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THE SPATIAL DISTRIBUTION OF THE TRACE ELEMENT EMISSION FROM CONVENTIONAL THERMAL POWER PLANTS IN EUROPE

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1 INTRODUCTION

The increased reliance on coal and oil to satisfy the growing energy demands has aroused considerable concern for the pollution consequences. Since coal typically contains 2 to 30 percent non-combustible mineral matter (1), enormous quantities of particulate matter are produced in power generation. Also the emission of particulate matter from oil-fired plants is considerable, and increases with the sulphur content. These particles are considered a potential health hazard because they contain a variety of toxic trace elements originally bound in the fuel.

In the present report the spatial distribution of the trace element emission from conventional thermal power plants in Europe and Turkey is estimated, using emission factors of trace metals from conventional power plants and data on net installed capacity of electricity generating plants in each country. Also data on type of fuel burned (emphazising the ash content in coal and the sulphur content in oil), data on stack gas cleaning installations, and the geographical position of the power plants have been used when available.

2 EMISSION FACTORS

From among more than 60 elements contained in the fuel, only 16 are normally analyzed: As, Be, Cd, Co, Cr, Cu, Hg, Mo, Mn, Ni, Pb, Sb, Se, V, Zn and Zr. These elements are either the most toxic, or appear in the highest concentrations (2).

Emission factors for the trace metals mentioned above were calculated for different types of power plants using enrichment factors of these pollutants in the flue gas stream and technological data on boilers and emission control installations. Details are available from earlier reports (2,3).

The emission factors, used to estimate the trace metal emission from coal-fired power plants are presented in Table 1.

Table 1: Emission factors of trace metals from coal-fired power plants (µg/MJ).

Element	Hard coal								
	Bituminous			Subituminous			Lignite		
	Cyclone	Stoker	Pulverized	Cyclone	Stoker	Pulverized	Cyclone	Stoker	Pulverized
As	24	28	16	29	34	19	40	47	27
Be	2.5	3.7	1.6	3.0	4.5	2.0	4.1	6.2	2.7
Cd	7.3	8.7	5.1	8.8	10.5	6.1	12.3	14.7	8.5
Co	44	51	25	54	62	31	75	86	43
Cr	120	200	85	145	242	103	201	336	143
Cu	94	164	63	114	198	76	158	276	106
Hg	0.5	1.0	0.4	0.6	1.3	0.4	0.9	1.8	0.6
Mn	102	186	70	123	226	85	171	314	118
Mo	31	42	19	37	51	23	52	71	32
Ni	150	243	96	182	294	117	253	409	163
Pb	85	128	55	103	156	66	144	217	92
Sb	15	23	9.3	17	28	11	24	39	15.7
Se	11	19	7.3	13	23	8.9	18.5	31	12.4
V	84	162	58	101	197	71	141	274	98
Zn	119	191	79	144	231	96	200	321	133
Zr	82	179	60	100	217	73	139	301	99

Data presented in Table 1 are average values, derived for different boilers and coal types burning a weighted "average" of coals in power plants with electrostatic precipitation.

The efficiency of dust removal installations was assumed to be 99 per cent and the ash content 10 per cent. For different efficiences and ash contents, similar data as in Table 1 can easily be obtained by proportionality, as shown in earlier publications (2,3).

For Hg and Se the emission factors in Table 1 are only 5 and 40 per cent of the total Hg and Se emission factors respectively. This is due to the volatile nature of both metals (4). To achieve the total mercury and selenium emissions one has to multiply those figures by factors of 20 and 2.5 for mercury and selenium respectively.

On the basis of literature data it was further assumed that electrostatic precipitators is the most commonly used fly ash control system in coal-fired plants in European countries (5,6,7,8). The average efficiency of electrostatic precipitators was assumed to be 99 per cent (1, 9,10).

The emission factors used to estimate the trace metal emission from oil-fired power plants are given in Table 2.

Table 2: Emission factors of trace metals for oil-fired power plants (µg/MJ).

Element	Emission factor	Element	Emission factor
As	24.4	Mo	28
Cd	11.6	Ni	1021
Co	129	Pb	126
Cr	43.3	Se	18.5
Cu	174	V	3700
Mn	41	Zn	89

The data in Table 2 were calculated for a power plant burning oil with 1 per cent of sulphur. For oils with different sulphur (or ash) contents similar data can be estimated, using the equations given in a previous report (2).

3 ELECTRICITY PRODUCTION

The electricity production in different types of European power stations is given in Table 3 (11,12).

Table 3: Electricity production in European countries in 1979 (in TWh)

Country	Total	Hydro	Nuclear	Conv.Ther.	Geothermal
Albania	2.4	1.9	0	0.5	0
Austria	40.6	28.0	0	12.6	0
Belgium	52.3	0.6	11.4	40.3	0
Bulgaria	32.5	3.3	6.2	23.0	0
Czechoslovakia	67.9	4.1	2.2	61.6	0
Denmark	22.3	v.small	0	22.3	0
Finland	39.1	11.2	6.8	21.1	0
France	240.1	73.7	32.3	134.1	0
German Dem.Rep.	99.0	1.3	8.0	89.7	0
German Fed.Rep.	372.2	18.5	42.3	311.4	0
Greece	22.4	3.2	0	19.2	0
Hungary	24.5	0.1	0	24.4	0
Iceland	2.8	2.7	0	0.1	v.small
Ireland	11.0	1.2	0	9.8	0
Italy	181.3	48.2	2.6	128.0	2.5
Luxemburg	1.1	0.1	0	1.0	0
Netherlands	64.5	0	3.5	61.0	0
Norway	86.5	86.4	0	0.1[x]	0
Poland	117.5	2.5	0	115.0	0
Portugal	16.1	11.2	0	4.9	0
Romania	64.9	10.7	0	54.2	0
Spain	105.8	47.5	6.7	51.6	0
Sweden	95.0	60.8	21.1	13.1	0
Switzerland	46.6	32.7	11.8	2.1	0
Turkey	24.3	10.5	0	13.8	0
USSR	1240.0	180.0	45.0	1015.0	0
United Kingdom	300.0	5.5	38.3	256.2	0
Yugoslavia	55.0	26.6	0	28.4	0

x) at Spitsbergen

Table 4 shows net installed capacity of electricity generation plants in particular countries in Europe (12).

Table 4: Net installed capacity of electricity generation in Europe in 1979 (MW).

Country	Total	Conv. Ther.	Hydro	Nuclear	Geothermal
Albania	610	134	476	0	0
Austria	13 190	4 330	8 200	0	0
Belgium	10 266	8 100	500	1 666	0
Bulgaria	7 528	4 780	1 868	880	0
Czechoslovakia	15 340	12 700	2 200	440	0
Denmark	6 451	6 443	8	0	0
Finland	9 415	6 605	2 390	420	0
France	56 671	30 771	18 700	7 200	0
German Dem.Rep.	18 378	16 220	768	1 390	0
German Fed.Rep.	81 241	66 416	6 510	8 315	0
Greece	4 830	3 405	1 425	0	0
Hungary	5 238	5 200	38	0	0
Iceland	720	130	582	0	8
Ireland	2 650	2 138	512	0	0
Italy	44 000	27 350	15 700	552	398
Luxemburg	1 360	231	1 129	0	0
Netherlands	17 500	16 997	0	523	0
Norway	18 375	162 x	18 213	0	0
Poland	23 900	23 100	800	0	0
Portugal	4 270	1 445	2 825	0	0
Romania	14 600	11 300	3 300	0	0
Spain	28 728	13 878	13 730	1 120	0
Sweden	27 000	8 450	14 650	3 900	0
Switzerland	12 850	650	11 170	1 030	0
Turkey	5 042	3 160	1 882	0	0
USSR	255 000	195 000	50 000	10 000	0
United Kingdom	74 307	65 258	2 451	6 598	0
Yugoslavia	13 000	5 775	0	0	

x) at Spitsbergen

The data in Tables 3 and 4 give total electricity production and total net installed capacity of conventional thermal power plants.

In order to estimate the emissions of trace elements it is necessary to assess the electricity production in coal-, lignite- and oil-fired power plants separately. This was done by using data for the fuel consumption in different types of power plants and heat values of the fuels burned. As an example of these calculations, data for Denmark are presented in Appendix A. In this connection the import and export of fuels between particular countries was considered (12). The estimated distribution of electricity production on different types of conventional power plants is presented in Table 5. Gas-powered power plants were not considered because their emissions of trace metals (13,14) are insignificant in this relation.

Table 5: Distribution of electricity production in several types of conventional thermal power plants in 1979. ($\cdot 10^9$ MJ/year).

Country	Total	Type of power plant			References
		Hard-coal fired	Lignite-fired	Oil-fired	
Albania	119	0	1.9	0	5,6,12,17
Austria	40.6	0.6	15.9	24.1	11,12,15,16 17,18
Belgium	123.8	44.3	0	79.5	11,12,18,19
Bulgaria	82.8	0	53.8	29.0	18,12,20
Czechoslovakia	221.6	0	221.6	0	12,17,20, 6,21,22
Denmark	80.3	52.3	0	28.0	12,15,16,17, 18
Finland	73.9	49.4	0	24.5	12,11,15,18
France	465.4	234.6	7.0	223.8	11,12,15,17, 18,23,41,42
German Dem.Rep.	322.9	0	322.9	0	12,20
German Fed.Rep.	920.3	304.7	534.8	80.8	11,12,17,24, 25,26,27,44
Greece	69.2	0	55.8	13.4	11,12,17,18
Hungary	87.7	8.4	49.2	30.1	12,17,18,28
Iceland	0.2	0	0	0.2	11,12,18
Ireland	32.7	0.4	0	32.3	11,12,15,18
Italy	428.3	24.4	10.3	393.6	11,12,15, 17,18
Luxemburg	0	0	0	0	11,12
Netherlands	142.6	24.5	0	118.1	11,12,15,18
Norway	0.5	0.5	0	0	11,12
Poland	414.0	331.2	82.8	0	12,4,24,30
Portugal	17.6	1.9	0	15.7	11,12,18,15,31

Table 5 cont.

Country	Total	Type of power plant			References
		Hard-coal fired	Lignite-fired	Oil-fired	
Romania	97.6	0	29.3	68.3	12,18,17,20
Spain	184.0	55.9	51.2	76.9	11,12,17,18,32
Sweden	47.1	0.3	0	46.8	11,12,15,18,33
Switzerland	7.2	0.1	0	7.1	11,12,27,18,43
Turkey	49.6	7.7	26.3	15.6	11,12,17,18
USSR	2 183.9	767.6	319.5	1 096.8	12,18,20, 6,34,35
United Kingdom	914.0	747.7	0	166.3	11,12,18,29
Yugoslavia	102.3	0	102.3	0	12,17

4 EMISSION OF TRACE ELEMENTS

The trace element emission from conventional thermal power plants in European countries has been calculated using data from Tables 1, 2 and 5. The following parameters were also considered: type and efficiency of dedusting installations, type of boilers, ash content in coal burned and sulphur content in oil burned. The emissions of trace elements from conventional thermal power plants in European countries are shown in Table 6. As an example, calculations for Denmark are presented in Appendix B.

Calculation for other countries will be given in a separate report.

Table 6: Emission of trace elements from convetional thermal power plants in Europe and Turkey in 1979 (t/year).

