

In order to discuss the comparability of Norwegian values to those reported internationally, urinary cadmium uncorrected for creatinine were compared to values from Sweden, Japan and the United States (Kjellstrøm, 1979; and Kowal et al., 1979). The values are summarized in Tables 7 and 8. It is difficult to compare values in a univariate table when two variables, both smoking and age, have strong impact on urinary cadmium. In Table 7, values were divided by age group but Swedish values only included nonsmokers, Japanese values both smokers and non-smokers, and the United States values both males and females and both smokers and nonsmokers. The Norwegian data includes both smokers and non-smokers, but separates males and females. Norwegian values lie clearly above those from Sweden, but this may purely reflect the effect of smoking. The Norwegian values lie under those of Japan, but seem similar to the values measured in Dallas, yet lower than those measured in Chicago.

In order to compare the Norwegian and the Swedish values with each other, we retabulated using male non-smokers only. Because of the sharp reduction in sample size, only values for age groups 10-19 (0.19  $\mu\text{g/l}$ ), 30-39 (0.19), and 40-49 (0.47) are relevant. These values indicate that the Norwegian levels of cadmium in urine are comparable to the Swedish values.

Table 8 compares urinary cadmium in smokers and non-smokers and indicates that Norwegian values closely resemble those measured in Dallas and lower than those measured in Chicago. Former smokers is a poorly defined category that is strongly influenced by how long the smokers had been smoking before they quit, and the time elapsed since quitting.

Table 4: Step-wise multiple regression analysis of urinary cadmium standardized for creatinine against age, smoking, air cadmium, sex, social class, cadmium related hobbies and town in adults in Oslo-Nydalen and Sørumsand. Values represent U-Cd(nmol/l)/U-Cr(mmol/l).

LAST STEP - COEFFICIENT TABLE												
VARIABLES IN EQUATION :												
(CONSTANT= -0.4363) I VARIABLES NOT IN EQUATION :												
B	F TO	P-VALUES	STANDARDIZED	BETA	95% CONF.	INT.	I	PARTIAL	F TO			
ID	COEFFICIENT	STD.ERROR	FOR B	B (R.PART)	UPPER	LOWER	I	ID	CORR.	TOLERANCE	ENTER	ENTER
0	0.029	0.008	0.001	1.0716	0.0447	0.0125	I	266	-0.0045	0.9879	0.0039	
14	-0.000	0.000	0.035	-0.6491	-0.0000	-0.0003	I	73	0.1044	0.9300	2.1286	
31	0.136	0.033	0.000	0.2539	0.2014	0.0710	I	78	0.0811	0.9486	1.2791	
							I	7	0.0103	0.9786	0.0205	
							I	46	0.0985	0.3375	1.8917	
							I	53	0.0317	0.9949	0.1946	

SUMMARY TABLE :												
STEP NR.	MULT.R	MULT.RSQ	INCREASE IN RSQ	RESIDUAL EFFECT	F-VALUE FOR E/I	VAR. NR ENTER	REMOVED	VAR. NAME				
1	0.4273	0.1026	0.1026	0.9041	43.772	0		AGE				
2	0.5020	0.2520	0.0702	0.8644	18.323	31		SMOKING				
3	0.5194	0.2690	0.0170	0.8545	4.511	14		AGE * AGE				

\*\*\*\*\* F-LEVELS ( 4.000 , 3.900) OR TOLERANCE INSUFFICIENT FOR FURTHER STEPPING \*\*\*\*\*

Occupationally exposed individuals excluded from the data set prior to data analysis.

Table 5: Cadmium concentrations in urine by 10 year age groups in Oslo-Nydalen.  
 Values represent U-Cd (nmol/l)/U-Creatinine (mmol/l)

