LONG-TERM AIR POLLUTION EFFECTS AND HEALTH

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1. Introduction

The atmosphere consists of a mixture of gases. The main components of dry air are nitrogen (78%), oxygen (21%), Argon (0.9%), and carbon dioxide (0.03%). The rest contains noble gases and sulphur dioxide which is emitted into the atmosphere through volcanic activities.

Since the beginning of industrialisation the burning of fossil fuel has caused a continuous increase of sulphur dioxide, especially in urban and industrial regions where large amounts of coal, mineral oil have a very high sulphur content (up to 3%); in hard coal it reaches about 1%; and in light mineral oil 0.5% or less. Due to the fuel burn up, the anthropogenous contribution of sulphur dioxide or - in connection with water - of sulphuric acid have strong effects on organic as well as on inorganic substances. The biosphere is attacked continuously by sulphur dioxide. Concentrations of this gas exceeding the natural level significantly impair the health of humans as well as vegetation, with both long-term and short-term effects on health. In this presentation I would like to discuss the mean SO^2-situation which has long-term effects on the biosphere.

2. Relationship Between Sulphur Dioxide-Concentration and Meteorological Parameters

Our research on the relation between the sulphur dioxide-concentration and meteorological parameters is based on values obtained by the sulphur dioxide-network of the Senate of Berlin (W) which consists of 31 measuring points with a grid distance of 4 km (Fig. 1). Furthermore we used the meteorological observations of the Institute of Meteorology (Free University of Berlin). Daily mean sulphur dioxide-values and temperature, wind direction, wind speed, and inversions near the surface were correlated and analysed.

Fig. 2 shows the mean sulphur dioxide-distribution on mild winter days (T_M>=-5^{O}C) with values from 100 to 200 ìg/m^3. On cold winter days (T_M=<-5^{OC}) the sulphur dioxide-concentration varies between 200 and 400 ìg/m^3 (Fig. 3). Thus we can conclude that on colder days the air pollution increases. It is evident that the intensity of residential heating is strongly affected by the daily mean temperatures.

Some parts of Berlin (FRG) report significantly higher pollution values than others. This fact is mainly due to the population density: In the outskirts of Berlin it is up to 2000 people/km^2, in most parts 4000 to 5000, and in the highest polluted parts of the city up to 12,600 people/km^2. Regarding all these facts it can be stated that the daily mean temperature in winter influences the emission of sulphur dioxide and that the degree of air pollution in certain areas depends on the population density.

An important factor for the degree of emission is the wind directions. Fig. 4 shows the sulphur dioxide-concentration associated with westerly winds; Fig. 5 shows the distribution of sulphur dioxide related with south-easterly winds. In case of winds from the west, north-west, north and north-east, the yearly mean sulphur dioxide values did not exceed 100 ìg/m^3, while very high values up to 250 ìg/m^3 were observed with winds from the south-east or south. Medium high concentrations with values up to 150 ìg/m^3 were connected with easterly (Fig. 6) and south-westerly winds.

The difference of sulphur dioxide-concentration on days with strong winds and days with weak winds is plotted in Fig. 7. The sulphur dioxide-concentration generally decreases with increasing wind speed, i.e. increasing turbulent diffusion. But there are exceptions to the rule. Fig. 8 demonstrates that the sulphur dioxide-values in the highly polluted inner parts of the city are reduced by stronger winds from the south-east while the transport of sulphur dioxide from the higher polluted inner parts of the city leads to an increase of pollution in the outskirts.

The degree of air pollution is strongly influenced by weather situations with inversions. Fig. 9 shows that the mean sulphur dioxide-concentration does not exceed 100 ìg/m^3 on days without an inversion. On days with a permanent inversion in the layer up to 300 m, however, the daily mean sulphur dioxide-values amount to 275 ìg/m^3 in the city centre (Fig. 10).

Summing up we can say that low temperatures, weak winds, and the existence of an inversion are the basic factors for smog and therefore for the most intense effects on the biosphere, including human health.