Element / Country	As	Be	Cd	Co	Cr	Cu	Hg *1	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
Albania	0.1	0.01	0.03	0.1	0.5	0.3	2.0	0.4	0.1	0.5	0.3	0.05	0.04	0.3	0.4	0.3
Austria	1.4	0.03	0.6	6.2	3.7	9.0	7.4	3.2	1.6	47.2	6.7	0.2	1.0	165.0	5.6	1.2
Belgium	6.3	0.3	2.6	23.4	21.1	36.5	57.6	18.2	7.5	166.9	28.0	1.6	4.0	553.8	26.8	10.5
Bulgaria	4.1	0.3	1.4	10.9	17.9	19.4	72.6	15.4	5.2	59.2	16.4	1.9	2.2	151.7	19.5	11.2
Czechoslovakia	14.1	1.4	4.3	26.6	71.4	56.2	319.1	60.8	18.3	89.8	50.9	8.4	6.6	50.0	70.9	49.1
Denmark	2.7	0.1	1.1	10.4	8.8	15.9	27.7	7.6	3.2	74.8	12.2	0.6	1.7	250.7	11.4	4.2
Finland	2.3	0.1	0.9	7.7	8.2	12.5	24.5	7.0	2.7	53.2	9.7	0.7	1.4	171.0	9.9	4.5
France	7.0	0.5	2.5	18.5	30.6	34.2	106.1	25.7	8.4	113.2	27.7	3.0	3.8	316.7	32.5	19.3
German Dem.Rep.	22.1	2.3	6.8	41.6	111.9	88.0	499.9	95.3	28.7	140.7	79.8	13.1	10.3	78.3	110.1	77.0
German Fed.Rep.	22.1	2.0	7.5	45.1	109.0	96.1	431.2	90.7	26.6	228.6	81.0	11.5	11.0	469.3	106.8	73.0
Greece	2.5	0.2	0.9	6.2	11.3	11.8	42.9	9.4	3.0	36.7	9.7	1.1	1.3	97.8	11.7	7.1
Hungary	4.3	0.3	1.5	11.3	18.4	20.0	74.0	3.4	5.4	61.3	16.9	2.0	2.3	157.5	20.1	11.5
Iceland *1	3.4	-	1.6	18.1	6.1	24.3	-	5.7	3.9	142.9	17.6	-	2.6	517.7	14.4	-
Ireland	0.5	-	0.2	2.7	0.9	3.6	0.2	0.9	0.6	20.9	2.6	-	0.4	75.5	1.8	0.0
Italy	14.3	0.1	6.6	71.9	29.0	98.5	22.1	26.6	16.5	560.6	71.8	0.6	10.5	2012.1	53.3	3.8
Netherlands	5.8	0.05	2.7	28.9	12.2	39.8	13.1	11.1	6.7	224.8	29.1	0.3	4.3	805.0	21.9	2.0
Norway *1 *2	9.5	1.0	3.1	15.2	50.8	37.7	0.2	42.0	11.5	57.9	32.9	5.6	4.3	35.0	47.4	36.1
Poland	26.8	2.8	8.3	50.6	136.1	107.0	576.2	115.9	34.9	171.1	96.9	15.9	12.5	95.2	135.0	93.6
Portugal	0.5	-	0.2	2.4	1.0	3.3	1.2	0.9	0.6	18.7	2.4	0.0	0.3	66.8	1.8	0.2
Romania	4.5	0.1	1.8	16.8	14.8	25.5	46.6	12.9	5.5	114.	20.0	1.2	2.8	376.0	19.2	7.2
Spain	5.8	0.4	2.2	16.7	23.6	29.3	87.9	19.9	6.8	107.6	23.4	2.2	3.3	321.0	26.0	14.0
Sweden	2.1	-	1.0	11.1	3.7	15.0	0.1	3.5	2.4	87.8	10.8	-	1.6	318.1	7.7	0.0
Switzerland	0.06	-	0.0	0.3	0.1	0.5	0.0	0.1	0.1	2.6	0.3	-	0.05	9.5	0.2	0.0
Turkey	2.4	0.2	0.8	5.7	11.3	10.7	47.6	9.7	3.1	26.7	9.3	1.3	1.2	55.3	11.8	7.4
USSR	104.4	7.2	38.0	316.5	413.6	525.9	1496.3	357.7	130.5	1908.2	431.0	41.2	58.8	5558.6	476.2	214.6
United Kingd.	20.5	1.9	6.9	42.2	100.5	89.4	373.8	83.6	24.6	216.3	75.2	10.6	10.3	453.7	98.7	68.1
Yugoslavia	7.2	0.7	2.2	13.6	36.5	28.7	162.9	31.1	9.4	45.9	26.0	4.3	3.	25.5	36.2	25.1

*1 in kg/year
*2 Spitsbergen

Table 7 shows emission of trace elements per person.

	Population in 1000 inhab.	As *1	Be *1	Cd *1	Co *1	Cr *2	Cu *2	Hg *1	Mn *2	Mo *1	Ni *2	Pb *2	Sb *1	Se *1	V *2	Zn *2	Zv *2
Albania	2,600	34	3	11	55	0.18	0.14	1	0.15	41	0.21	0.12	20	16	0.13	0.17	0.12
Austria	7,500	188	4	83	834	0.49	1.20	1	0.43	219	6.29	0.89	26	130	22.0	0.74	0.16
Belgium	9,800	648	29	263	2391	2.16	3.73	6	1.86	762	17.02	2.86	166	408	56.51	2.74	1.07
Bulgaria	8,800	470	38	162	1245	2.03	2.20	8	1.75	595	6.73	1.86	216	249	17.24	2.22	1.27
Chechoslovakia	15,000	941	97	291	1770	4.76	3.74	21	4.06	1222	5.99	3.39	558	437	3.33	4.73	3.27
Denmark	5,100	535	22	222	2036	1.72	3.13	5	1.48	627	14.66	2.39	126	341	49.16	2.23	0.82
Finland	4,700	484	26	192	1640	1.75	2.66	5	1.50	572	11.31	2.07	147	293	36.39	2.10	0.95
France	53,000	132	10	48	349	0.58	0.64	2	0.48	158	2.13	0.52	56	72	5.96	0.61	0.36
German Dem.Rep.	16,900	1308	135	404	2462	6.62	5.21	30	5.64	1699	8.33	4.72	776	608	4.63	6.51	4.55
German Fed.Rep.	61,800	358	32	121	729	1.76	1.56	7	1.47	430	3.70	1.31	186	179	7.59	1.73	1.18
Greece	9,300	270	21	96	669	1.21	1.27	5	1.01	322	3.94	1.04	121	144	10.52	1.26	0.76
Hungary	10,600	402	32	140	1067	1.74	1.89	7	0.32	509	5.78	1.59	185	213	14.86	1.89	1.08
Iceland	220	16	-	7	82	0.03	0.11	-	0.03	18	0.65	0.08	-	12	2.35	0.07	-
Ireland	3,200	158	1	74	829	0.29	1.12	-	0.27	182	6.52	0.81	2	119	23.58	0.58	-
Italy	56,400	253	2	117	1275	0.51	1.75	1	0.47	293	9.94	1.27	11	187	35.68	0.94	0.07
Netherlands	13,900	419	4	193	2082	0.88	2.86	1	0.80	484	16.18	2.09	22	306	57.92	1.57	0.14
Norway *3	4,000	2	1	1	4	0.01	0.01	-	0.01	3	0.01	0.01	1	1	0.01	0.01	0.01
Poland	34,700	774	81	238	1458	3.92	3.08	17	3.34	1006	4.93	2.79	460	360	2.74	3.89	2.70
Portugal	8,800	55	1	25	273	0.12	0.38	-	0.11	63	2.12	0.28	3	40	7.59	0.21	0.02
Romania	21,700	207	10	82	773	0.68	1.18	2	0.60	252	5.29	0.92	56	129	17.33	0.88	0.33
Spain	36,000	160	11	60	465	0.66	0.81	2	0.55	190	2.99	0.65	61	91	8.92	0.72	0.39
Sweden	8,300	254	-	120	1342	0.45	1.80	-	0.42	292	10.58	1.31	1	192	38.32	0.92	-
Switzerland	6,400	10	-	5	53	0.02	0.07	-	0.02	12	0.41	0.05	-	8	1.49	0.04	-
Turkey	40,400	60	5	20	140	0.28	0.27	1	0.24	77	0.66	0.23	31	30	1.37	0.29	0.18
USSR	191,200	546	38	196	1655	2.16	2.75	8	1.87	683	9.98	2.25	215	308	29.07	2.49	1.26
United Kingd.	56,000	366	33	124	753	1.79	1.60	7	1.49	440	3.86	1.34	189	183	8.10	1.76	1.22
Yugoslavia	21,800	330	34	102	622	1.67	1.32	7	1.42	429	2.10	1.19	196	154	1.17	1.66	1.15

*1 in mg/year·person

*2 in g/year·person

*3 Spitsbergen

Table 7: Emission of trace elements per person (1979)

5 SPATIAL DISTRIBUTION

The spatial distribution of the trace element emissions were based on location and capacity of the conventional thermal power plants in each country. For the OECD countries and the Eastern European countries (except USSR) information was available on the location of the conventional thermal power plants. (15,16,21,22,24, 25, 28,29,32,41,42,43,44,45,46,47). For other countries the spatial distribution has been inferred subjectively by the author, using any available information such as SO_2 emission, population density, energy consumption density, location of industrial areas, etc. Also the emission survey prepared in the OECD-LRTAP programme (36,39,40) has to some extent been used.

The EMEP grid system was used. The grid length is 150 km. Further details about the EMEP grid system are available from previous reports (36, 37, 38).
The spatial distribution of the trace elements examined in this work are presented in Figures 1-16. The square marks in these figures show places with emission being between 50 and 75 percent of the maximum emission. The circles mark present places with emission over 75 per cent of the maximum value.

6 UNCERTAINTIES

Many of the assumptions used in estimating the national emissions and their spatial distribution may well be improved (38). This would require further information from the countries with respect to the kind of fuels burned in power stations, performance of installed fly ash removal equipment type of boilers, etc.

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APPENDIX A

ESTIMATION OF ELECTRICITY PRODUCTION IN CONVENTIONAL THERMAL POWER PLANTS IN DENMARK

In Denmark all the 22.3 x 10^9 kWh (80.3 MJ) of electricity is produced in hard-coal fired - and oil fired-power plants. To produce this amount of electricity, 6151 x 10^3 tonnes of hard coal and 1974 x 10^3 tonnes of oil were burned in 1979 (11).
Hard coal was imported mostly from Poland (3.5·10^6 tonnes) and South Africa (2.6 · 10^6 tonnes). Other quantities of hard coal came from Australia, West European countries, Canada and USSR (15,16). Heat values for coals from Poland and South Africa were found to be 24.1 MJ/kg and 24.4 MJ/kg respectively. Taking into account the quantities of coal imported from both countries and the heat values of these coals, an average heat value of coals burned in Denmark was estimated to 24.25 MJ/kg.

Oil was imported to Denmark from the Middle East (29 per cent), Western European countries (48 per cent) and Centrally Planned European countries (21 per cent). An average heat value of 40.56 MJ/kg for oil burned in Denmark was estimated in the same way as for hard coal. Multiplying quantities of hard coal and oil fired in Danish power plants by the average heat values of these fuels and assuming the same efficiencies of hard-coal- and oil-fired power plants, it was found that 65.1 per cent of the electricity in Denmark is generated in hard coal power plants. The rest, 34.9 per cent, is produced in oil power plants. In the other words, an amount of 52.3·10^9 MJ of electricity has been produced in coal fired power plants, and 28.0·10^9 MJ in oil-fired power plants.