City	Age group	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-
O S L O	Mean	0.34	0.24	0.50	0.41	0.43	0.72	1.05	1.84	0.85	0.84
	St. Dev.	0.21	0.19	-	0.31	0.27	0.12	0.38	1.36	0.34	-
	N	35	52	1	41	36	4	2	6	5	1
	Median	0.31	0.20	-	0.29	0.38	0.71	0.78	2.15	0.94	-
	Mean	0.30	0.45	0.33	0.58	0.67	1.21	1.50	0.77	0.65	0.67
	St. Dev.	0.23	1.09	0.05	0.56	0.39	0.97	0.81	-	0.29	0.26
S Ø R U M S A N D	N	33	37	2	66	28	3	3	1	11	4
	Median	0.29	0.22	0.30	0.45	0.61	1.11	1.54	-	0.57	0.55
	Mean	0.26	0.20	0.22	0.43	0.60	0.57	0.86	-	1.59	-
S Ø R U M S A N D	St. Dev.	0.10	0.08	-	0.24	0.43	0.24	0.44	-	-	-
	N	4	8	1	8	5	4	2	-	1	-
	Median	0.20	0.19	-	0.34	0.53	0.55	0.55	-	-	-
S A N D	Mean	0.39	0.26	0.32	0.48	0.59	0.70	0.32	-	-	2.28
	St. Dev.	0.23	0.06	-	0.19	0.36	0.23	-	-	-	-
	N	6	6	1	14	16	6	1	-	-	1
S A N D	Median	0.39	0.25	-	0.41	0.44	0.82	-	-	-	-

Occupationally exposed individuals excluded for analysis from the data set prior to data analysis.

Table 6: Urinary cadmium values as a function of smoking.  
 Values represent U-Cd (nmol/l)/U-Creatinine (mmol/l)

	CHILDREN		WOMEN				MEN			
	Not exp. pas. smok.	Expos. pas. smok.	Never smoked	Prev.	Occas.	Smoker	Never smoked	Prev.	Occas.	Smoker
Oslo-Nydalen:										
Mean	0.30	0.27	0.49	0.83	1.02	0.76	0.42	0.44	0.38	0.81
St. Dev.	0.21	0.22	0.35	0.52	1.73	0.64	0.30	0.30	0.28	0.81
N	78	61	63	17	15	33	37	23	10	32
Median	0.30	0.24	0.44	0.77	0.40	0.55	0.42	0.33	0.29	0.55
Sørumsand:										
Mean	0.27	0.50	0.55	0.60	0.59	0.61	0.35	0.92	0.44	0.63
St. Dev.	0.12	0.38	0.47	0.43	0.28	0.22	0.19	0.46	0.39	0.36
N	17	2	19	10	5	7	6	4	7	6
Median	0.23	0.42	0.42	0.41	0.61	0.61	0.33	0.77	0.26	0.74

Occupationally exposed individuals excluded from data set prior to data analysis.