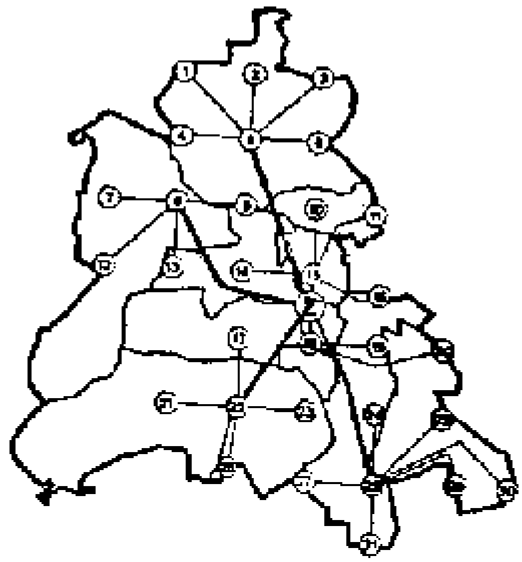

Figure 1: SO_2 - network of Berlin (W)

Figure 2: Mean SO_2-distribution on mild winter days (T_M>5^{O}C)

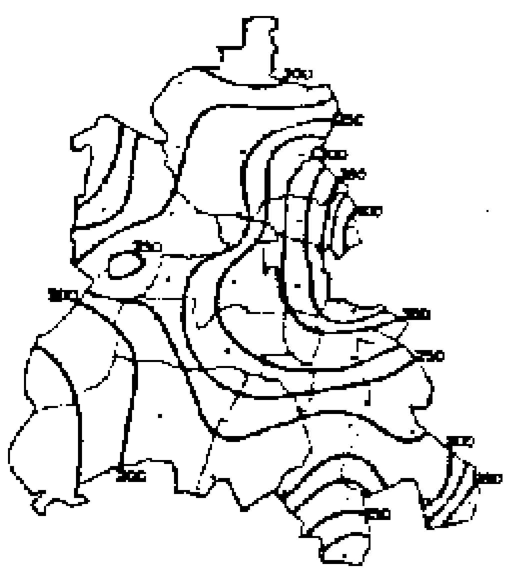

Figure 3: Mean SO -distribution on cold winter days (T <-5$^{OC)}$

2 M

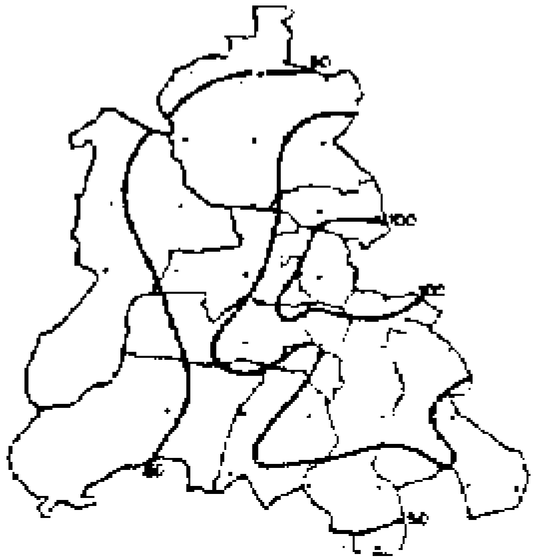

Figure 4: Mean SO_2-distribution on days with westerly winds

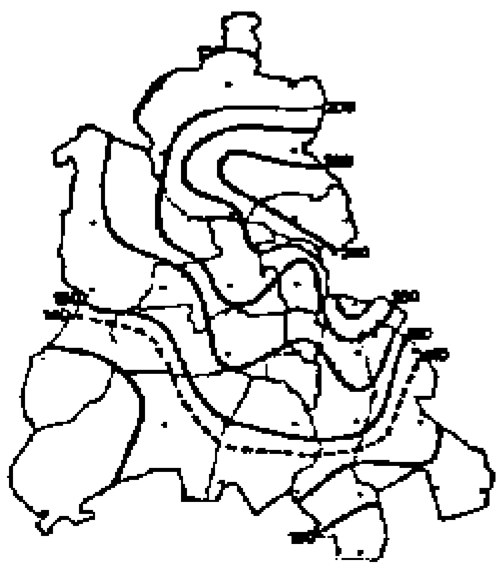

Figure 5: Mean SO_2-distribution on days with southeasterly winds

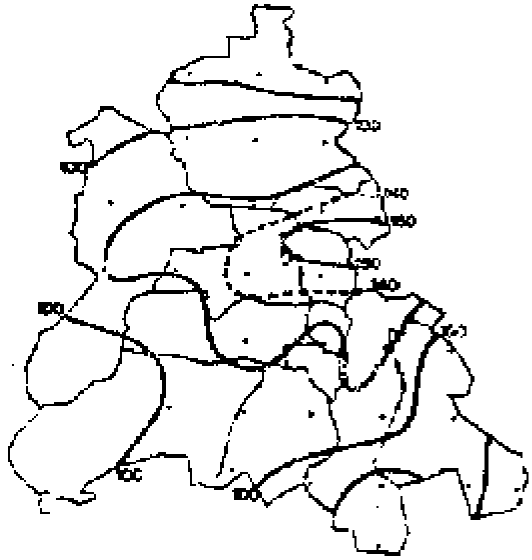

Figure 8: Mean SO_2-difference on days with strong vs weak winds from southeast

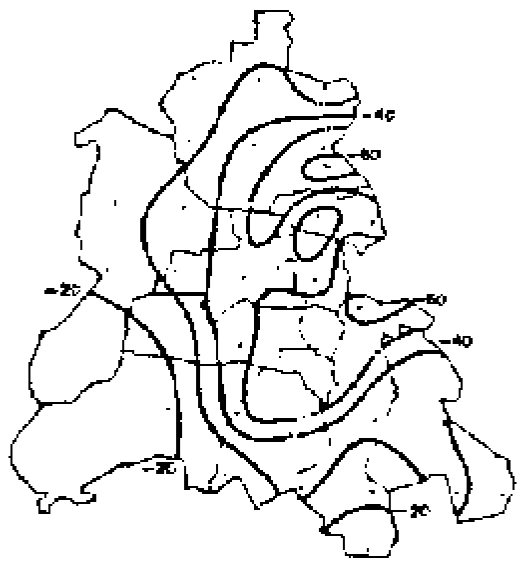

Figure 9: Mean SO_2-concentration on days without an inversion

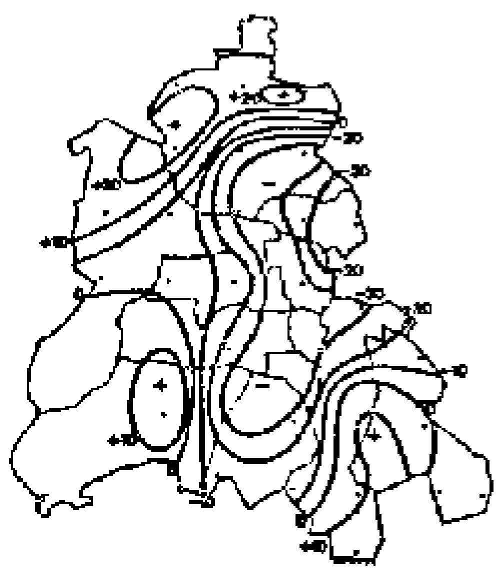

Figure 10: Mean SO_2-concentration on days with an inversion

3. Variation in Sulphur Dioxide-Concentration Since 1971

The sulphur dioxide-network of the Senate of Berlin (FRG) began operating in summer 1975, so yearly mean values are available since 1976. For the time before this date we have no information about the sulphur dioxide-concentrations at the grid points. Based on the relation between sulphur dioxide-amounts and meteorological parameters discussed before, we developed regression equations. In the most simple case such statistical equations have the linear form

$$SO_2=a_0 + a_1x_1 + a_2x_2 + ... a_nx_n$$

where x_1 to x_n are the predictors, i.e. the meteorological parameters, and a_0 to an are coefficients. For our purpose we used more efficient regression equations with non-linear terms

$$SO_2=F_M (F_{M-1}(...F_2(F_1(x_1 ,x_2)x_3....1).$$

The orders of the predictors were different for outer and inner parts of the city, as shown in Table 1.