APPENDIX B

EMISSION OF TRACE ELEMENTS FROM CONVENTIONAL THERMAL POWER PLANTS IN DENMARK

The emission of trace elements from conventional thermal power plants in Denmark was calculated from the quantities of electricity produced in coal- and oil-fired power plants and trace element emission factors. Estimates of the electricity production are given in Appendix A, the emission can be obtain from the data in Tables 1 and 2.

Table 1 shows trace element emission factors calculated for various boiler types burning different quantities of coal. The efficiency of dedusting installastions was assumed to be 99 per cent and the ash content 10 per cent. For coals burned in Danish power plants an average ash content of 13.25 per cent was estimated (Polish coals contain 12.4 per cent of ash and South African coals 14.4 per cent) (15,16). The majority of Danish power plants burn bituminuous coals and are equipped with electrostatic precipitators working at an efficiency of 99 per cent. The calculated trace emission factors for Danish coal power plants are shown in Table B-1.

Table B-1: Emission factors of trace elements for Danish coal-fired power plants (µg/MJ).

Element	Emission factor	Element	Emission factor
As	21.2	Mo	25.3
Be	2.1	Ni	127.9
Cd	6.8	Pb	72.6
Co	33.5	Sb	12.3
Cr	112.2	Se	9.7
Cu	83.3	V	77.4
Hg	0.5	Zn	104.5
Mn	92.7	Zv	79.6

An example of calculations is given below. The arsenic emission factor for bituminous coals with the ash content 10 per cent burned in pulverized boilers was found to be 16 µg/MJ (Table 1). For coals with the ash content 13.25 per cent, the arsenic emission factor can be reach multiplying 16 µg/MJ by factor of 1.325.

The trace element emission factors for oil-fired power plants listed in Table 2, were calculated for oil with 1 per cent of sulphur. The average sulphur content in oil burned in Danish power plants was estimated to 2.8% on the basis of sources of import, amounts, and sulphur contents (as in Appendix A).

Calculated emission factors for trace elements in oil-fired power plants in Denmark are presented in Table B-2.

Table B-2: Emission factors of trace elements for Danish oil-fired power plants (µg/MJ).

Element	Emission factor	Element	Emission factor
As	58.1	Mo	66.9
Cd	27.6	Ni	2429.0
Co	308.0	Pb	299.2
Cr	103.0	Se	44.0
Cu	413.6	V	8800.5
Mn	96.9	Zn	211.1

To achieve the factors from Table B-2, equation (1) must be taken into account.

$$C_p = 1.25 \cdot S + 0.38 \qquad (1)$$

where C_p = the particulate emission factor, kg of dust/10^3 liters
S = the percentage by weight of sulphur in the crude oil.

For oil with 1 per cent of sulphur, the particulate emission factor is equal 1.63 kg/10^3 liters and for 2.8 per cent of sulphur the factor is 3.88. Thus, the trace emission factors for the oil burned in Danish plants are 2.38 times as high as the factors for oil with 1 per cent of sulphur (Table 2).

Taking into account data on electricity production in Danish coal- and oil-fired power plants (Appendix A) and the emission factors of trace elements given in Tables B-1 and B-2, the trace element emissions from Danish conventional thermal power plants have been calculated. The results are presented in Table B-3.

Table B-3: Emission of trace elements from conventional thermal power plants in Denmark in 1979 (t/year).

Element	Emission from power plants firing		Total emission
	Hard coal	Oil	
As	1.10	1.63	2.73
Be	0.11	-	0.11
Cd	0.36	0.77	1.13
Co	1.75	8.63	10.38
Cr	5.87	2.89	8.76
Cu	4.36	11.59	15.95
Hg*1	27.71	-	27.71
Mn	4.85	2.79	7.64
Mo	1.32	1.88	3.20
Ni	6.69	68.08	74.77
Pb	3.80	8.38	12.18
Sb	0.64	-	0.64
Se	0.51	1.23	1.74
V	4.05	246.67	250.72
Zn	5.47	5.91	11.38
Zr	4.16	-	4.16

*1 in kg/year

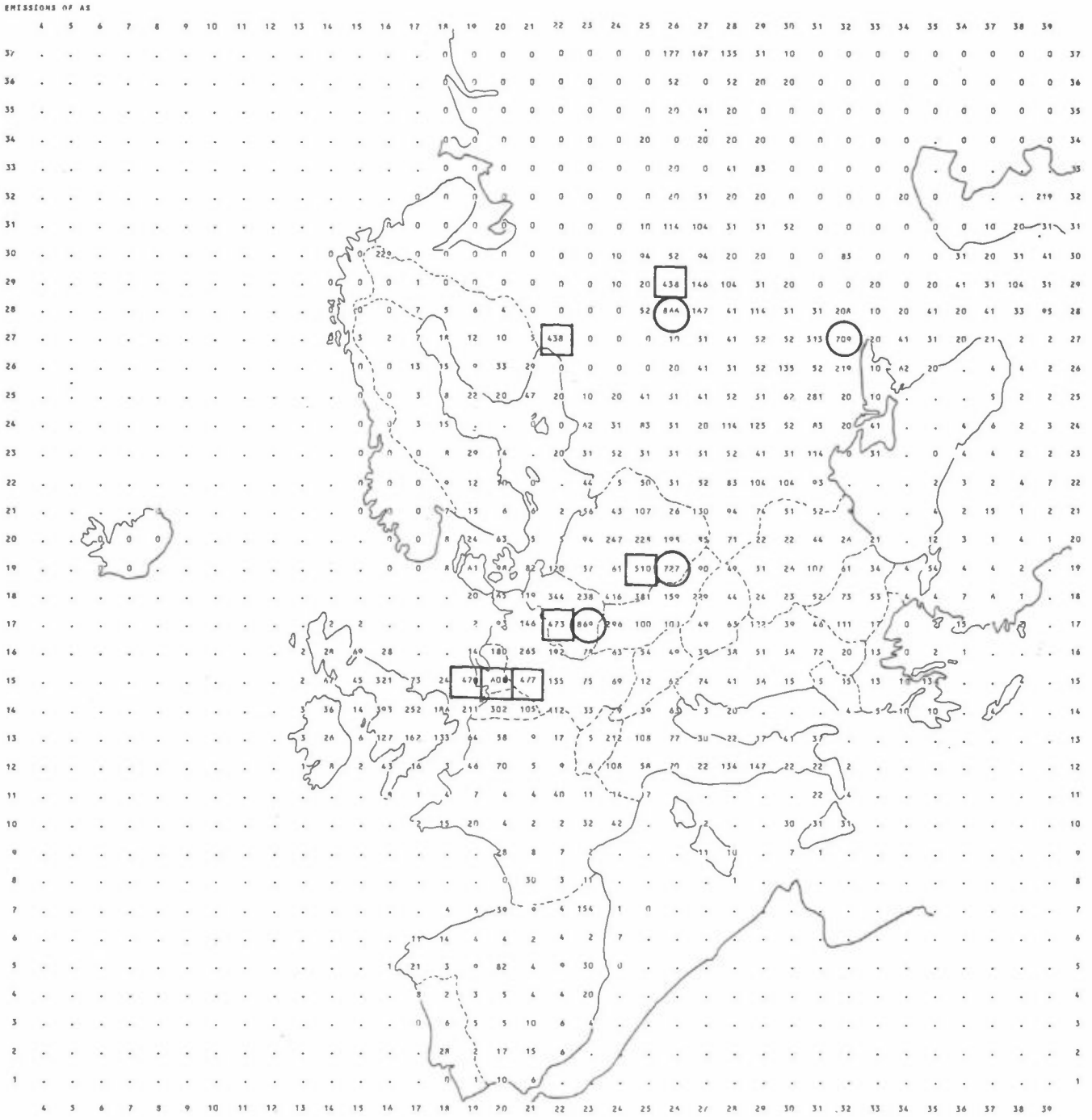

Fig. 1: Estimated annual emission of arsenic (x10 kg As) from conventional thermal power plants in grid elements with side length 150 km.

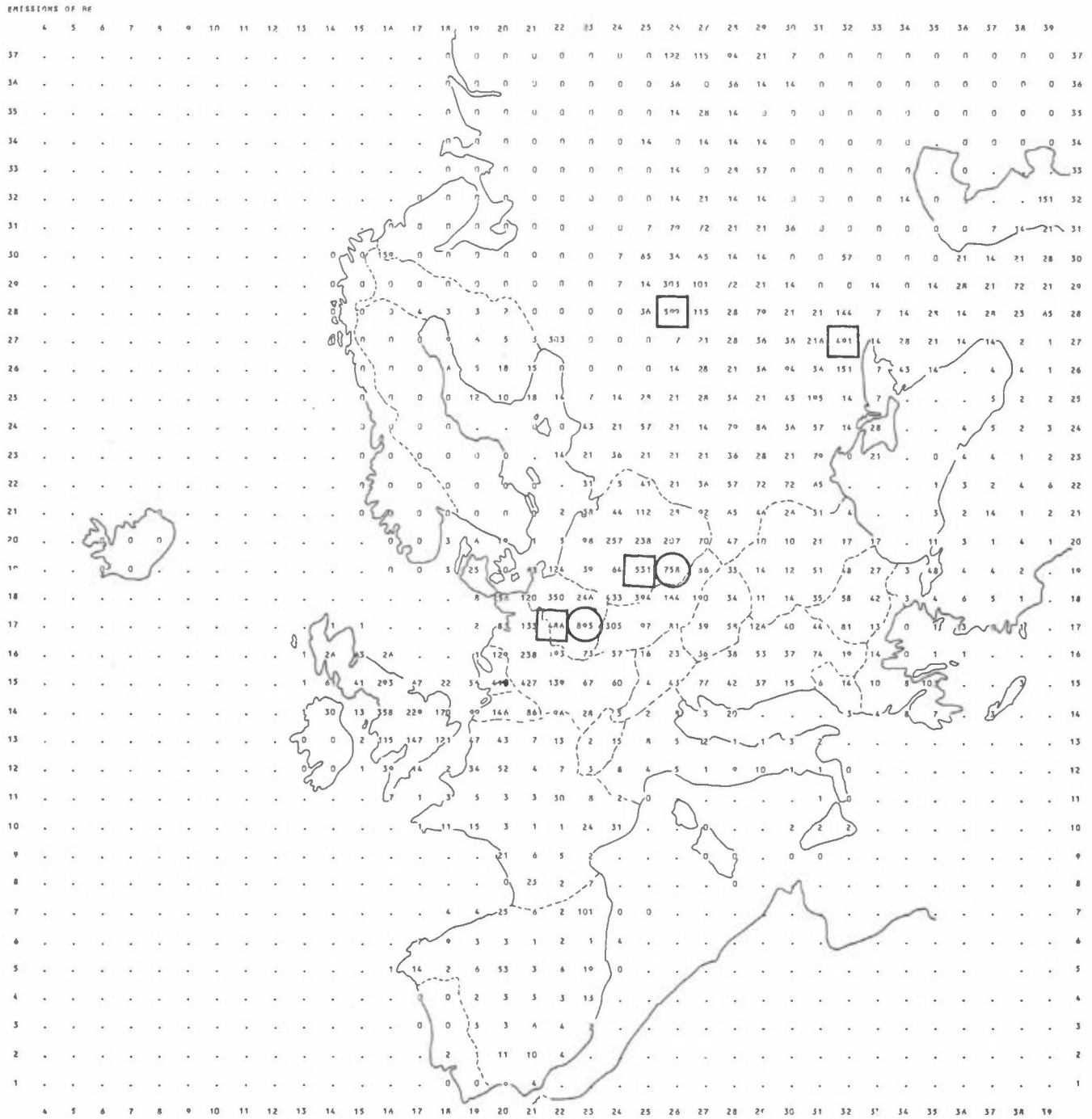

Fig. 2: Estimated annual emission of beryllium (kg Be) from conventional thermal power plants in grid elements with side length 150 km.