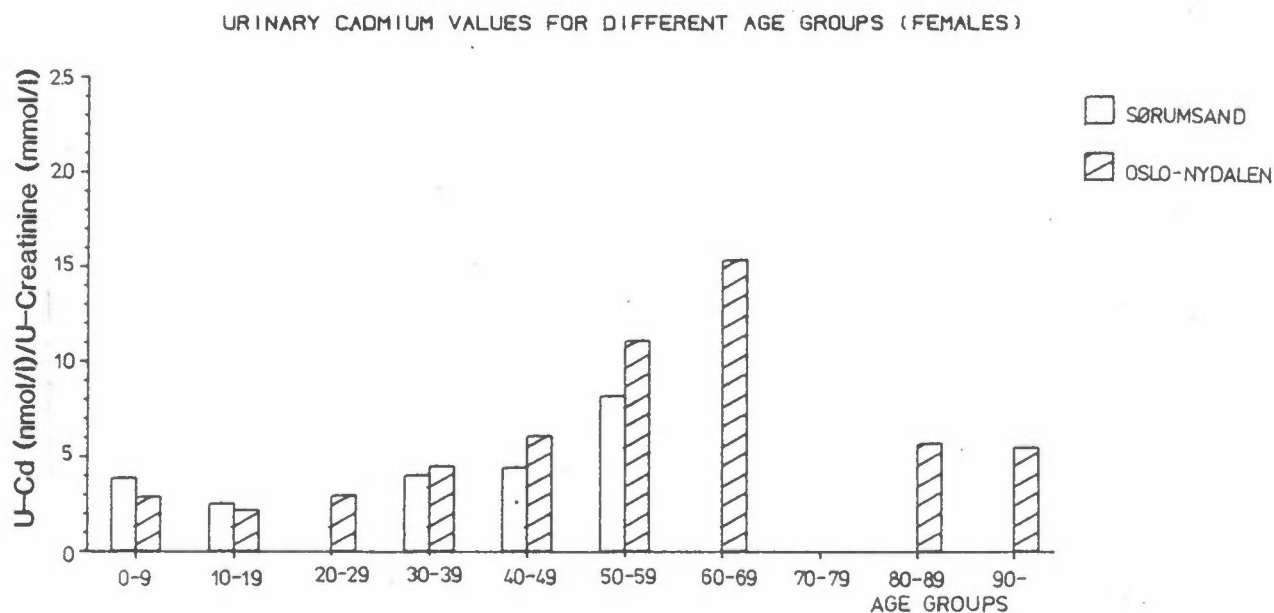
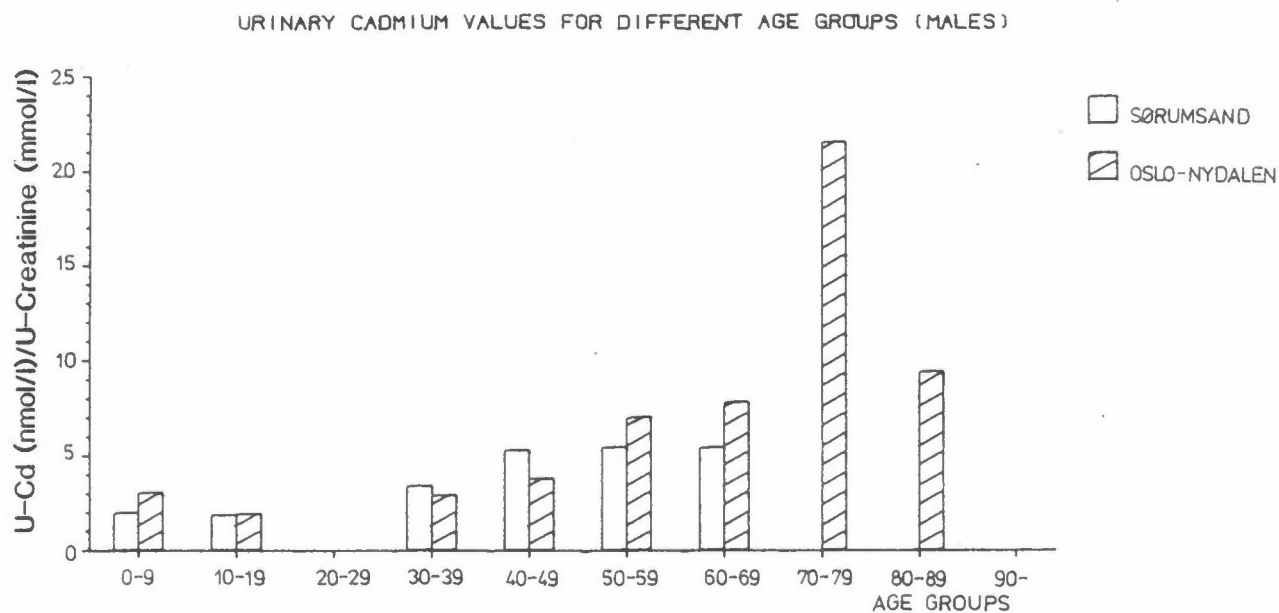


Figure 1: Median values of urinary cadmium (n mole/l)/urinary creatinine (m mole/l) in adult men and women living in Oslo-Nydalen and Sørumsand as a function of age group.  
 a) adult men                      b) adult women  
 Occupationally exposed individuals excluded for analysis.

