# INFLUENCES OF AIR POLLUTION AND WEATHER ON CROUP SYNDROME

### Obstructive Respiratory Tract Diseases Of Children In West-Berlin (1979-1982)

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Due to the big "smog"-catastrophes of our century (Maastal/Belgium 1930; Donora/USA 1948; London/UK 1952), the first attempts were made to study the connection between gaseous and dusty air polluting substances and increased mortality. The epidemiological research focused on the effects of air pollution on the course of morbidity for which extensive programs were developed particularly in England but also in the USA and Japan, in order to examine the connections between air pollution and both the incidence of chronically respiratory tract diseases and diseases of the cardiovascular air system.

The more the difference of opinions by the respective author in defining the effects of air pollutants, the more the difference in judging the toxic thresholds of the single components of air pollution. However, there was common agreement that the concentration of sulphur dioxide is of particular importance. Later, the effects of nitrogen oxides and ozone were placed in the foreground of research interest. For instance Shy and Pearlman et al. found that the forced expiration volume of children exposed to high nitrogen dioxide-concentration was significantly lower that that of the control group (mean concentration of 100 to 160 mg/m$^3$). A further result was that the incidence of acute upper respiratory tract diseases increased markedly if the daily mean concentration ranged from 117 to 205 mg/m$^3$. Similar studies in East-Bohemia supported these results.

Combined effects of sulphur dioxide and light suspended dust particles on bronchitis and other diseases of the lower respiratory tract of children were described by the famous study of Douglas and Waller: frequency and severity of air way diseases were increased above a yearly mean concentration of sulphur dioxide of 140 mg/m$^3$ and of dust particles of 130 mg/m$^3$ . These concentrations of both sulphur dioxide and light suspended dust are reached in many industrial centres of Europe. Nevertheless, if the examined children started to smoke cigarettes the air pollution effects were fully covered by those of smoking.

Generally, the relations between air pollution and the incidence of both cardiac and respiratory diseases seem to be too complex to be derived from simple, linear dose-response-models.

In the FRG and West-Berlin the discussion on the relations between air pollution load and respiratory tract diseases grew by parent's reports about an increased incidence of children suffering from Croup Syndrome during periods with high concentrations of air polluting substances. Different opinions referring to this point and the lack of other epidemiological studies in Germany motivated us to start an interdisciplinary medical-meteorological investigation concerning influences of weather and air polluting substances on respiratory tract diseases of children living in the highly polluted area of West-Berlin. This study was partly supported by the Senator for Environmental Protection in Berlin.

The basic question of our study was to find out whether there was a temporal correlation between the morbidity rate of the most frequent infectious diseases of children (diseases of the upper and lower respiratory tract) within winter periods (with high concentration of air pollution) and both air pollution-concentration and meteorological environmental factors in Berlin-West; furthermore we analysed differences between above-average polluted city districts and districts with under-average concentrated air polluting substances.

During the period from July 1979 to June 1982 the frequency of children suffering from Croup Syndrome and obstructive respiratory tract diseases was investigated. The data was based on the rates of children living in the surrounding supply area (75%-supply area) of the Neukölln Children's Hospital (high pollution load) and the Rittberg Children's Hospital (lower air pollution load).* This patients' rate of both districts was assumed representative of the morbidity of the respective area. Air pollution was registered by the 31 measuring points of the Berlin Air Quality Measuring Network (Blume). The values of each measuring point were representative for an area of nearly 16 square kilometres (so called Blume-area) around them. The above mentioned 75%-supply-areas of both hospitals (nearby-supply-area) were defined by the number of Blume-areas containing the residence of about 75% of all children presented in the respective hospitals during the three year period of investigation.

### Parameters Of Investigation

A. Independent variables The values of sulphur dioxide-concentration obtained by Blume were used as an indicator of gaseous and dusty air pollution (Tab. 1). The corresponding meteorological parameters are:

a) equivalent temperature as an indicator of the cooling load of the mucosa of the respiratory tract (MRT) while staying outdoors;
b) the relative humidity of indoor climate (RHIC) indicating the desiccation load of MRT indoors.