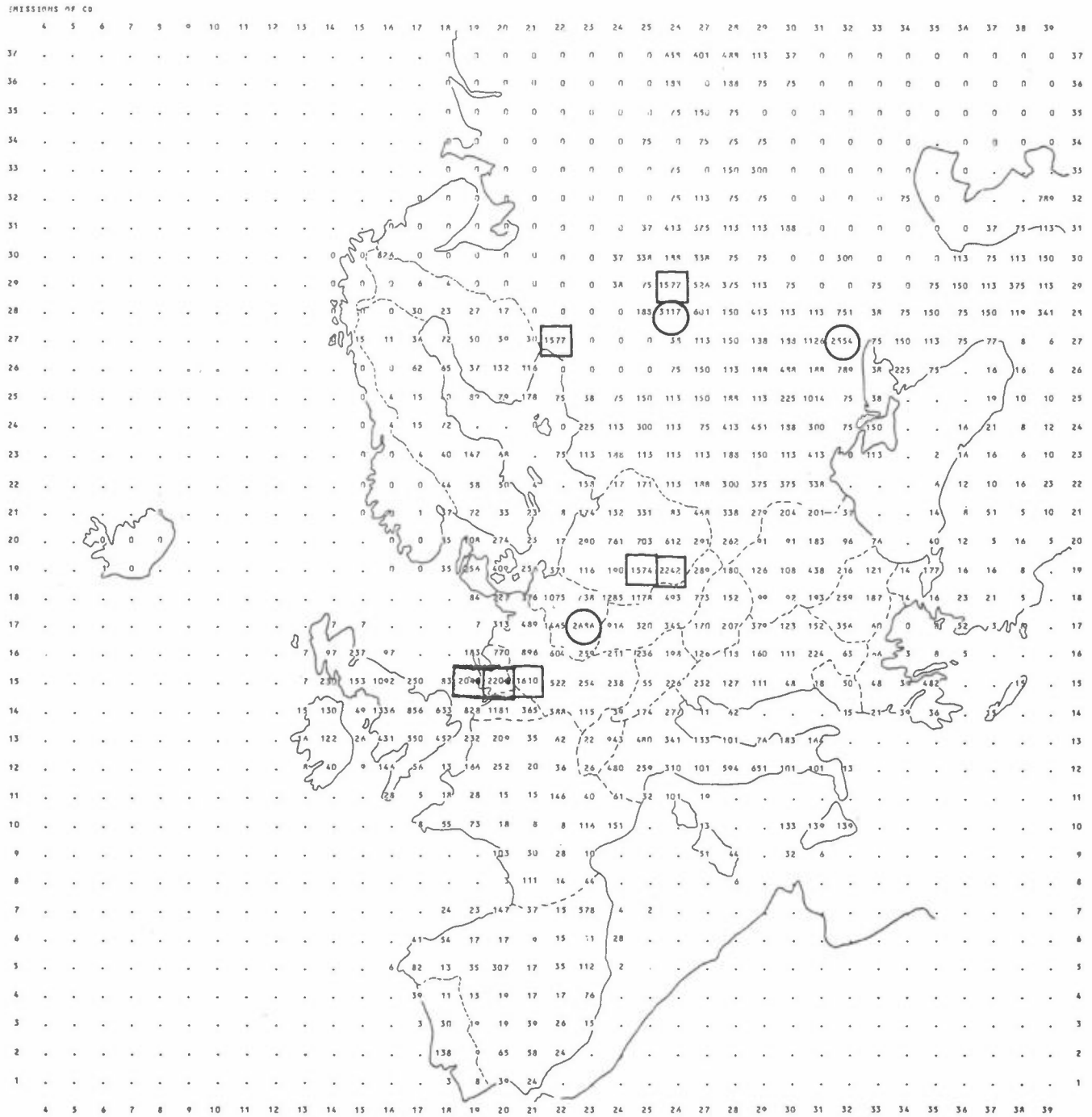

Fig. 3: Estimated annual emission of cadmium (kg Cd) from conventional thermal power plants in grid elements with side length 150 km.

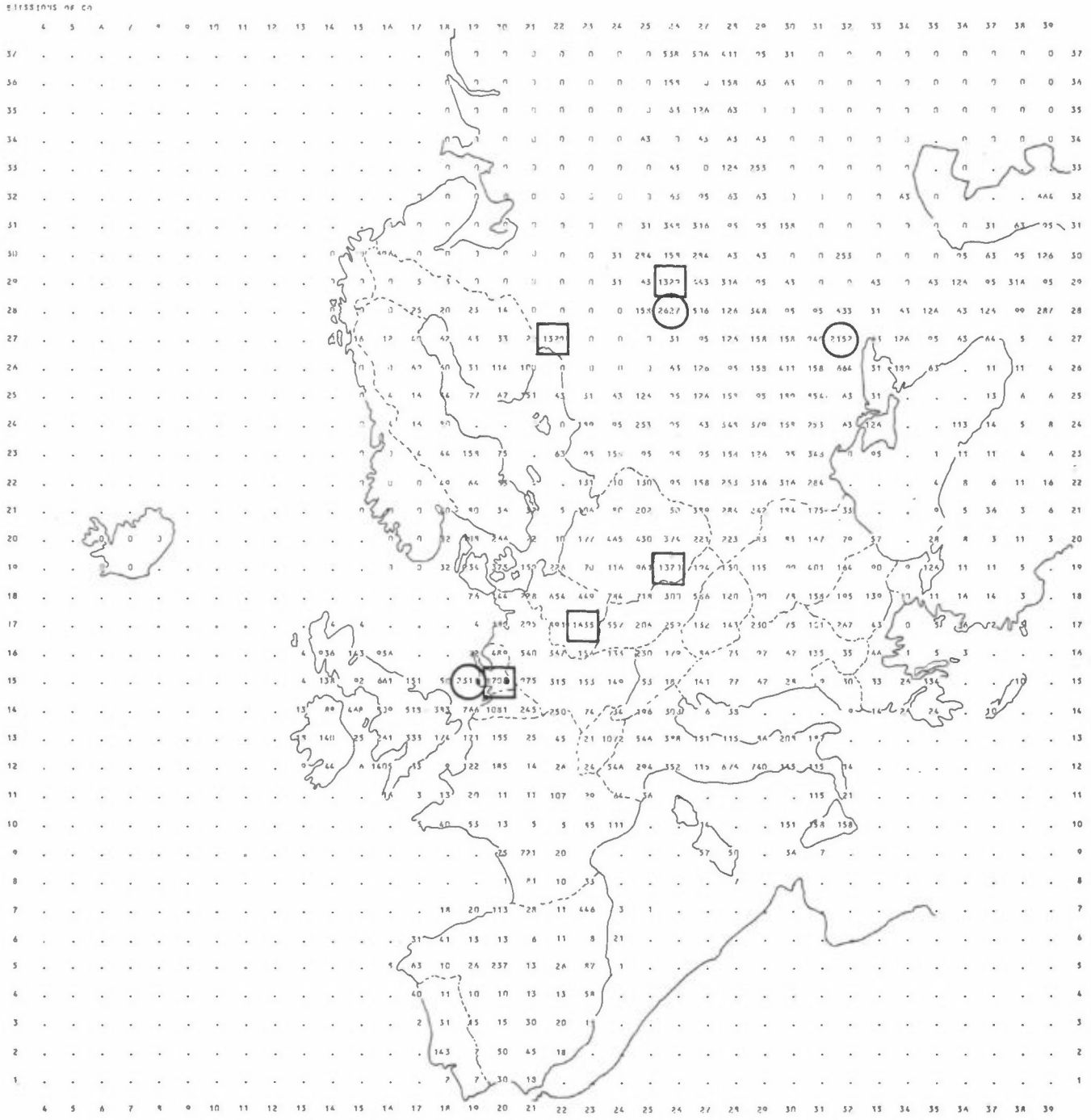

Fig. 4: Estimated annual emission of cobalt (x10 kg Co) from conventional thermal power plants in grid elements with side length 150 km.

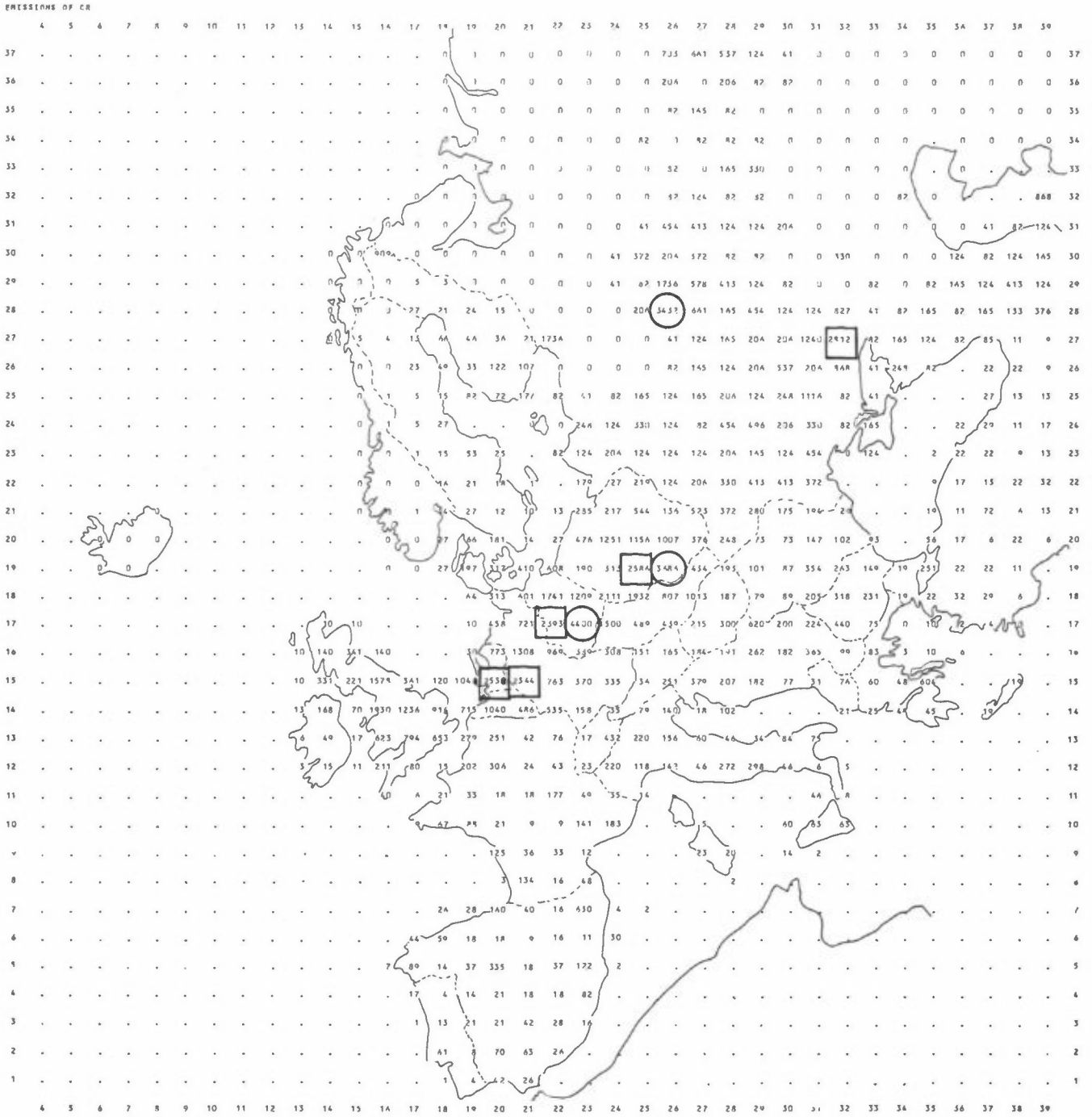

Fig. 5: Estimated annual emission of chromium (x10 kg Cr) from conventional thermal power plants in grid elements with side length 150 km.