Table 1: Order of sulphur dioxide-predictors

outer parts	inner parts
1. wind direction	1. persistency
2. persistency	2. inversion
3. inversion	3. temperature
4. temperature	4. wind direction
5. wind speed	5. wind speed

Since measuring points in the city are surrounded by intense sulphur dioxide-sources, the wind direction in this area is less important than in the outskirts.

Fig. 11 shows the course of the yearly sulphur dioxide-mean of 3 stations for the 15-year period 1971-1985. The variations from 1971-75 are based on calculated values, the variations since 1976 on observed data. P 11 represents the part of Berlin (FRG) with the highest pollution; P 31 represents the situation in the green belt on the fringe. The values of P 9 are typical for the larger region in between.

The highest air pollution values are measured in the period 1971-1975. The five-year mean of sulphur dioxide was 167 ìg/m^3 in the city centre, 117 ìg/m^3 in the transition zone, and 74 ìg/m^3 in the outskirts. A slow sulphur dioxide-decrease is reported for the period 1976-80. However, the reduction reaches only about 10 mg/m3, and the highest concentration amounts to 154 ìg/m^3 near the city centre.

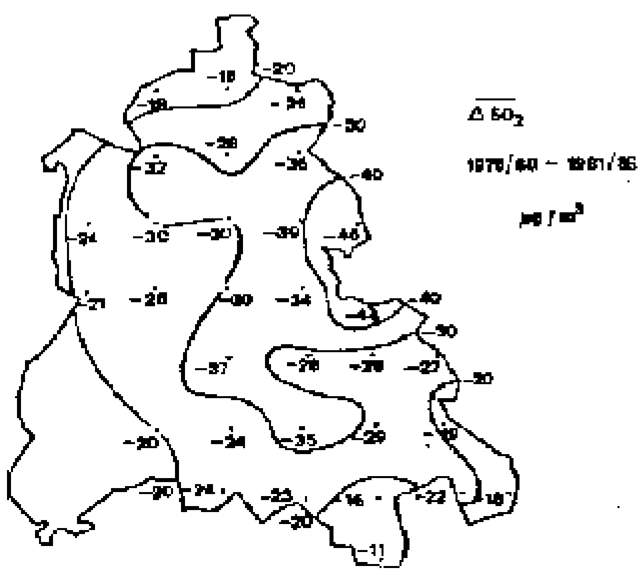

Figure 14: Mean SO_2 - decrease between the two time intervals 1976/80 vs. 1981/85

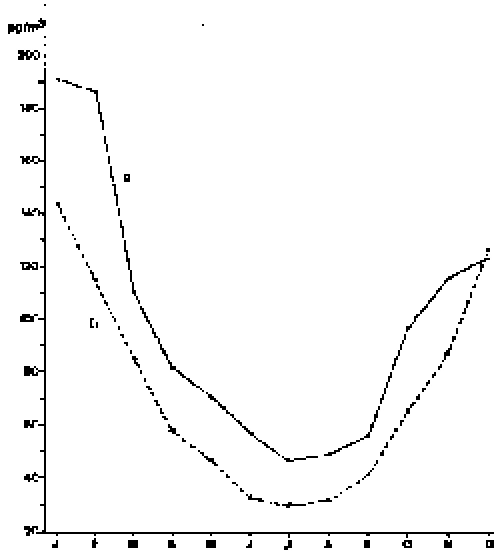

Figure 15: Yearly mean variation of SO_2 of the two periods 1976/80 (a) and 1981/85 (b)