B. Dependent variables

The dependent variable "patients' rate" (PR) was defined as the daily number of children under medical treatment provided by either first aid care of admittance to one of the hospitals (hospital care) because of illness of the upper or lower airways. The diagnosis was classified as follows:

1. Croup Syndrome
2. Obstructive respiratory tract diseases
3. Bronchitis, pneumonia
4. Upper respiratory tract infections (Tab.2)

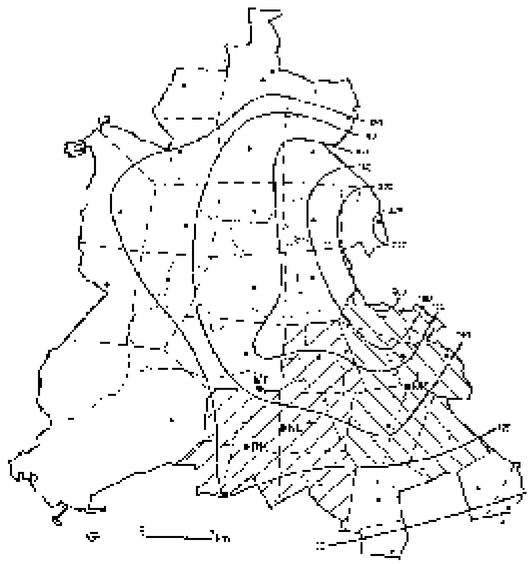

**Figure 1:** Berlin (West), mean $SO_2$-concentration (ìg/m$^3$) winter period (Oct-Apr 1975-80)

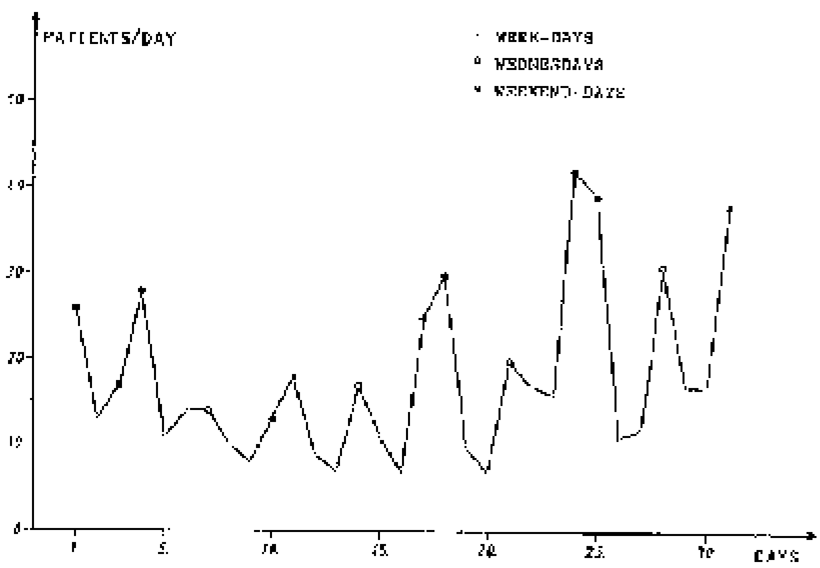


**Figure 2:** Patients rate before eliminating the weekly rhythym

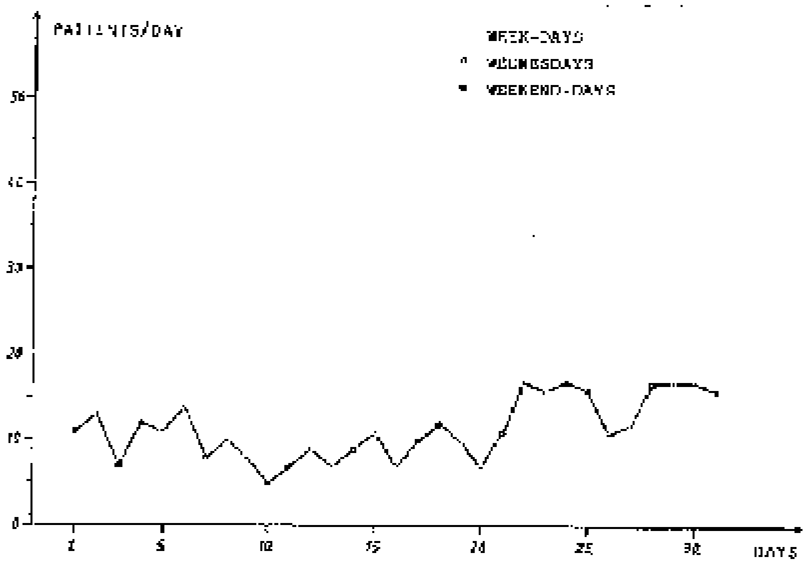

**Figure 3:** Patients rate after eliminating the weekly rhythym

**Data Basis**

The research program covered the period from July 1979 to June 1982. In the course of these three years 57,955 cases (= clinical data) have been investigated; about 26,000 of these have been related to the diagnoses mentioned above.

The measurement of the sulphur dioxide-concentration were performed every 30 minutes by the automatic measuring points of Blume: these values were the basis for the calculations of daily, weekly, and monthly means for the 75% SAH of NK and RK.

The necessary meteorological data were provided by the measuring devices of the Meteorological Institute of the Free University of Berlin, Berlin-Dahlem. Equivalent temperature and relative humidity are significantly related to each other (R=0,99) and represented only a common independent variable in our case.

**Methods of Evaluation**

Regarding the time series of daily patients' rates for the four diagnostic groups, a remarkable diurnal variation can be seen. With the weekly rhythm, with peaks on Saturdays, Sundays, and Wednesdays corresponding to the closing hours of paediatrician practices (Fig. 2). These weekly rhythms which did not depend on pollution or weather conditions were eliminated by mean ratios obtained by relating the frequency of cases on Saturdays and Sundays on one hand, and Wednesdays on the other hand to the remaining weekdays. These patients' rates - free on weekly rhythms - served as basis for all following calculations (Fig. 3).