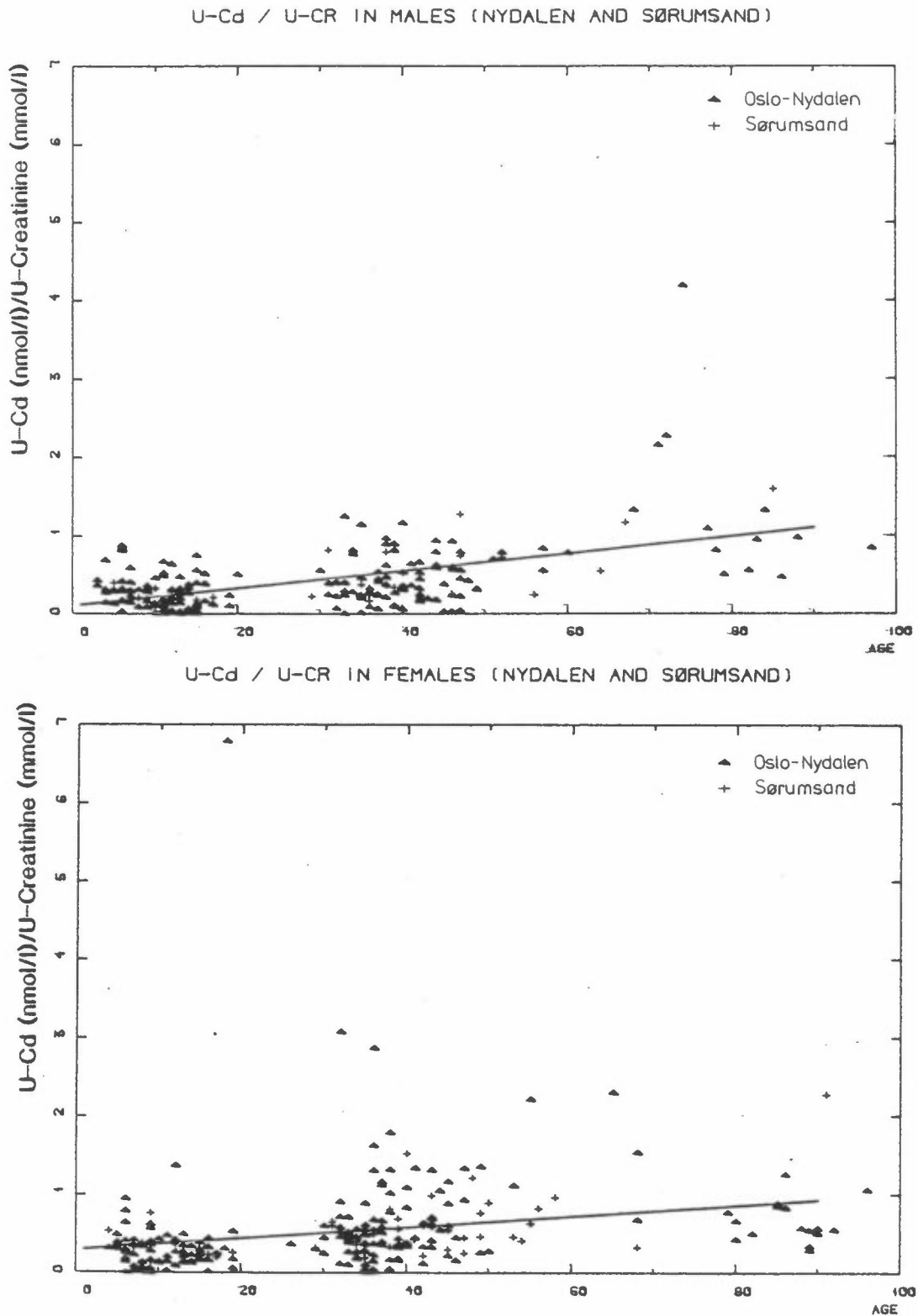


Figure 2: Scatter plot of urinary cadmium (nmol/l)/urinary creatinine (mmol/l) as a function of age in Oslo-Nydalen and Sørumsand. Occupationally exposed individuals excluded from data set prior to data analysis.