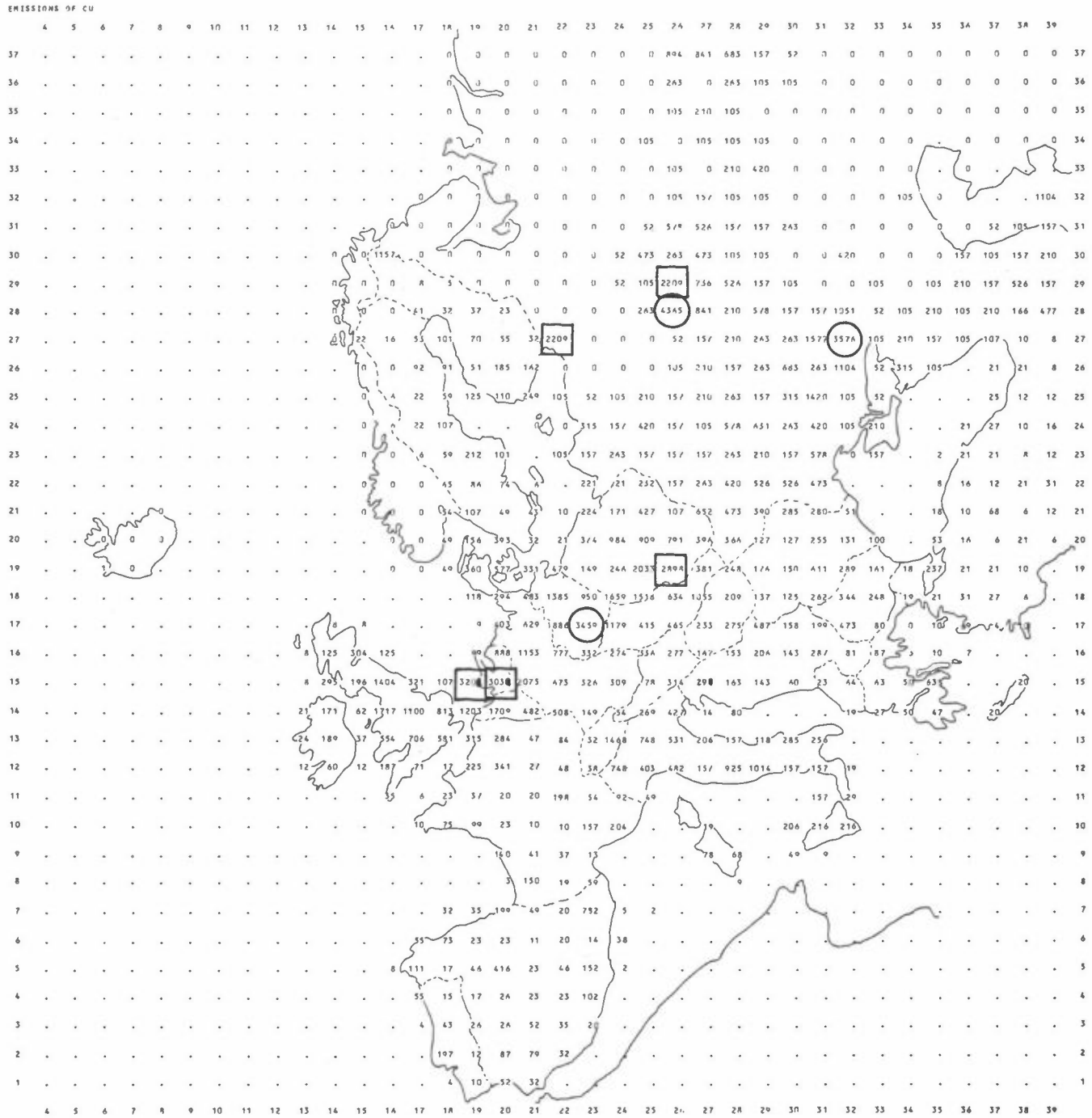

Fig. 6: Estimated annual emission of copper (x10 kg Cu) from conventional thermal power plants in grid elements with side length 150 km.

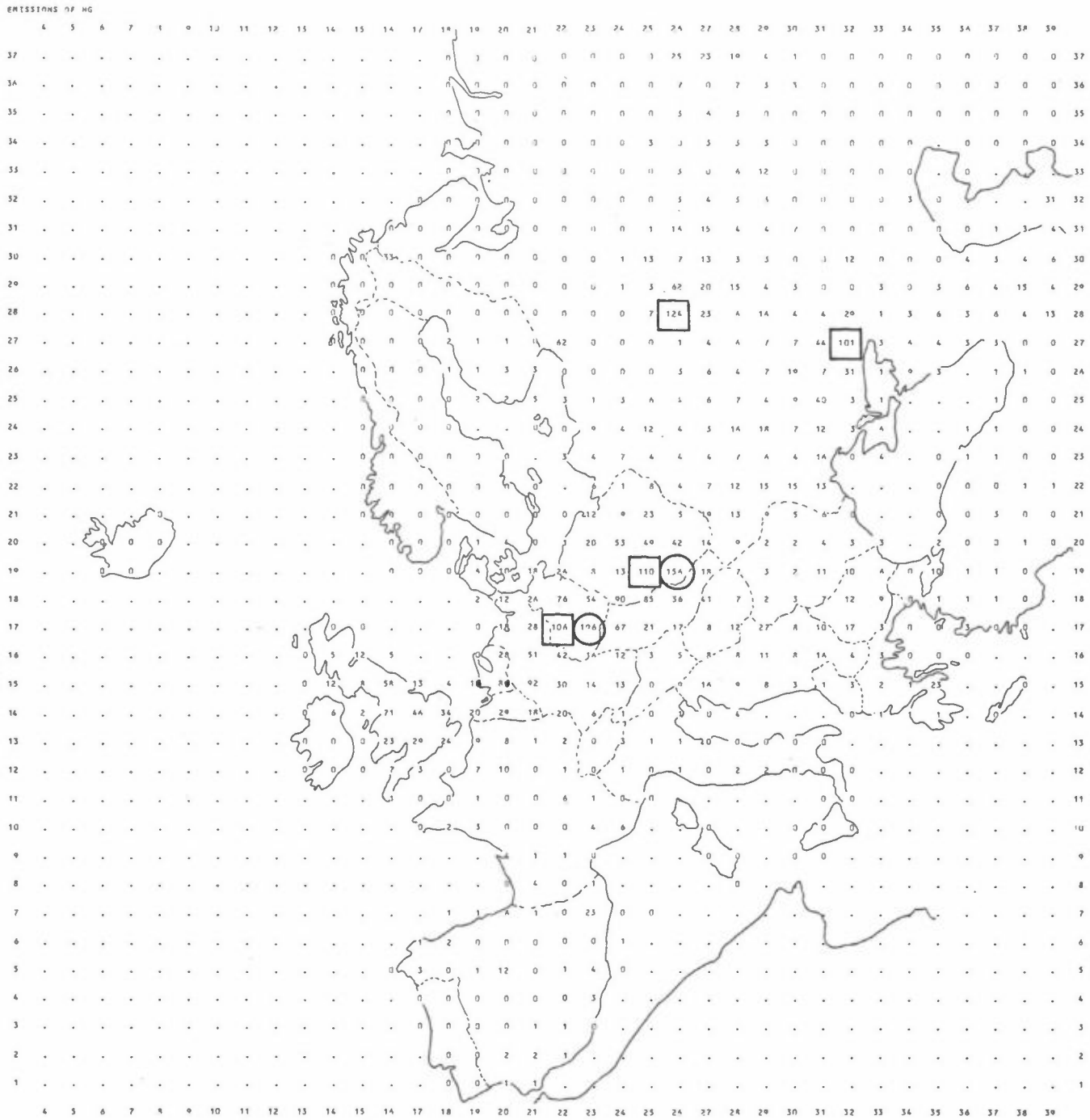

Fig. 7: Estimated annual emission of mercury (kg Hg) from conventional thermal power plants in grid elements with side length 150 km.