Independent and dependent variables were correlated in different time scales (monthly, weekly, and daily means) for the same time and with regard to the influence of incubation periods with time lags (linear, univariate correlations). Furthermore, "partial" multivariate correlations were computed in order to determine the covariation between dependent and independent variables excluding the influence of competitive independent variables.

Croup Syndrome and obstructive respiratory tract diseases as well as the other two diagnostic groups and also the independent variables showed remarkable annual variations with coinciding winter peaks and summer lows which run the risk of influencing formal correlations. In order to reduce these influences, the correlations were calculated for shorter periods, i.e. the autumn period (Sept. and Oct.), the interval period (Nov. to Dec.) and shorter time scales (weekly means).

**Table 1**
VARIABLES

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**Independent**
AIR QUALITY FACTOR
- Sulphur dioxide-concentration (indicator for gaseous and dust emissions)

METEOROLOGICAL FACTORS
- Equivalent temperature (indicator for cooling load of the respiratory tract mucosa while staying outdoors)
- Relative indoor humidity (indicator for desiccation load of the respiratory tract mucosa while staying indoors)

**Table 2**
VARIABLES

**Dependent**
- Croup Syndrome
- Obstructive respiratory tract disease
- Bronchitis without obstruction
- Upper respiratory tract infections

**Meteorological and Air Quality Characteristics**

Sep./Oct. 1979 and 1981 were characterised by remarkable changes from warm (summer) to cold (winter) periods while the temperature in the same period 1980 decreased continuously and slowly. The invernal periods (Nov./Feb.) 1979/80 and 1981/82 showed several cold periods with poor vertical exchange and slight wind movements. This produced high concentrations of dust and gaseous air pollution. On the other hand the period 1980/81 had frequent and quick changes from warm to cold periods and strong ventilation airing the town and leading to low levels of air pollution. The meteorological character of this winter period was similar to the falls of 1979 and 1981.