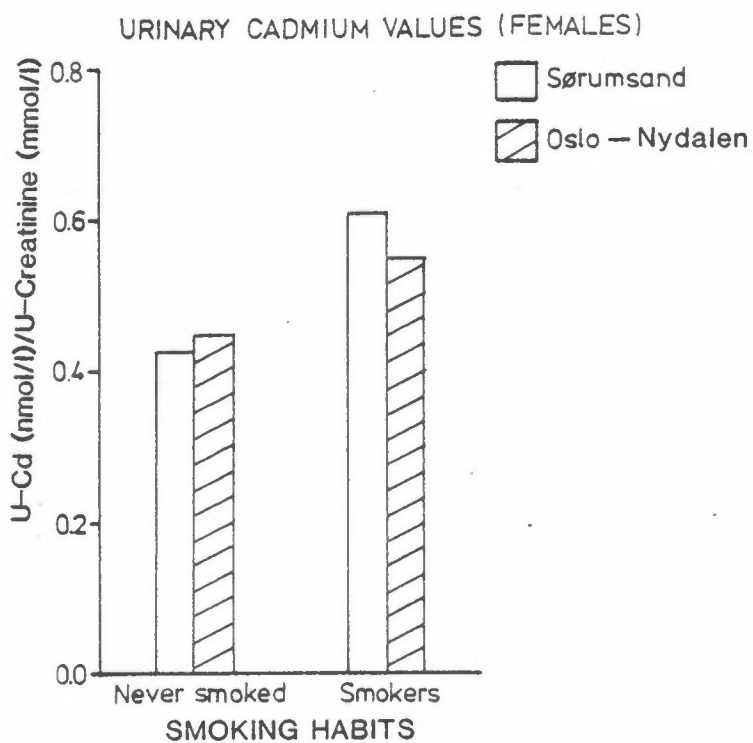
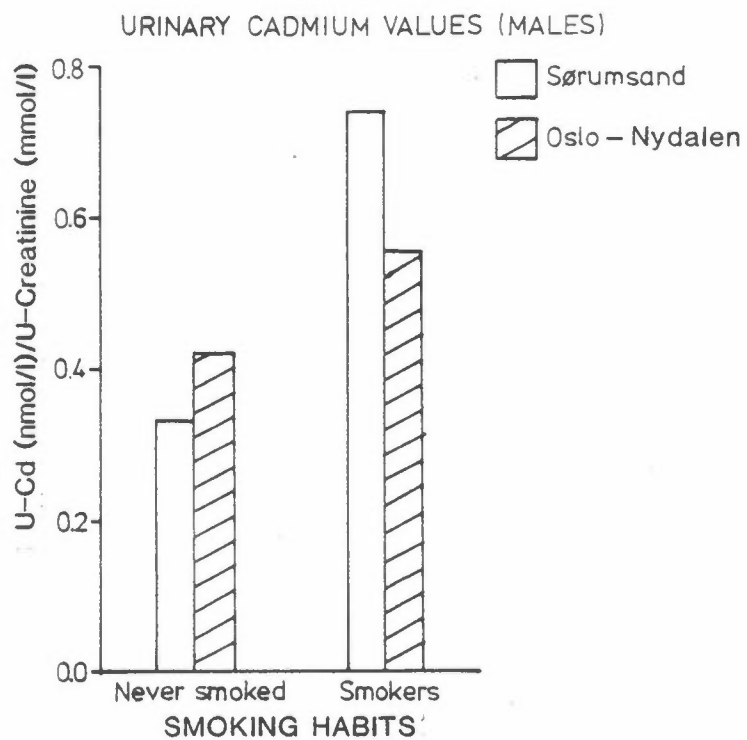


Figure 3: Comparison of median values of urinary cadmium (nmol/l)/ urinary creatinine (mmol/l) in different smoking categories of adult men and women living in Sørumsand and Oslo-Nydalen. Occupationally exposed individuals excluded from data set prior to data analysis.