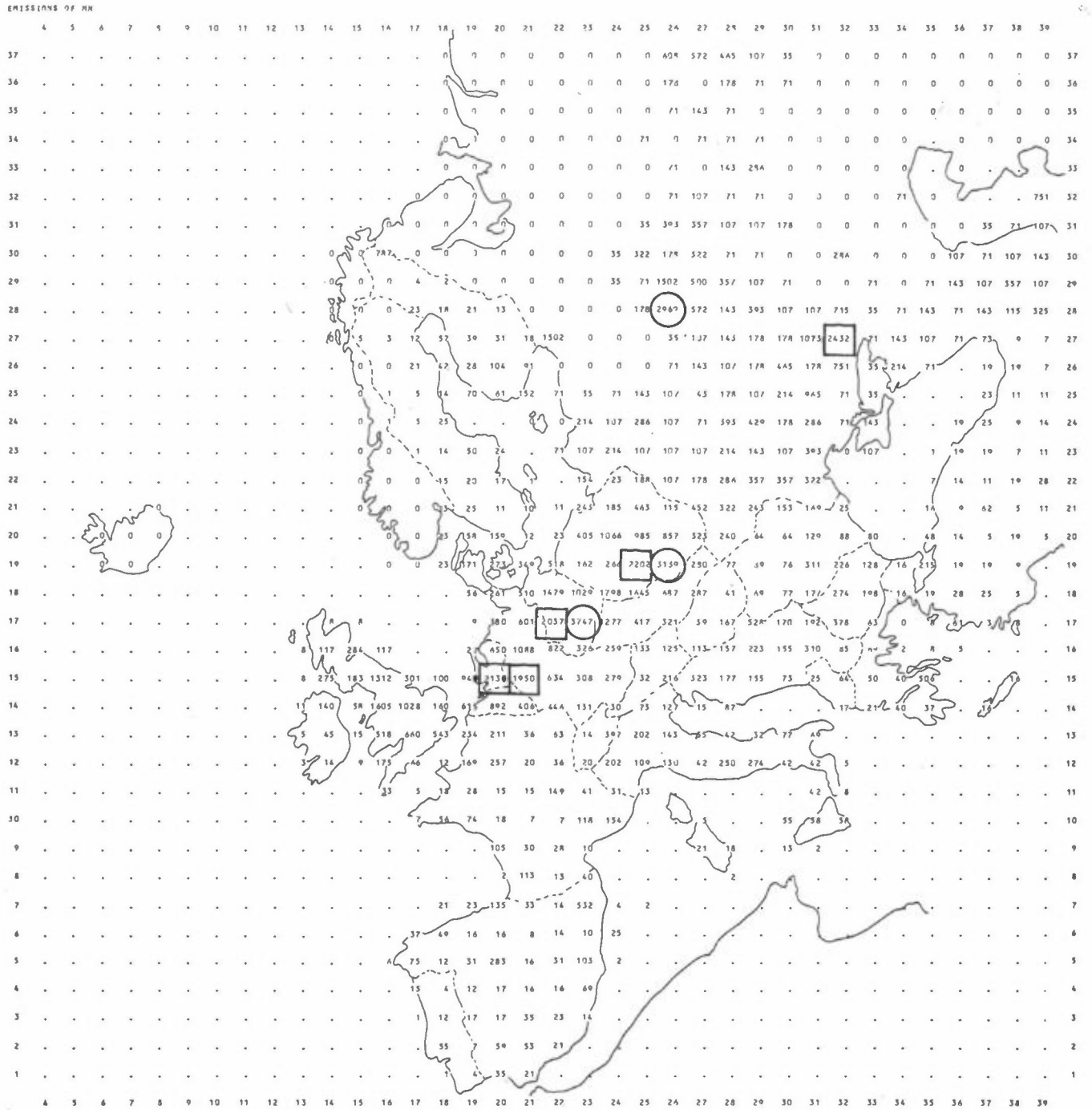

Fig. 8: Estimated annual emission of manganese (x10 kg Mn) from conventional thermal power plants in grid elements with side length 150 km.

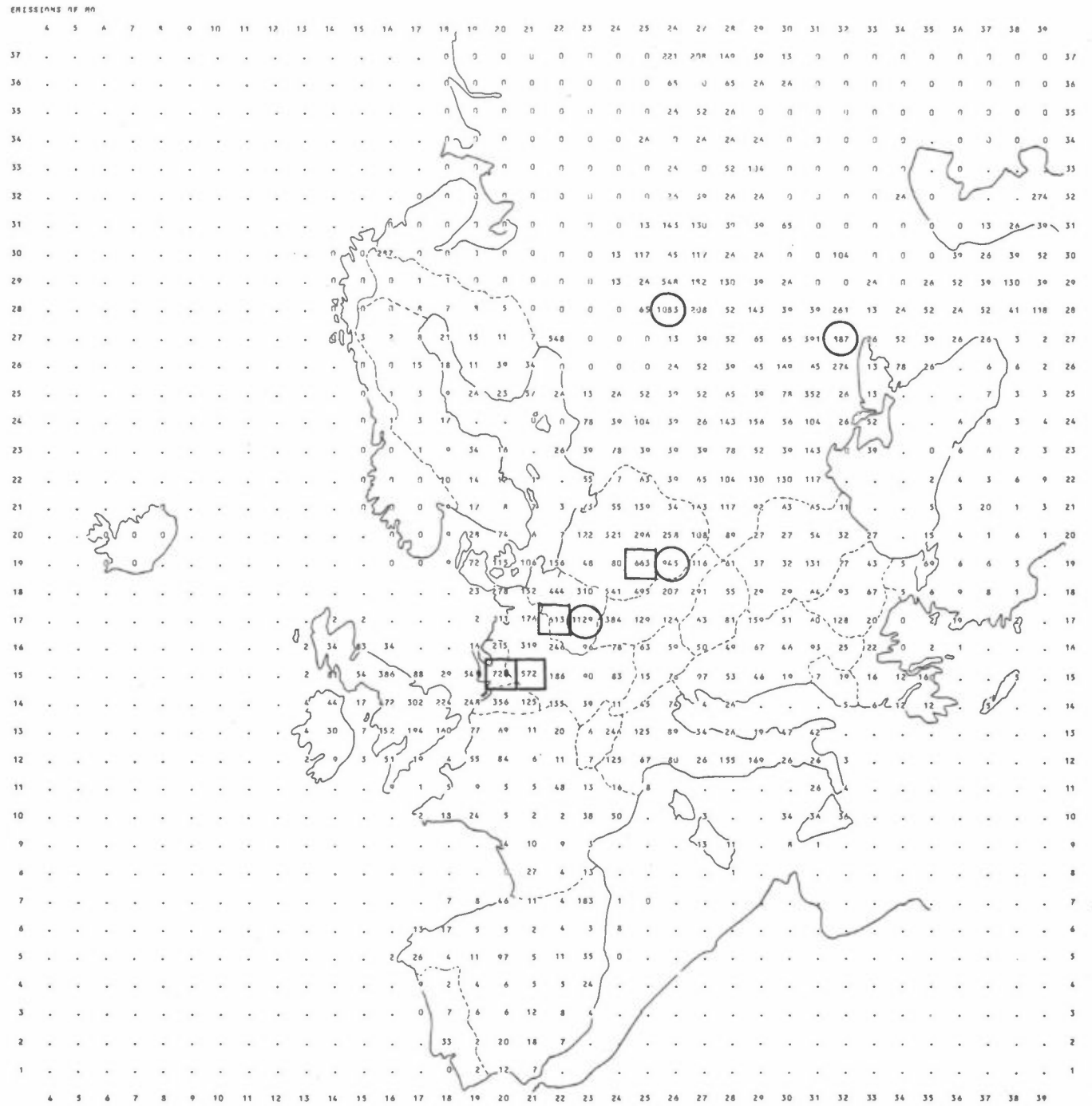

Fig. 9: Estimated annual emission of molybdenum (x10 kg Mo) from conventional thermal power plants in grid elements with side length 150 km.

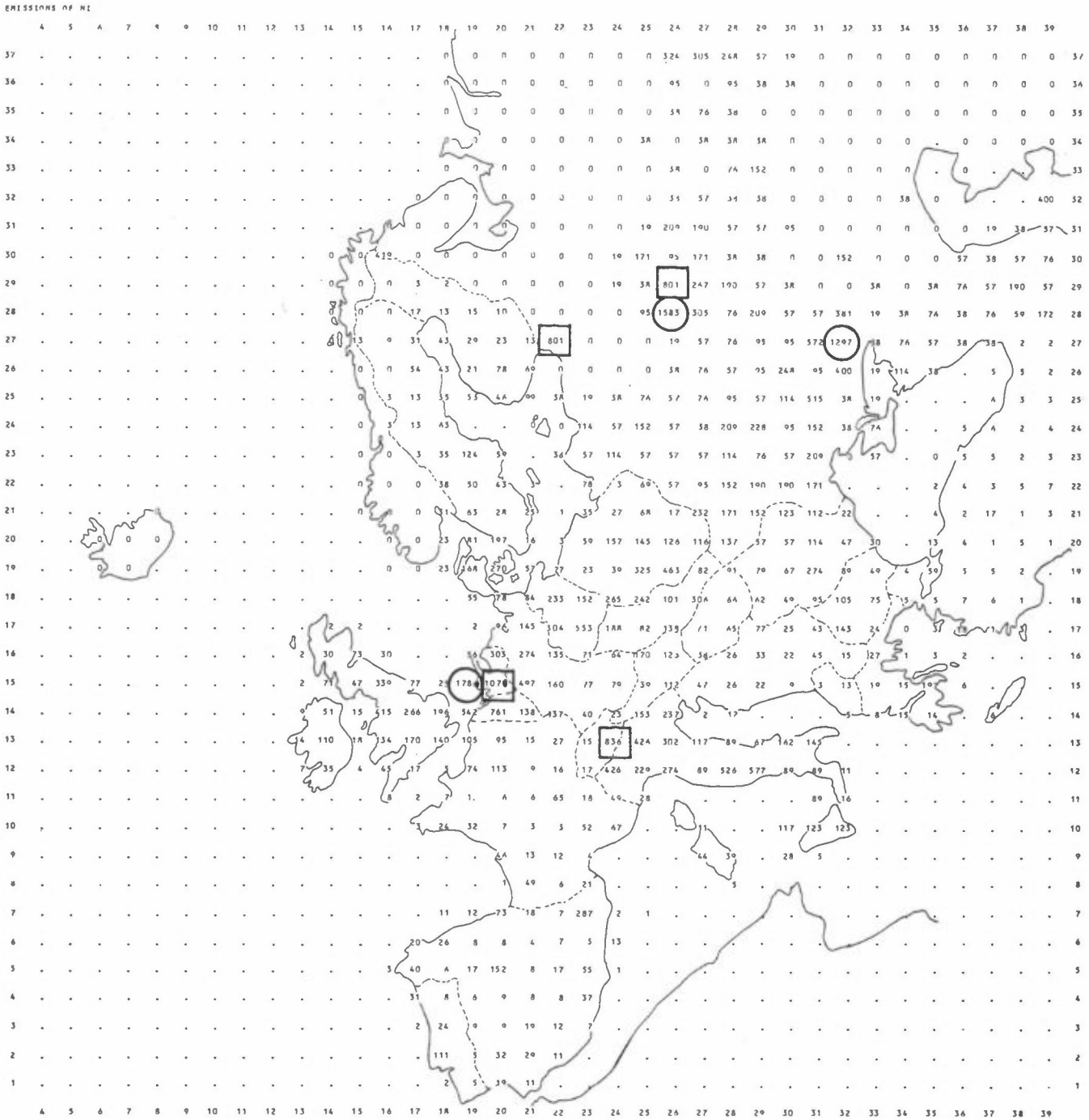

Fig. 10: Estimated annual emission of nickel (x100 kg Ni) from conventional thermal power plants in grid elements with side length 150 km.