**Table 3**
METEOROLOGICAL CHARACTERISTICS

Fall (Sept/Oct) 1979, 1981; Winter (Nov-Feb) 1980/81

Distinct and quick changes from warm to
cold periods; strong ventilation
winter 1980/81: "autumn character"

Fall (Sept/Oct) 1980

Slowly decreasing temperatures from
summer to winter level

Winter (Nov-Feb) 1979/80, 1981/82

Several extremely cold periods with slight
wind movements and poor vertical exchange

Meteorological comparable in this sense were the periods Sep./Oct. 1979, 1981 and Nov. to Feb. 1980/81 as well as the winter periods Nov. to Feb. 1979/80 and 1981/82. The 1980 fall was outstanding without comparable markers within the investigation period and shows the monthly means of sulphur dioxide concentration of the 75%-SAH within the investigation period. The supply area of the NK - in comparison to that of RK - was located by 30 to 50 mg/m$^3$ higher concentrations of sulphur dioxide. 156 mg/m3 were registered as mean sulphur dioxide-concentrations of the 75%-SAH of NK during the highly loaded invernal periods 1979/80 and 1981/82 while the corresponding value for the RK was 128 mg/m$^3$.

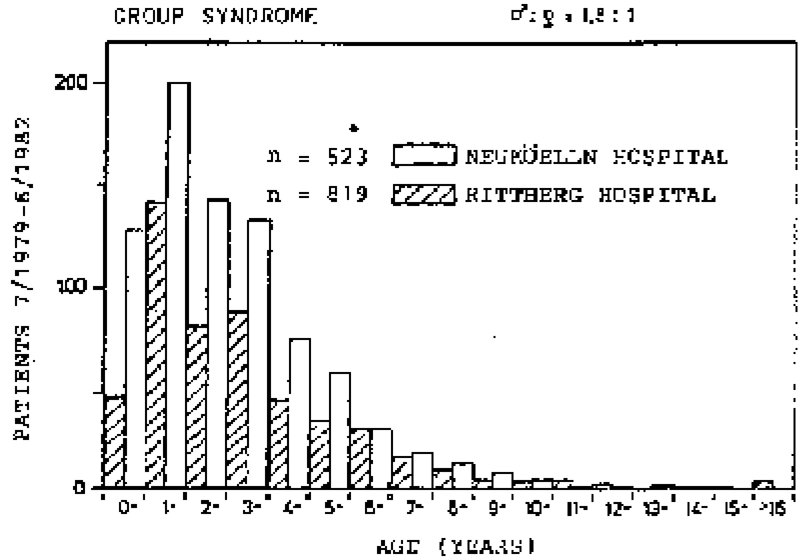



**Figure 4:** Distribution of age July/1979-June/1982

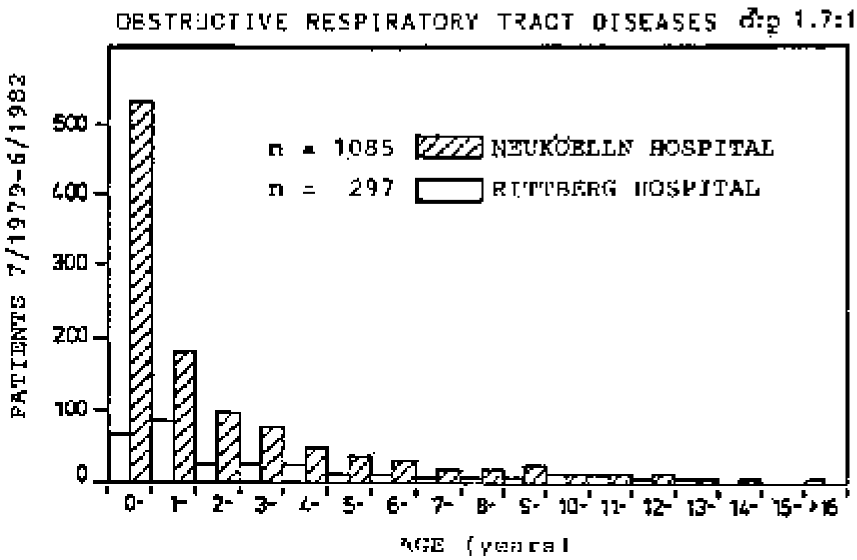



**Figure 5:** Distribution of age July/1979-June/1982

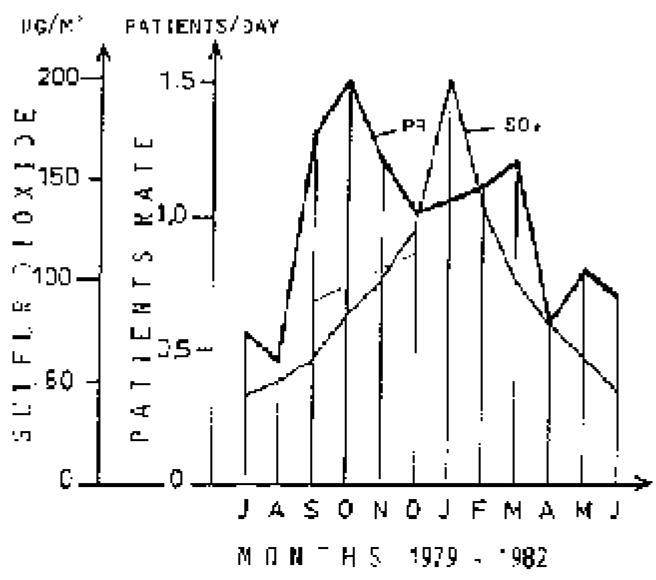



**Figure 6:** Mean annual variations of the Croup Syndrome rate and the SO2 concentration within the 75% supply areas of the hospitals 1979-1982.

