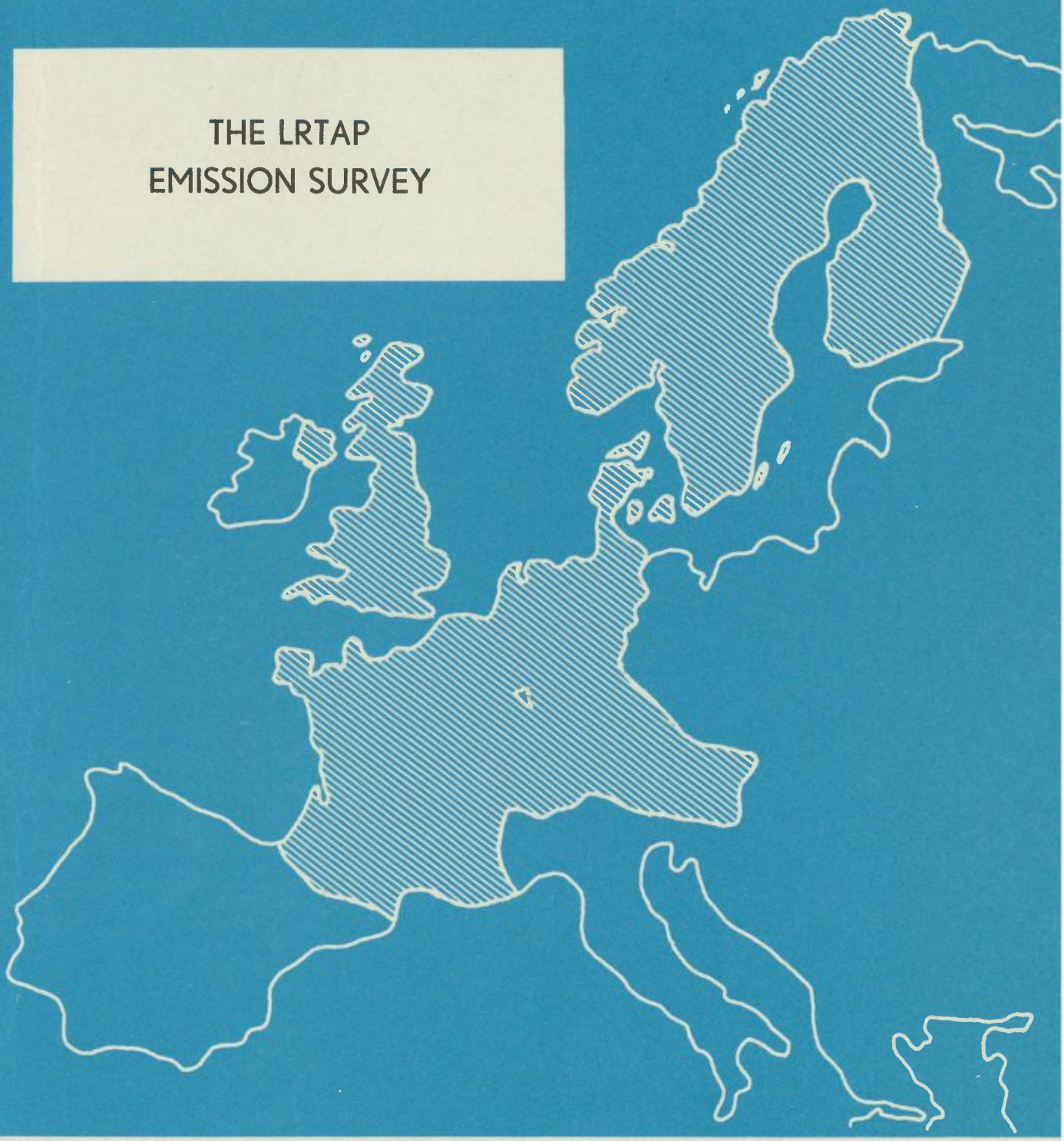
LONG RANGE TRANSPORT OF AIR POLLUTANTS

A cooperative OECD technical programme

THE LRTAP EMISSION SURVEY



CENTRAL COORDINATING UNIT
Norwegian Institute for Air Research
P.B. 115 – 2007 Kjeller – Norway

LRTAP - 2/74

Dato: November 1974

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by

B Rystad, S Strømsøe, E Amble, T Knudsen

NORWEGIAN INSTITUTE FOR AIR RESEARCH
P.O. BOX 115, 2007 KJELLER
NORWAY

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SUMMARY

A survey of the emissions of sulphur dioxide in North-west Europe has been made in connection with the OECD Programme "Long Range Transport of Air Pollutants".