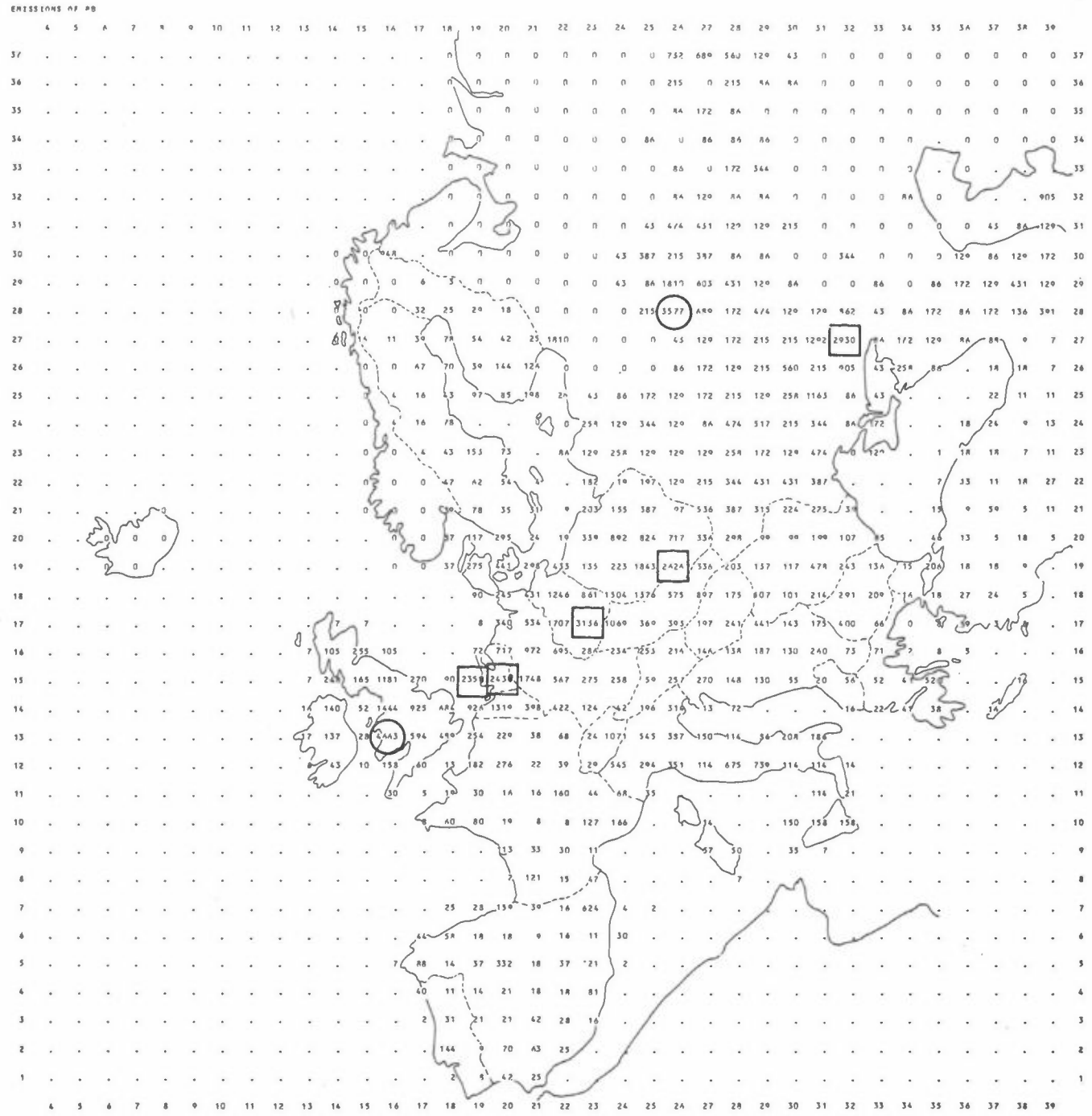

Fig. 11: Estimated annual emission of lead (x10 kg Pb) from conventional thermal power plants in grid elements with side length 150 km.

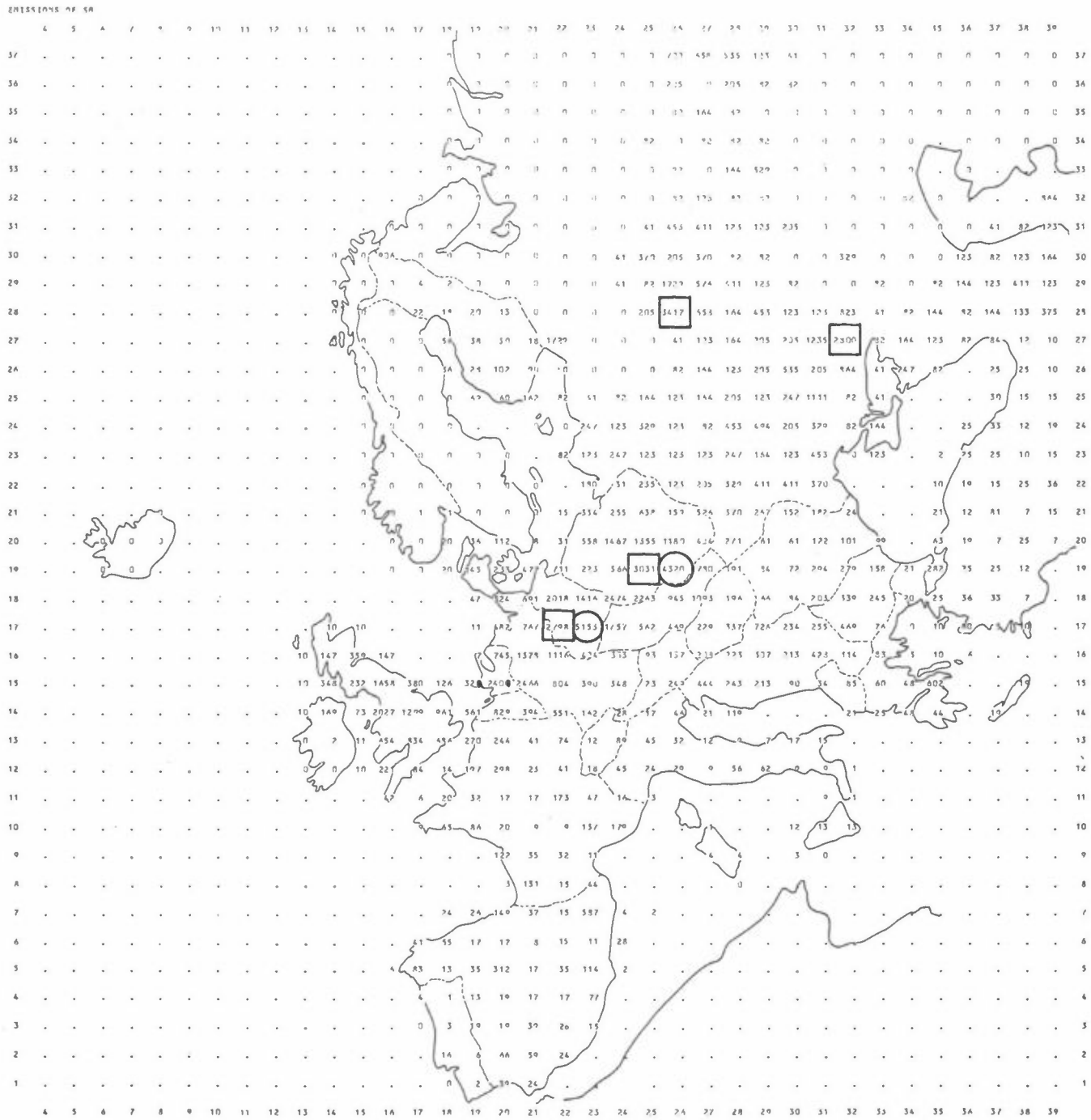

Fig. 12: Estimated annual emission of antimony (kg Sb) from conventional thermal power plants in grid elements with side length 150 km.

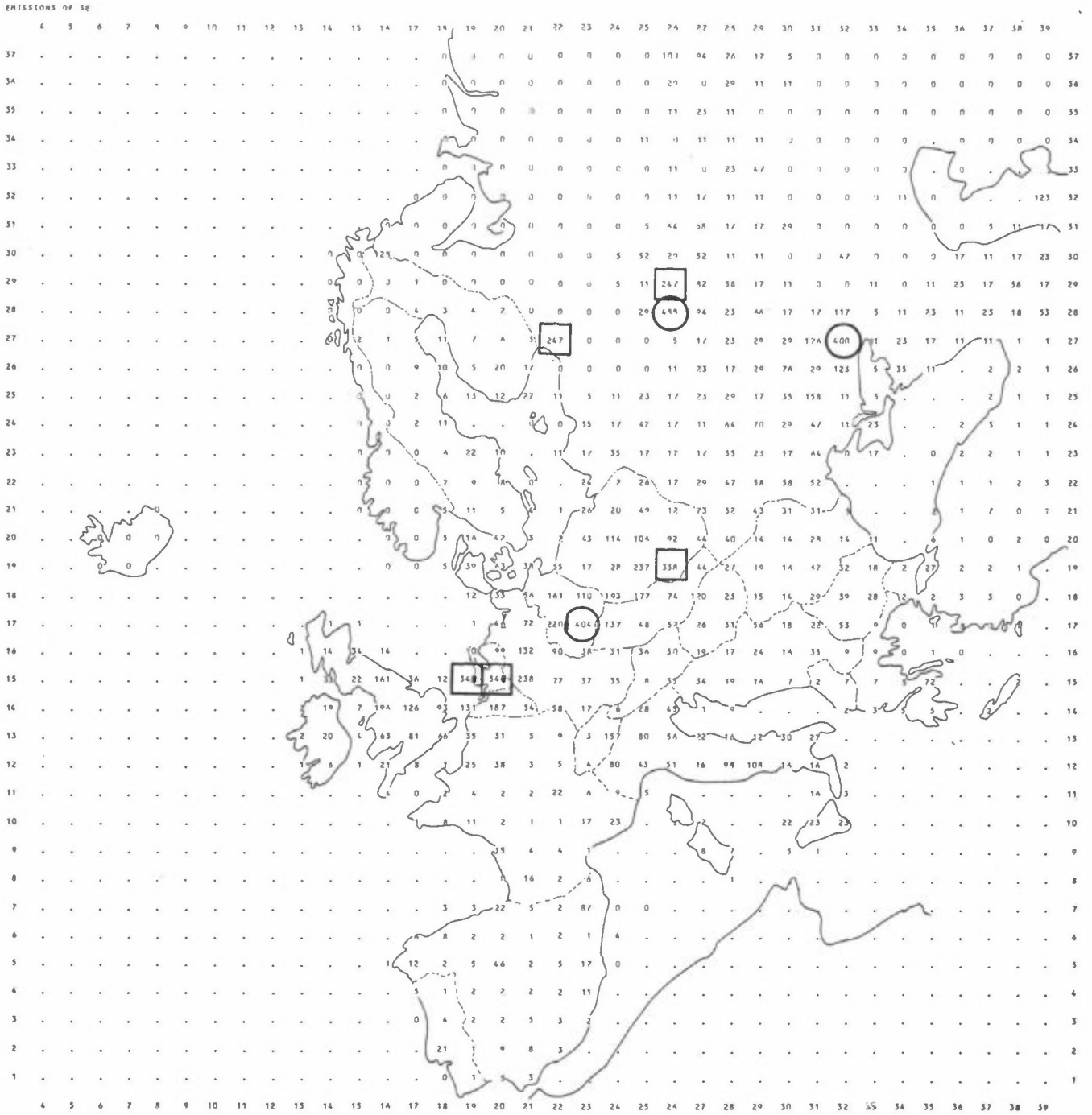

Fig. 13: Estimated annual emission of selenium (x10 kg Se) from conventional thermal power plants in grid elements with side length 150 km.