**Results**

1. The distribution of age of the children suffering from Croup Syndrome showed its maximum the second year of life; boys fell ill 1.8 times more frequently than girls (Fig. 4). This relation differs widely from the normal relation of boys and girls born in West Berlin in the period 1973/82. (1.1.1.) Beyond the seventh year of life the Croup Syndrome was rarely found.
The distribution of age of the children suffering from ORTD showed its maximum at the first (NK) or second (RK) year of life. 83% belonged to the age group 0-6 years (Fig. 5). ORTD occurring in the first year of life - as to be seen in the higher polluted area of NK - are characterised by a clearly worse prognosis than in later years of life, because about 50% of the cases proceed to chronic bronchial asthma.
2. Relations: sulphur dioxide - patients' rate
Comparing the three years-monthly-means of the patients' rate (PR) and the sulphur dioxide-concentration there can be seen different relations regarding both the Croup Syndrome and the ORTD (Fig. 6). The average course of the Croup Syndrome-patients' rate shows an impulse like increase from the summer minimum in August to the yearly main-maximum in Sep./Oct.
After that, the morbidity rate decreases to a slightly increased level if compared to the summer course within the period Nov. to March. After a little secondary maximum in March the rate decreases quickly and reaches the low summer levels (April to August).
The yearly main maximum of the sulphur dioxide-concentrations is found in January, with a symmetrical development of increasing concentration from August to January and a decreasing from February to April. The maxima of sulphur dioxide-concentration and Croup Syndrome are clearly separated on the same line.
The average PR of the ORTD increases from August to September and October (Fig. 7), jumps to the broad yearly maximum (reaching from November to March), and decreases afterwards. In June there is a secondary maximum which is likely to be explained by the pollen release. Compared to the Croup Syndrome, the courses of sulphur dioxide-concentration and the patients' rate of ORTD showed a better congruence but were also separated on the same line.
3. Correlation analyses performed on the level of weekly means lead to surprising results. We found significant correlations between the sulphur dioxide-concentration and the Croup Syndrome in those seasons which were well comparable by meteorological environmental factors, i.e. Fall 1979, 1981 and Nov. to Feb. period (winter) 1980/1981 (Tab. 4). These correlations remained constant after eliminating the correlating influence of the meteorological factors by computing "partial" correlations. This result is remarkable in so far, that in these periods the sulphur dioxide-concentration was relatively low. On the other hand there were marked changes of weather conditions. Correlation analyses between the independent meteorological variables equivalent temperature and relative indoor humidity and the Croup Syndrome rate showed similar results as mentioned for sulphur dioxide-concentration. After eliminating the competitive influence of sulphur dioxide-concentration by computing partial correlations the former results did not prove to be constant. Children suffering from Croup Syndrome seem to be particularly effected by air pollution within periods of strong changes of meteorological influencing factors like equivalent temperature and relative indoor humidity.
Correlation analyses between sulphur dioxide-concentration and meteorological factors on one hand and ORTD on the other hand by the same procedure showed no significant results. Regarding the "partial" correlation, rel. indoor humidity, equivalent temperature, and sulphur dioxide-concentration showed a strong mutual interference with the PR of ORTD. At first approximation one can say that the PR of ORTD of children is equally affected by both thermal conditions and environmental air pollution influences.