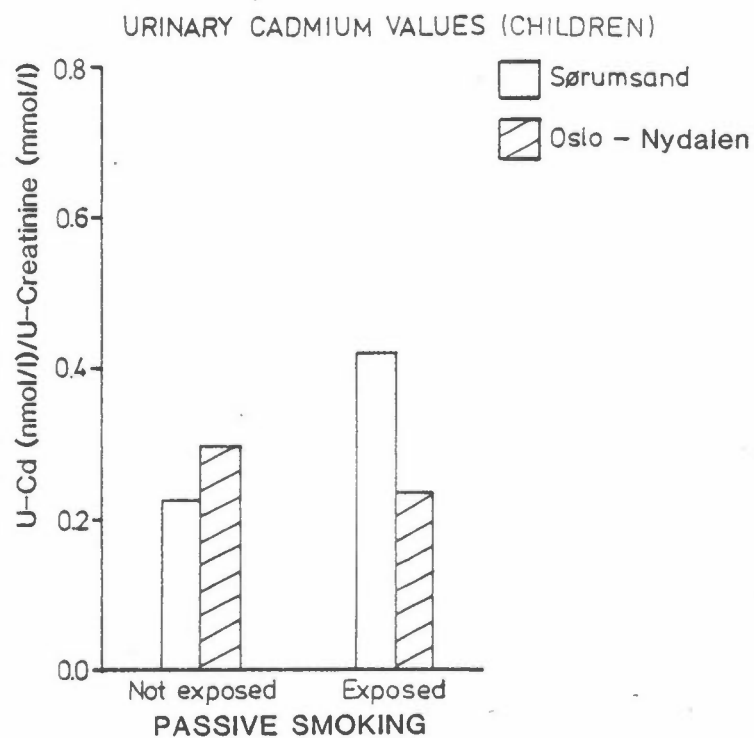


Figure 4: Comparison of median values of urinary cadmium (nmol/l)/ urinary creatinine (mmol/l) in children, exposed or not exposed to passive smoking in Sørumsand and Oslo-Nydalen

Table 7: Comparison of the medians of urinary cadmium values measured as  $\mu\text{g/l}$  in the inhabitants of Oslo-Nydalen and Sørumsand with values measured in Sweden (Stockholm), Japan (Tokyo) and the United States (Dallas and Chicago) as a function of 10 year age-groups. Sample size in parenthesis.

Location Age	Oslo-Nydalen		Sørumsand		Sweden *1		Japan *1		United States (both M+ F)				
	M	F	M	F	M	F	M	F	Dallas	Chicago	1974	Chicago	1976
0-9	0.30 (35)	0.28 (33)	0.17 (4)	0.34 (6)	0.17 (6)	0.22 (2)	0.35 (18)	0.42 (15)	0.37 (15)	0.50 (65)	0.41 (47)		
10-19	0.19 (52)	0.22 (37)	0.26 (8)	0.33 (6)	0.18 (10)	-	0.79 (29)	0.66 (28)	0.31 (8)	0.54 (38)	0.29 (40)		
20-29	0.54 (1)	0.40 (2)	0.30 (1)	0.33 (1)	0.21 (10)	-	0.80 (23)	0.90 (21)	0.38 (16)	0.63 (34)	0.56 (20)		
30-39	0.43 (41)	0.53 (66)	0.56 (8)	0.45 (14)	0.28 (10)	-	1.20 (45)	1.42 (41)	0.45 (7)	0.67 (47)	0.55 (44)		
40-49	0.46 (36)	0.69 (28)	0.78 (5)	0.51 (16)	0.29 (10)	0.46 (10)	1.42 (52)	1.53 (73)	0.87 (16)	0.76 (15)	0.58 (13)		
50-59	0.69 (4)	2.00 (3)	0.80 (4)	0.82 (6)	0.45 (10)	0.66 (10)	1.49 (48)	1.75 (52)	0.65 (24)	0.86 (18)	0.87 (19)		
60-69	1.10 (2)	1.90 (3)	0.80 (2)	0.29 (1)	0.38 (10)	-	1.68 (41)	1.38 (53)	-	0.88 (6)	0.88 (6)		
70-79	1.51 (6)	0.80 (1)	-	-	0.57 (11)	-	1.65 (30)	1.47 (24)	-	-	-		
80-89	0.79 (5)	0.58 (11)	1.00 (1)	-	0.36 (9)	-	1.15 (6)	1.33 (8)	-	-	-		

Swedish values are for non-smokers only. United States and Norwegian values from both non-smokers and smokers.

\*1 Values from Kjellström, 1979.

\*2 Values from Kowal et al., 1979.

Table 8: Comparison of the medians of urinary cadmium values measured as  $\mu\text{g/l}$  in the inhabitants of Oslo-Nydalen and Sjørumsand, with values measured in United States (Chicago and Dallas) as a function of smoking habits. Sample sizes in parenthesis.

Smoking history	Oslo-Nydalen		Sjørumsand		United States (both M and F)* <sup>1</sup>		
	M	F	M	F	Dallas	Chicago 1974	Chicago 1976
Never	0.40 (37)	0.46 (63)	0.56 (6)	0.45 (19)	0.40 (51)	0.54 (157)	0.43 (131)
Former	0.40 (23)	0.84 (17)	0.80 (4)	0.50 (10)	0.69 (21)	0.73 (25)	0.71 (23)
Present	0.70 (32)	0.58 (33)	1.00 (6)	0.51 (7)	0.65 (14)	0.85 (41)	0.57 (35)

\*<sup>1</sup> Values from Kowal et al., 1979.

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