The results are given in a grid system with individual grid areas of $\frac{1}{2}^{o}$ latitude times 1^{o} longitude. Emissions are given in tons SO_2 per grid square as estimated for the year 1973, and have been divided in a constant component, and a seasonal component.

Reservations are made with respect to the accuracy of the calculations and the sources of information. The survey has been constructed for use in connection with large scale atmospheric dispersion calculations only and should not be used for evaluations on a scale of less than 100 km between significant points.

1 INTRODUCTION

During the first measurement phase of the OECD-project "Long Range Transport of Air Pollutants", it was considered sufficient with the emission data from the countries which were compiled by Dehove (1) and distributed in the squares of a 127 x 127 km grid system and adjusted by Saltbones (2). In the second measurement phase a more complete emission survey was wanted. The collection of information from the countries was started in December 1972. The countries were asked to provide sulphur dioxide emission data to conform with a reference grid system of $\frac{1}{2}^{o}$ latitude times 1^{o} longitude. It was also requested that the emission within each grid should be separated into a constant plus a variable, temperature-dependent term.

Emission data according to these specifications have been supplied by Switzerland, the Federal Republic of Germany, Sweden, Denmark, Norway, Finland and the United Kingdom.

Emission data with a slightly different breakdown into regions and emission sources have been given by France and the Netherlands.

The emissions from Austria and Belgium were estimated by the use of population statistics, information on the economic and industrial structure and data from other available sources. Finally, the emission data have been processed and presented with the aid of a computer programme.

The data given in this report include all corrections and revised figures received from the countries by 1st November 1974.

The emission data from the different countries are not strictly comparable, because of different basis material and different basic assumptions made in the compilation of the data.

The estimated figures for Belgium and Austria are probably less accurate both with respect to the total emissions and the distribution on the various grid squares. There are also uncertainties in connection with the use of an estimated constant annual growth rate in the emissions, due to differences in types of fossile fuels used, and differences in future trends from one country to another. In some countries for instance there has been a considerable shift from solid fuels and oil towards natural gas with a very low sulphur content.

For use of the survey in other connections than for the atmospheric dispersion calculations, the reservations mentioned above should be taken into due account. A description of the methods used, and of sources of information in the various countries are given in the following.

2 BASIS FOR THE ESTIMATIONS

2.1 Categories of emissions

The countries have been asked to classify their sulphur dioxide emissions as continuous or variable emissions, and give these separately. The continuous emission is defined as being equal from one week to another, during the whole year. Diurnal variations are not considered. Most of the emissions from the industry and some of the emission from the power stations (here taken as 50%) fall in this category.

The variable emission includes all seasonal heating. This is the heating in the category "domestic and commercial", some of the emission from power stations, and when it has been possible to calculate it, a comparatively small fraction of the emission from the industry. Seasonal industry which operates mainly in the cold season has also been included in this group.

2.2 The grid system

The reference grid system is formed by each half degree of latitude and each degree of longitude. Each square is identified by the coordinates of its lower left corner. Thus, the square limited by 55 and 55.5 degrees of latitude and 1 and 2 degree of longitude (east), is labelled (55.0, 1).

The area of the squares is proportional with the cosinus to the corresponding latitude. The area of a square situated at 60° latitude is

$$55.55 \times 111.11 \cos 60 = 3086 \text{ km}^2.$$

2.3 Degree-days

The degree-days are calculated with $18^{\circ}C$ as a base. When the average temperature a given day is t, the number of degree-days this day is 18 - t.

3 CALCULATION OF EMISSION FACTORS

The number of inhabitants in each square was calculated for all countries. The latest population statistics available for each country were used, mostly for the year 1970. No growth in the population has been stipulated beyond this date. The population statistics used give the number of inhabitants for districts less than a grid square. The

distribution of the district area on grid squares is then measured, and the population within each community distributed on the squares in proportion with the areas of the community falling within the grid squares.

It is possible to calculate the continuous and variable emission per inhabitant and year for each square in the countries where the emissions are known. These emission factors vary between the countries, and are dependent on the economic and industrial structure in the countries, and the properties of the fuels available. Table 1 on page 15 shows the emission factors for each country. The basis for the calculations is given in chapter 4.

4 EMISSIONS FROM THE COUNTRIES

4.1 Switzerland

The emission data collected by Dr. Morkowski, Eidgenössische Materialprüfungsanstalt (3) were given in a grid system of $1/4^{\circ}$ latitude times $\frac{1}{2}^{\circ}$ longitude for the following categories.

A: Domestic heating.
B: Fuel combustion in steam- and hot water boilers.
C: Fuel combustion in cement, brick and steel production.
D: Other industrial processes.
E: Transport and traffic.

Category A forms the variable component. The emissions were calculated for 1970, and an annual growth rate of 3% was assumed. The distribution of the population on squares was given together with the emissions. In calculation of the degree-days, $20^{\circ}C$ was used as base temperature.