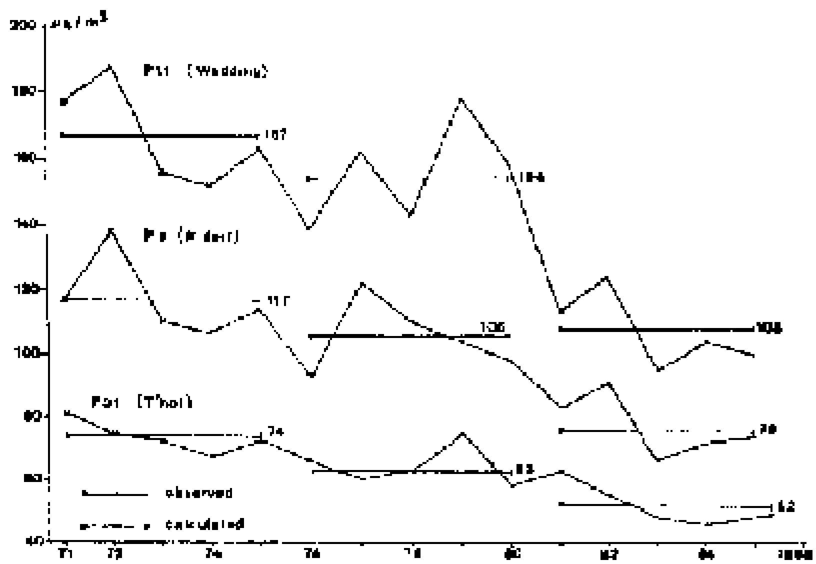

Figure 11: Course of the yearly SO_2-mean of 3 stations

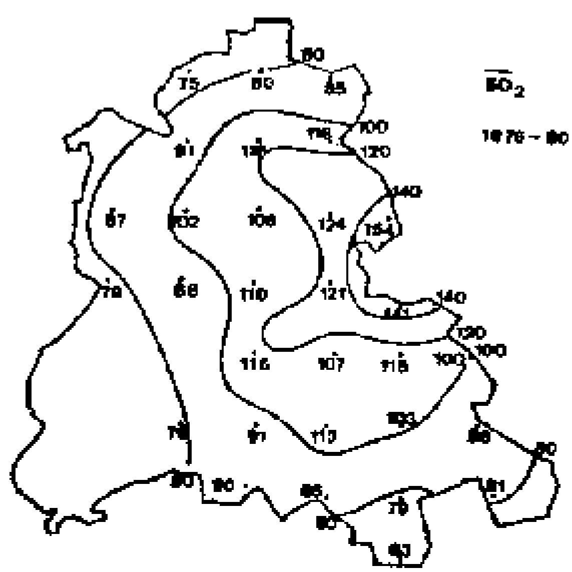

Figure 12: Mean SO_2-distribution for the period 1976-80

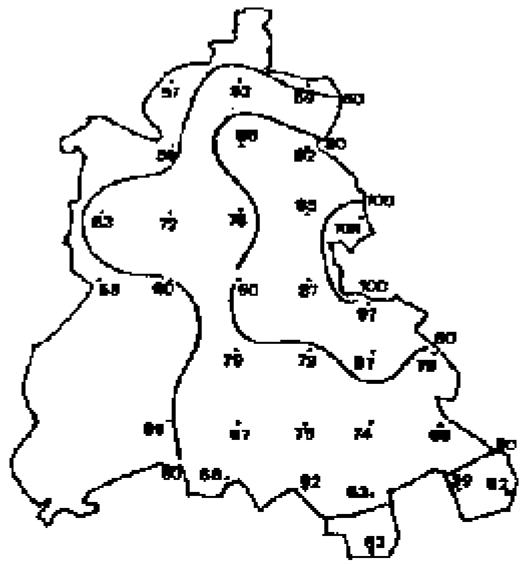

Figure 13: Mean SO_2-distribution for the period 1981-85

A rapid fall of sulphur dioxide-concentration can be observed in the years 1981-1985. The decrease amounts to 10 ìg/m^3 at P 11, thus the five-year mean reaches 108, 76, and 52 ìg/m^3 at the three stations. The following figures demonstrate this significant sulphur dioxide-decrease based on all 31 observation points. Fig. 12 shows the mean sulphur dioxide-distribution in Berlin for the period 1976-80. The concentrations reach 60-80 ìg/m^3 in the outskirts and values higher than 140 ìg/m^3 in the centre of Berlin (W). In Fig. 13 pollution varies also by a factor of two between the outer and the inner districts of the city, but the sulphur dioxide-values only reach from 50 up to 108 ìg/m^3 in the period 1981-85.