4. The PR was investigated within five equally long periods before, during, and after epochs of high air pollution-concentration (mean epoch lengths: [5-13] days and median values of sulphur dioxide-concentration of 271 mg/m3, (Fig. 8). During these periods the median value of the Croup Syndrome morbidity rose from 100% before the high pollution epoch to 113% during the epoch itself and to 116% during the following period.
The median value of PR on days with first stage smog alert was 135%. These results indicate immediate and delayed effects of air pollution on Croup Syndrome. The PR of ORTD rose to 149% during the highly polluted epoch and remained constant during the highly polluted epoch and remained constant during the following period. On days with smog alert the median value of ORTD morbidity rate increased to 223% and exceeded the highly polluted epochs by about 74% (Fig. 9). The morbidity rate of ORTD seems to be more closely linked to epochs of high air pollution than the rate of Croup Syndrome.
5. The daily median sulphur dioxide-values exceeding 400 mg/m3 correspond to a remarkable increase of Croup Syndrome morbidity rate on every day of that load (+ 53% with regard to the average of the other concentration classes), on the third (+ 38), the fourth (+ 122%), and on the sixth following day (Fig. 10).
The results relative to the ORTD present a strong increase of the morbidity rate on the very day of load (+ 85%) and on the third day after the main sulphur dioxide-concentration (+ 74%; Fig. 11). These results point to a direct (first PR maximum) and to an indirect (second PR maximum) influence of air pollution.
6. The last investigations showed us some characteristic courses of the PR of both Croup Syndrome and ORTD if influenced by air pollution or meteorological (thermal) environmental factors. Certainly, the polluting substances play an important part in triggering these diseases, perhaps the main part. But on the other hand there are some aspects that indicate the importance of other influencing factors, particularly factors of the indoor environment. Let me explain this by the example Croup Syndrome.
Let us look again at this curious, impulse-like increase of the morbidity rate in the autumn periods (Fig. 6). This characteristic course can also be seen in other publications of the German speech area (Fig. 12, 13) as well as in the USA (Fig. 14).
Nevertheless, no one of the respective authors described this phenomenon or tried to explain it. The American publication dealing with the median course of Croup Syndrome morbidity over 11 years did not show the autumnal impulse-like increase of the PR from August to September/October as figured in the European publications, but one month lager - from September to October/November.

The other course corresponds well. If you have a look at the monthly means of temperature in Berlin and compare them to those of Chapel Hill (Tab. 5), the location of the American study, you will find that the autumnal temperature-means of Berlin are reached in Chapel Hill just one month later. Analysing the daily patients' rate of September/October as means of all six Sep./Oct.-months within the investigation period the first remarkable increase occurs about Sep. 20 with a following broad maximum until the end of the second half of October (Fig. 15). About Sep. 29 (ca. 1 week) the mean beginning of the heating period in Berlin can be computed. At the same time the first increase of the sulphur dioxide-concentration can be noted.