4.2 The Federal Republic of Germany

The emissions have been estimated for 1970 by NUKEM GmbH (4) for the standard reference grid squares in the categories continuous and variable emissions, and also with a separation in the emissions from househeating, public power stations, industry and traffic. The distribution of the population was given together with the emissions. Some minor corrections and additions have been made. The variable component in square (53.0, 11) was missing, this was taken as 317 tons SO_2. The number of inhabitants was missing in square (52.0, 11), this was taken as 20.000. The emission per inhabitant then became relatively high in this square. An annual growth rate in the emission of 3% was assumed.

4.3 Norway

The emissions have been calculated by NILU in cooperation with the Norwegian Federation of Industry. The emissions were given for the standard reference grid squares and in the following categories; fishing industry, continuous emission from the industry, emission from service-industry (small workshops etc), and variable emission from domestic and commercial sources. The emission from the fishing industry was taken as continuous, as well as 50% of the emission from the service-industry. The emissions were calculated for 1970, and an annual growth rate of 3% was assumed. Population statistics from 1971 (5) was used.

4.4 Sweden

The emissions were estimated by Statens Naturvårdsverk (6) for 1972, for the standard reference squares and given in the categories:

A: Emission from the oil combustion by the 800 largest consumers of fuel oil.

B: Emission from power plants (included A).

C: Emission from industrial processes.

D: Variable emission.

E: Amount of sulphur dioxide from fuel oils retained in the industrial processes.

The population in each square was given together with the emissions. The emission from the power plants was divided equally between the continuous and the variable component. An annual growth rate of 3% in the emission was assumed.

4.5 Finland

The emissions for 1973 were given by the Finnish Meteorological Institute for the standard reference grid squares and in the categories continuous and variable emissions. A small part of the total emissions due to the use of oil in domestic heating in north and east was not distributed on the grid squares by FMI. This distribution was done by NILU in proportion with the population density as requested by FMI. The population statistics from 1971 was used (7).

4.6 England, Scotland and North Ireland

The emissions were calculated by the Warren Spring Laboratory for 1970 and divided on standard reference squares in the categories industry, domestic sources, oil refineries and power stations. The variable component was taken as the emission from domestic sources plus 50% of the emission from power stations. The emission figures for 1970 were reduced by 5% to fit with the total emissions of 5.6 million tons for 1973 estimated by the Warren Spring Laboratory. This development is mainly due to the more extensive use of gas. The population statistics from 1971 (8) was used.

4.7 France

The emissions were calculated by Centre Interprofessionnel Technique d'Etudes de la Pollution Atmospherique for 1971. The emissions were given for each Department and in the categories.

A: Domestic heating and small industries.

B: Industry and steel production.

C: Electricité de France.

D: Refineries plus emissions from the Lacq district.

E: Centrales Charbonnages de France.

Category C and E refers to power stations, and 50% of this emission together with the emission from domestic heating and small industries forms the variable component. The emissions given include the total emissions from the iron and steel industry and the refineries. They do not include the emissions from other industrial processes as chemical industry, pulp and paper industry, and desulphurization of ores. C.I.T.E.P.A. estimates this to 5% of the continuous

component, thus 5% for the whole country. An annual growth rate of 3% in the emission was assumed. The population statistics from 1968 (9) was used.

4.8 Denmark

The emissions were calculated by the Meteorological Institute in Copenhagen (19), divided on squares and given in the categories:

A: Industry
B: Power stations
C: Domestic and commercial sources.

For this country it is claimed that 25% of the emissions from the power stations together with the emission from commercial and domestic sources forms the variable component.

An annual growth rate of 3% in the emissions was assumed. The population statistics from 1973 was used (10).

4.9 Belgium

So far no emission data has been received from Belgium. A variable emission factor of 33 kg SO_2/inhabitant and year (1973) was estimated for the whole country. The total emissions as well as the distribution of the continuous emissions on squares according to degrees of industrialization was estimated by using available relevant information (11, 12, 13). The population statistics from 1970 (14) were used.

4.10 The Netherlands

The emission data are based on information given in a publication by Suurland and Houweling (15). This report considers SO_2-emissions by fuel combustion in stationary sources. The figures are given per province and divided on 25 different categories of sources. The emission from industrial processes is estimated to 150.000 tons and from traffic to 100.000 tons SO_2/year (1973) according to this report. The variable component represents the sum of the emissions from agriculture, commerce and households, to which has been added 50% of the emissions from power stations. No increase in the emissions from 1972 to 1973 was assumed. The population statistics from 1971 (16) were used.

4.11 Luxembourg

The population statistics from 1970 (11) was used. The variable emission factor was taken as 50 kg SO_2/inhabitant and year (1970), and the continuous emission factor as 100 kg SO_2/inhabitant and year (1970). An annual growth rate of 3% in the emissions was assumed.