The remarkable sulphur dioxide-decrease between the two time intervals is given in Fig. 14 with general reductions of 20-40 ìg/m^3; the highest reduction values are measured in the most polluted area. A correlation of mean sulphur dioxide-values of the 12 districts of Berlin (FRG) and the number of inhabitants of the respective areas shows that the mean sulphur dioxide-concentration per head was 103 ìg/m^3 in the period 1976-80 while it reached only 75 ìg/m^3 in the years 1981-85; this is a reduction of 27%.

Fig. 15 shows the yearly mean variation of sulphur dioxide for the two five-year intervals. We recognise that a sulphur dioxide-decrease is reported for all months with the exception of December when the values remained unchanged. In this respect it has to be noted that the December months of the period 1981-85 were 0.4^{O}C colder than the Decembers 1976-80. The highest sulphur dioxide-concentration is found in winter, minimum values in summer; spring and fall show a strong decrease or strong rise, respectively.

It is important to define the reasons for the improvement of the air quality. For reasons shown below we can exclude significant meteorological differences between the two time intervals. As we have seen from Fig. 15, the sulphur dioxide-concentrations reach their highest values in winter, which means the emission of sulphur dioxide strongly depends on home heating. This corresponds to the fact that the sulphur dioxide-concentrations of different districts increase with the population density. If we accept - as a first guess - the temperatures of the winter season (6 months) as an indicator for the meteorological situations during the two periods 1976-80 and 1981-85 we see that there was practically no difference. In the interval 1976-80 we had a mean temperature of 3.1^{O}C, in the period 1981-85 of 3.2^{O}C, respectively.

Several factors are responsible for the remarkable decrease of sulphur dioxide: since the beginning of this decade, people became more sensible to environmental problems and made first efforts to avoid pollution. This, however, is not the only reason for the fast progress of this development. The main impulse was the oil-price-shock of 1979. The high price-level for mineral oil was a challenge for everybody including the industry and government. New laws were enacted; power stations had to reduce the output of sulphur dioxide by implanting filtering equipment; private homes as well as industrial plants were allowed to only burn coal or oil with reduced sulphur content. Heating became very expensive, therefore the buildings were equipped with heat-insulating material. Indoor temperatures were reduced, thus the consumption of fuel decreased. A temperature decrease of 1oC reduces the heating costs as well as the output of sulphur dioxide by about 5%.

The result is the observed 27% decrease of sulphur dioxide-emissions and of other components of air pollution. This is an encouraging development but still no solution to the problem. Polluted air does not stop at national borders. A reduction in the amount of sulphur dioxide transported to Berlin (FRG) from neighbouring areas has not been observed lately. In order to improve the air quality, all nations are required to reduce air pollution and to increase the investments and research in this field.

Conclusion

A high level of air pollution damages human health as well as the entire biosphere. The German government has limited the yearly mean sulphur dioxide-concentration value to 140 ìg/m^3. Although most parts of Berlin never reached this value, people living in the city centre for many years had to suffer from sulphur dioxide-concentrations far exceeding this value. Due to the efforts made in past years, the air quality improved since 1980, but is still not as good as it should be, and co-ordinated international efforts are necessary to save the biosphere from further damages.

Professor **Horst Malberg**, from the Federal Republic of Germany, was awarded the Diploma in meteorology and climatology in 1965. He received a Ph.D. in the same field and became a Professor in 1970. Since then, he has been the acting Director at the Institute of Meteorology at the Berlin Free University and has carried out research in the fields of air pollution, synoptic meteorology, satellite meteorology and urban climate.