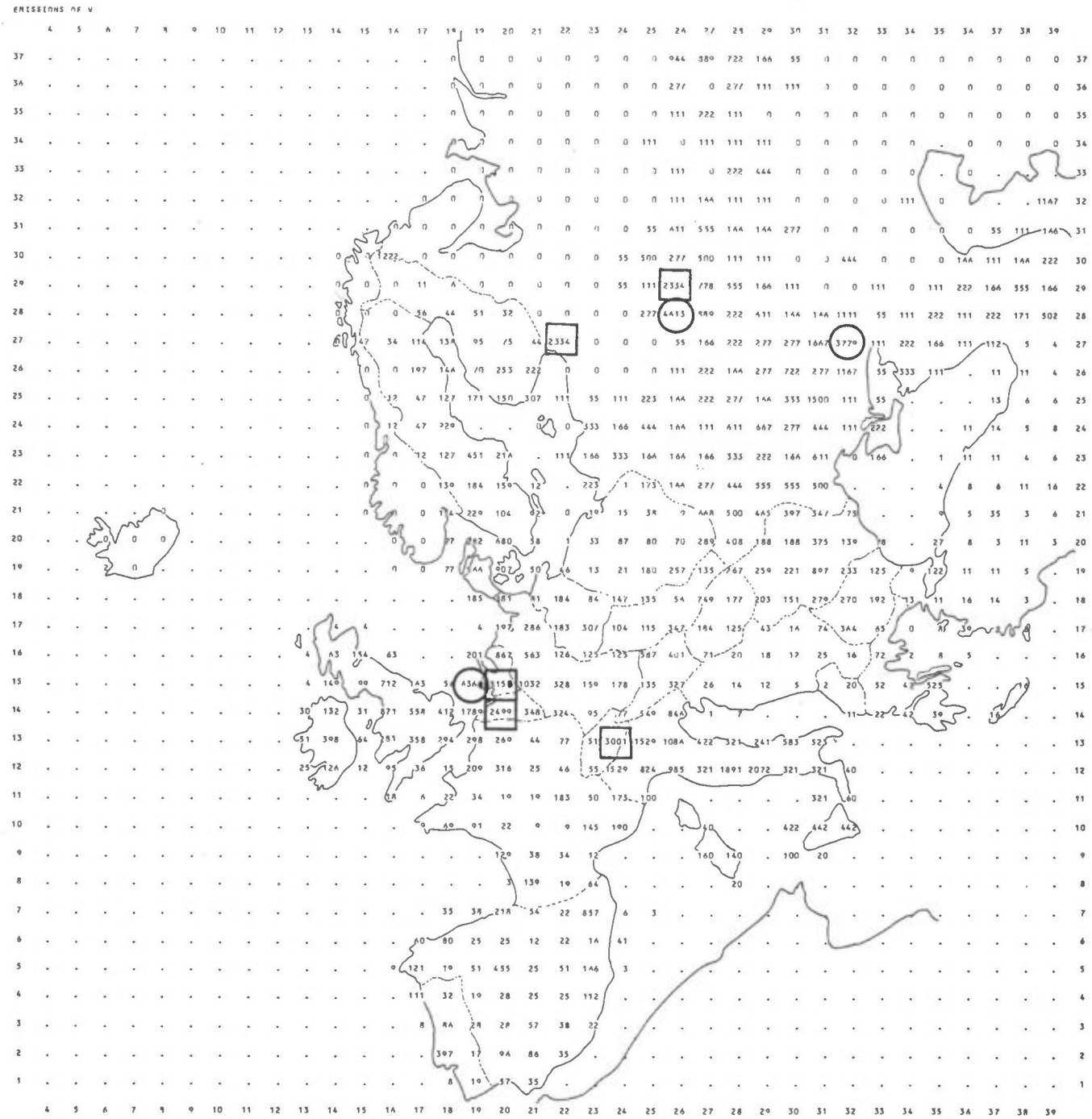

Fig. 14: Estimated annual emission of vanadium (x100 kg V) from conventional thermal power plants in grid elements with side length 150 km.

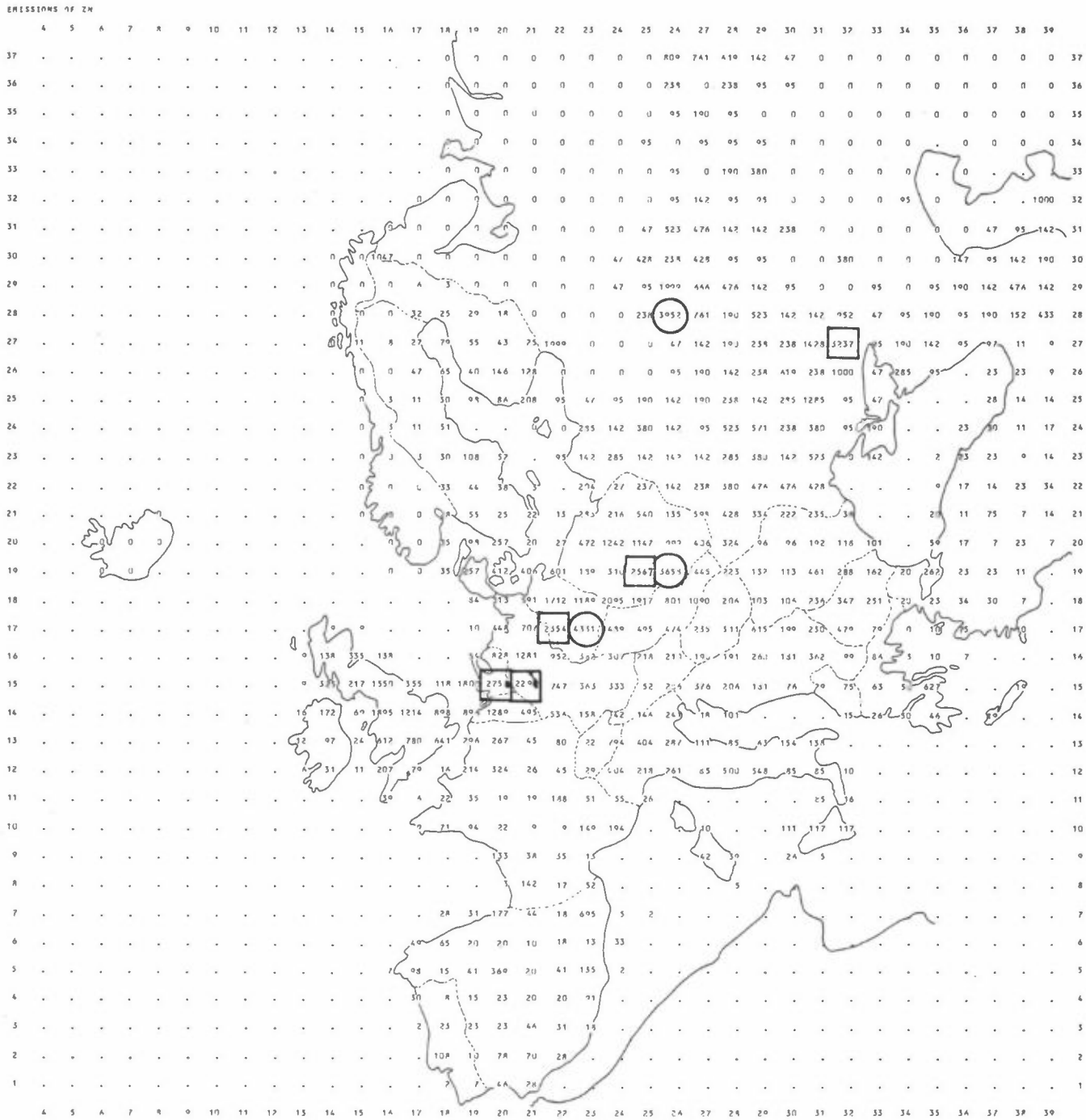

Fig. 15: Estimated annual emission of zinc (x10 kg Zn) from conventional thermal power plants in grid elements with side length 150 km.

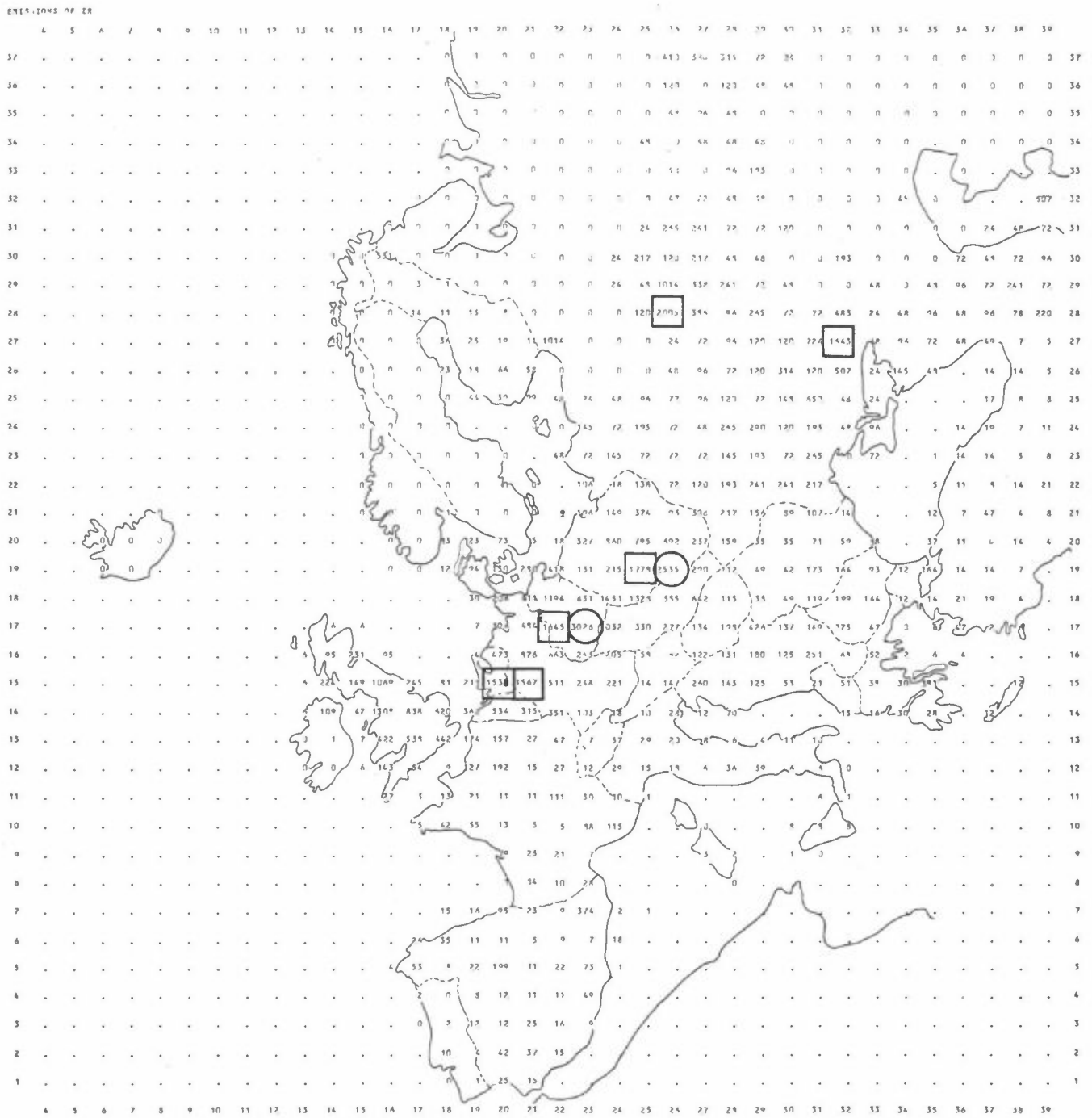

Fig. 16: Estimated annual emission of zirconium (x10 kg Zr) from conventional thermal power plants in grid elements with side length 150 km.

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In the report the spatial distribution of the trace element emission from conventional thermal power plants in Europe is estimated, using emission factors of trace metals from conventional power plants and data on net installed capacity of electricity generating plants in each country. Also data on type of fuel burned (emphazising the ash content in coal and the sulphur content in ail), data on stack dust cleaning installations and geographical position of the power plants have been used when available.

**Kategorier: Åpen - kan bestilles fra NILU A
Må bestilles gjennom oppdragsgiver B
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