4.12 Austria

Data about consumption of fossile fuels in Austria for 1972 were recently supplied by Bundesstaatliche Bakteriologisch-serologische Untersuchungsanstalt, Abteilung für Lufthygiene. The information was given for each fuel type separated in the categories:

A: Industry
B: Power plants
C: District heating plants
D: Commerce
E: Traffic

F: Households
G: Other

Consumption figures in the categories A, B and C were divided on standard reference grid squares while data in group D, E, F and G were given as totals for Austria.

Emissions of SO_2 were calculated by the use of sulphur contents also supplied by Bundesstaatliche bakteriologisch-serologische Untersuchungsanstalt. The emissions from industrial processes were estimated to 20.000 tons SO_2/year.

The variable component is 15% of the total emissions and consists of category F together with a part of the emissions from heat and power production. An increase of 3% in the emissions from 1972 to 1973 was assumed. The population in each square was given together with the other data.

5 TABLE OF EMISSIONS BY COUNTRIES

Country	Population	Emission of sulphur dioxide per inhabitant, kg SO_2/inhabitant year 1973.									Total emission of SO_2 per country, tons SO_2/year 1973.		
		Continuous comp.			Variable comp.			Sum cont. + var.					
		max	min	aver	max	min	aver	max	min	aver	cont.	variable	sum
Switzerland	6.272.227	35.0	1.0	15.7	10.8	6.2	8.4	42.9	8.9	24.1	98.230	52.746	150.976
West-Germany	61.166.000	211.5	0.0	46.2	36.3	12.5	18.0	229.3	18.2	64.2	2.825.792	1.102.252	3.928.044
Norway	3.866.468	1876.9	2.4	34.0	24.9	7.1	12.9	1886.5	9.8	46.9	131.462	50.048	181.510
Sweden	7.975.880	3277.4	0.0	74.0	39.9	18.0	29.9	3312.5	19.1	104.0	590.466	238.847	829.313
England, Wales, Scotland, and North Ireland	54.236.601	726.9	0.0	57.3	422.1	0.0	46.0	1059.3	3.7	103.3	3.111.345	2.493.655	5.605.000
France	49.509.100	586.1	0.0	45.3	99.6	3.8	20.0	590.3	5.8	65.3	2.243.040	991.517	3.234.557
Denmark	5.009.548	294.9	0.0	56.9	220.1	18.8	67.6	467.5	19.1	124.4	284.842	338.537	623.379
Finland	4.710.674	1176.2	0.0	86.9	481.5	1.1	29.7	1178.3	7.8	116.5	409.160	139.810	548.970
Belgium	9.650.944	130.3	20.9	72.2	31.4	30.2	31.2	161.6	52.3	103.4	696.763	301.363	998.125
Netherlands	13.266.000	112.2	16.8	40.9	24.8	12.7	18.1	137.0	31.8	59.0	542.537	239.496	782.033
Austria	7.456.403	453.8	10.1	50.3	91.2	4.7	8.9	458.5	15.0	59.2	375.015	66.319	441.333

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7 APPENDIX

7.1 Continuous, variable and total emission per grid square

7.2 Continuous and variable emission factors and population per grid square

7.3 Emission per area, population density and area per grid square

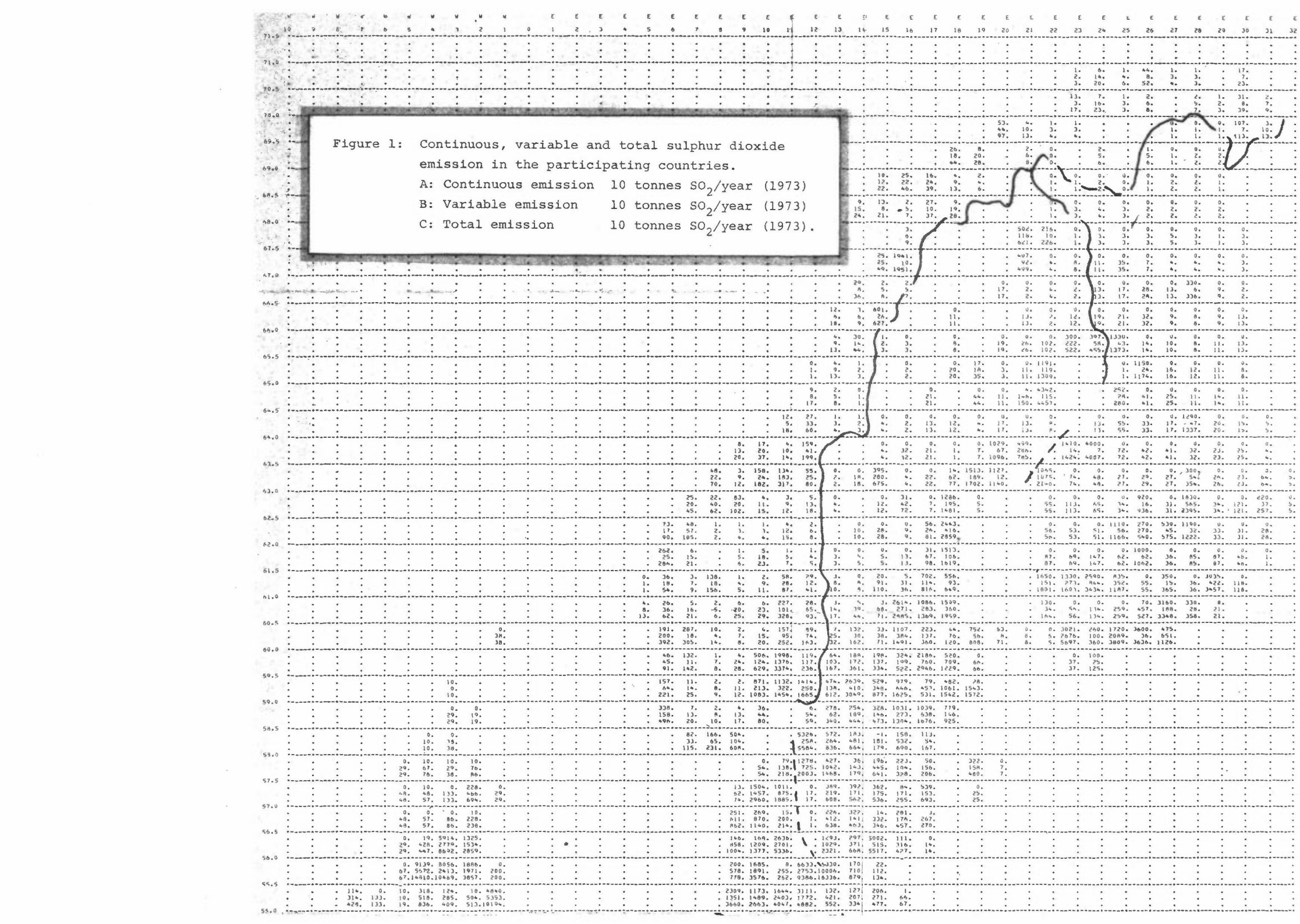
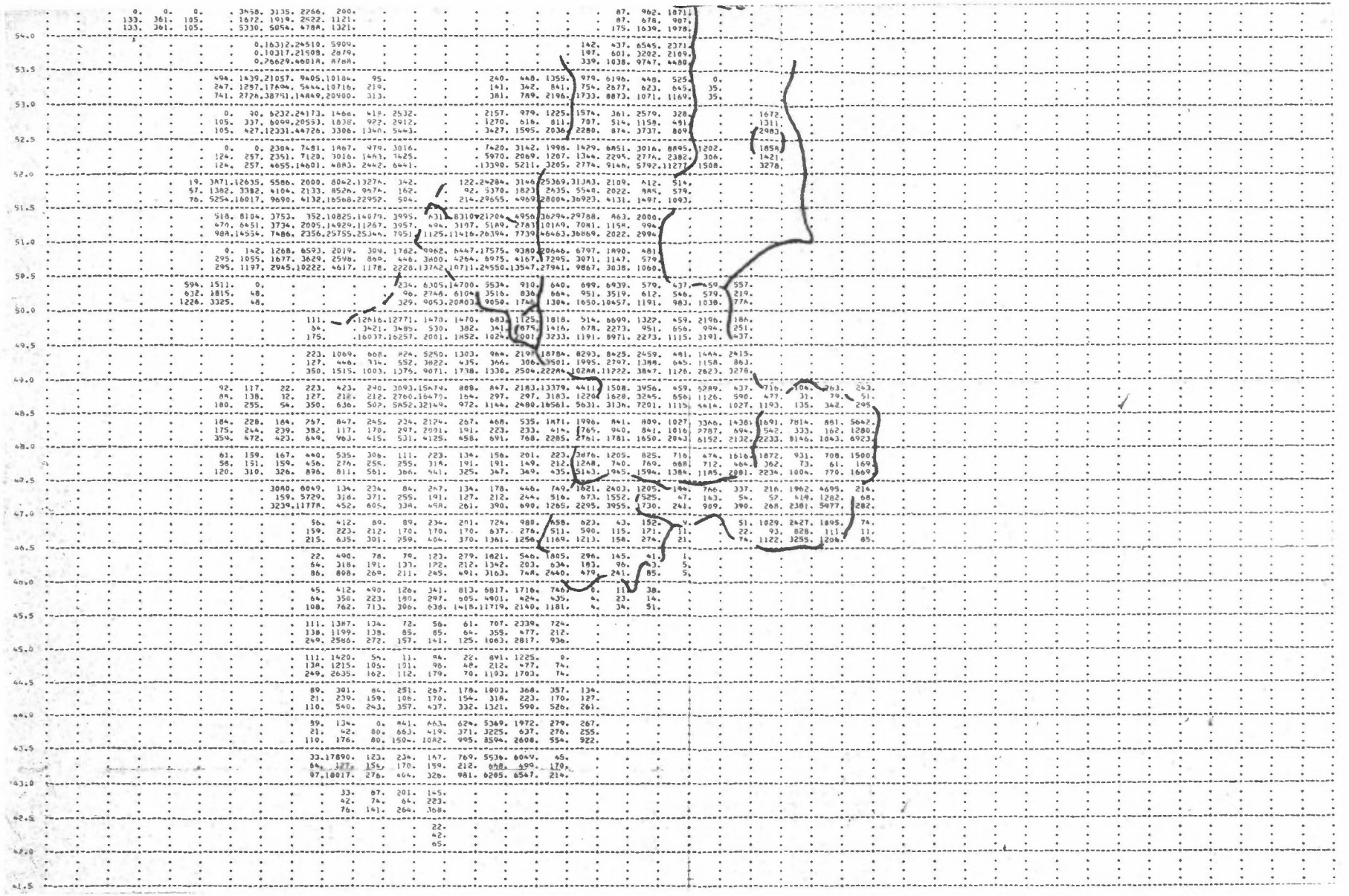


Figure 1: Continuous, variable and total sulphur dioxide emission in the participating countries.

A: Continuous emission 10 tonnes SO_2/year (1973)

B: Variable emission 10 tonnes SO_2/year (1973)

C: Total emission 10 tonnes SO_2/year (1973).



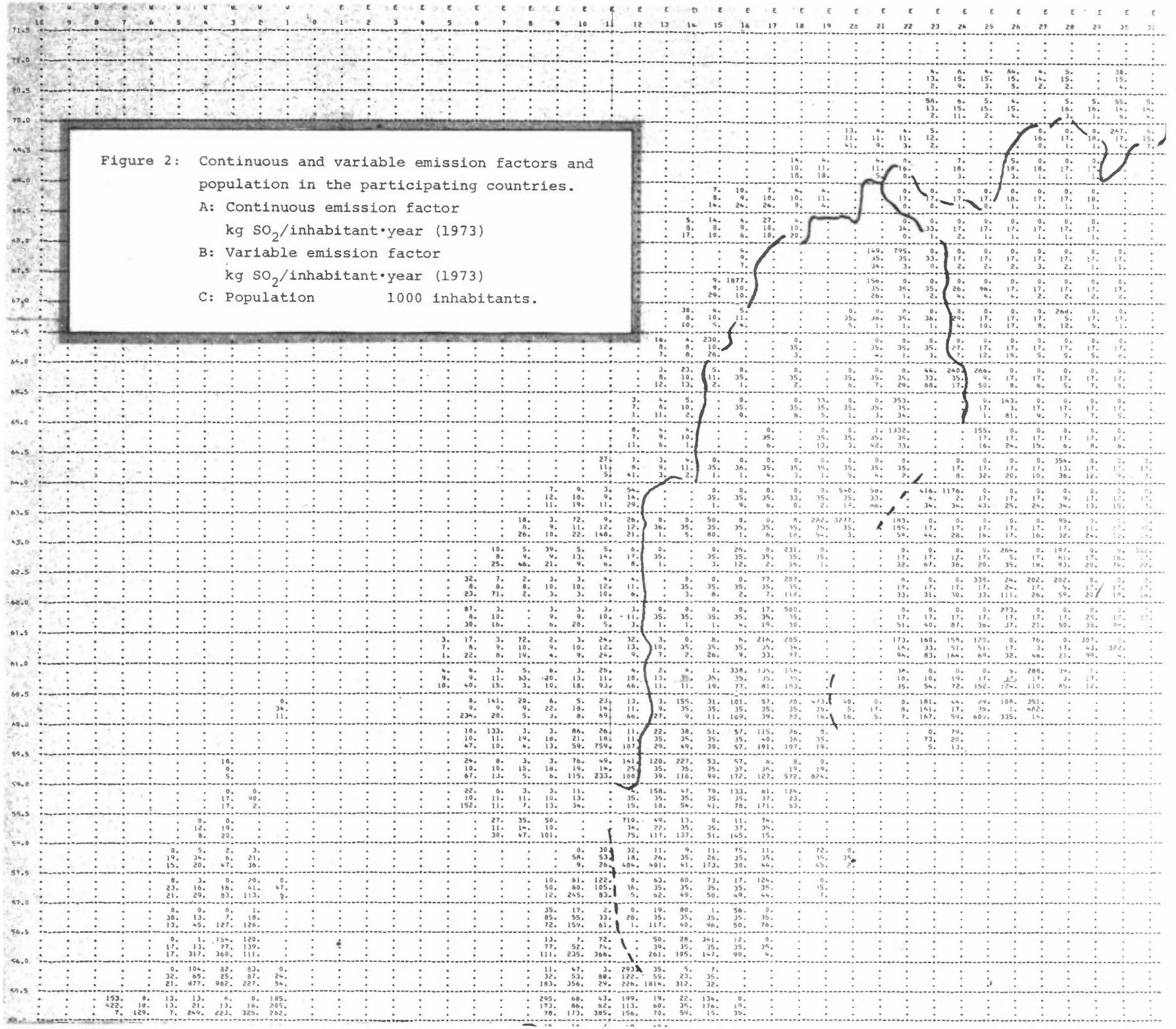
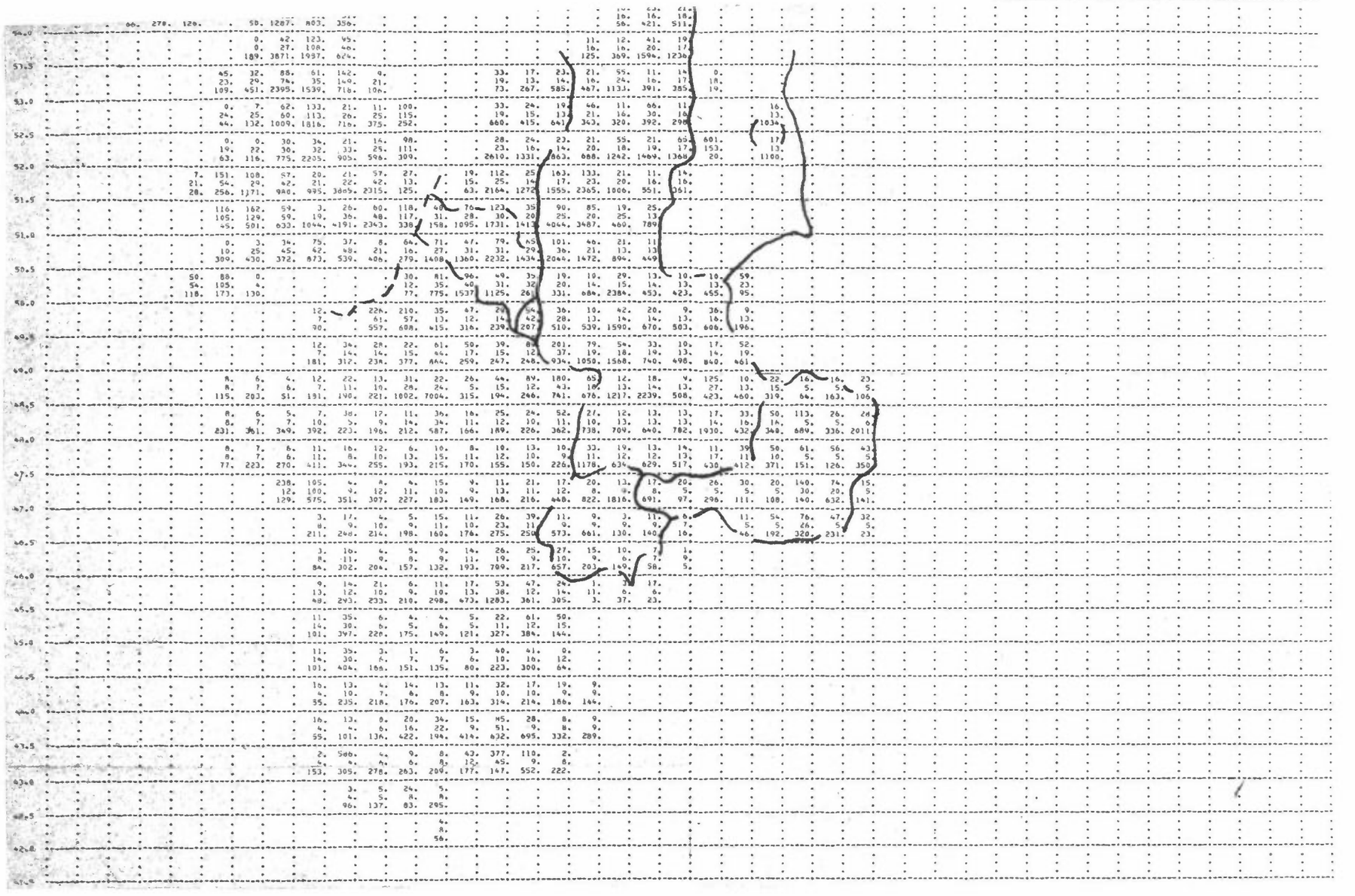


Figure 2: Continuous and variable emission factors and population in the participating countries.

A: Continuous emission factor
kg SO_2/inhabitant·year (1973)

B: Variable emission factor
kg SO_2/inhabitant·year (1973)

C: Population 1000 inhabitants.



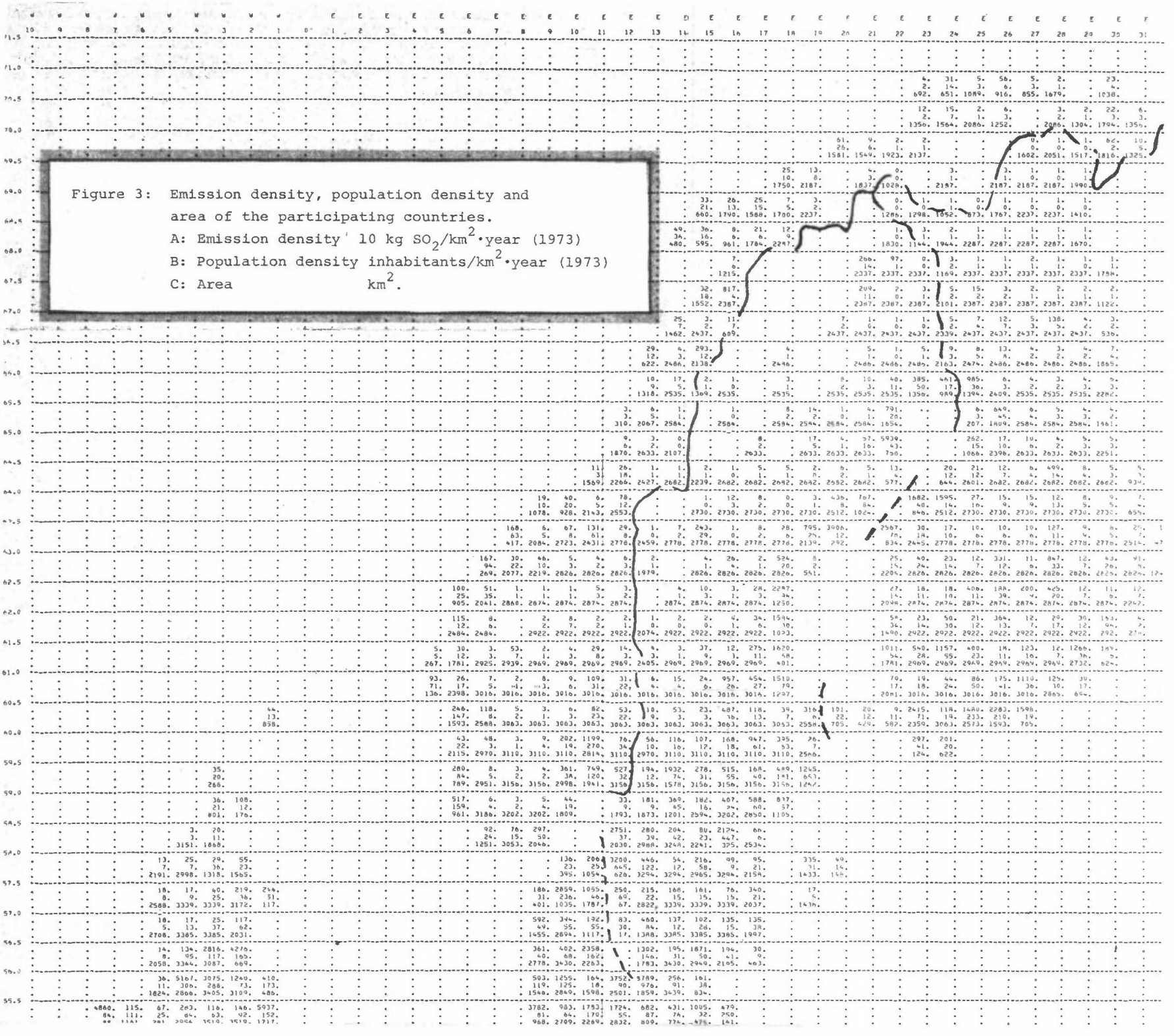


Figure 3: Emission density, population density and area of the participating countries.
A: Emission density 10 kg $SO_2/km^2 \cdot year$ (1973)
B: Population density inhabitants/$km^2 \cdot year$ (1973)
C: Area km^2.