The simultaneous and homogenous appearance of this impulse-like autumnal increase of Croup morbidity in the middle-European area suggests an equal and common cause. This could be described by the simultaneous beginning of the heating period that is synchronised in Europe by a drop of temperature below a defined threshold. This produces a quick change of the indoor climate and an increase of sulphur dioxide-concentration. Such relatively quick changes of environmental conditions affect corresponding adaptation-demands of the human organism, particularly the respiratory tract mucosa as the most exposed organ. Therefore, the Croup Syndrome could be understood partially as an adaptation disease to quickly changing environmental conditions. This hypothesis involves the conclusion that within periods of quick changes of thermal environmental factors even low level concentration of air pollutants may trigger Croup Syndrome, a situation, which is given exactly during autumn. Rather than the absolute concentration of air pollutants, the crucial point seems to be the "background" of other co-operating and - above all - changing thermal factors in affecting the respiratory tract mucosa. This hypothesis is supported by the onset of the impulse-like increase of Croup in Chapel Hill/USA one month later because, according to the temperature, the heating period here begins exactly one month later.

A similar analysis of the ORTD morbidity course showed only in the months of September 1979 and 1981 short increasing impulses at the end of the third decade but a decrease already at the beginning of October.

| Fall (Sept/Oct) | Winter (Nov-Feb) |
|---|---|
| 1979 (+) | 1979/80 |
| 1980 | 1980/81 sig (++) |
| 1981 sig (+) | 1981/82 |
| 1979-<br>1981 sig (+) | 1979/80-<br>1981/82 |

**Table 4**

Results of partial correlations between the weekly means of croup syndrome rate and sulphur dioxide concentration 1979-1982

| | Chapel Hill | Berlin-Dahlem |
|---|---|---|
| July | 26.1° C | 16.3° C |
| August | 25.4° C | 16.7° C |
| September | 22.6° C | 14.8° C |
| October | 16.7° C | 8.2° C |
| November | 10.9° C | 4.2° C |
| December | 6.3° C | 0.9° C |
| January | 6.3° C | −2.2° C |
| February | 7.1° C | 0.7° C |

**Table 5**

Mean air temperatures of Chapel Hill (N.C., USA) and Berlin-Dahlem (Berlin West) 1979-1982.

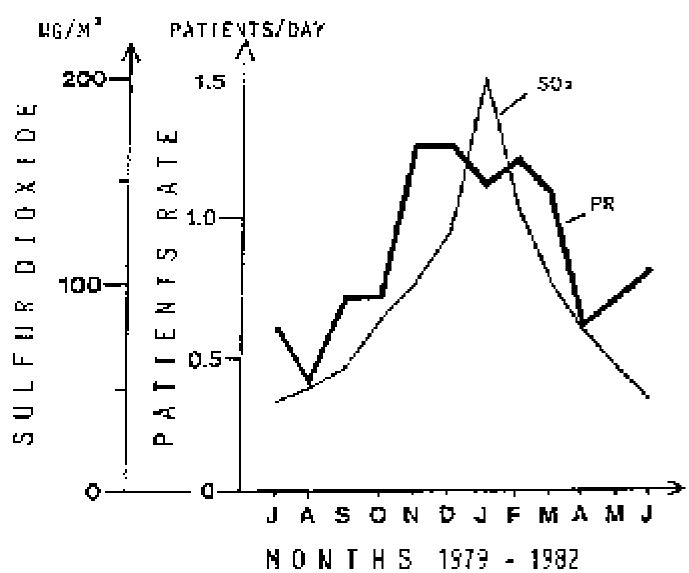



**Figure 7:** Mean annual variations of the obstructive respiratory tract diseases and the $SO_2$ concentration within the 75% supply areas of the

hospitals 1979-1982.

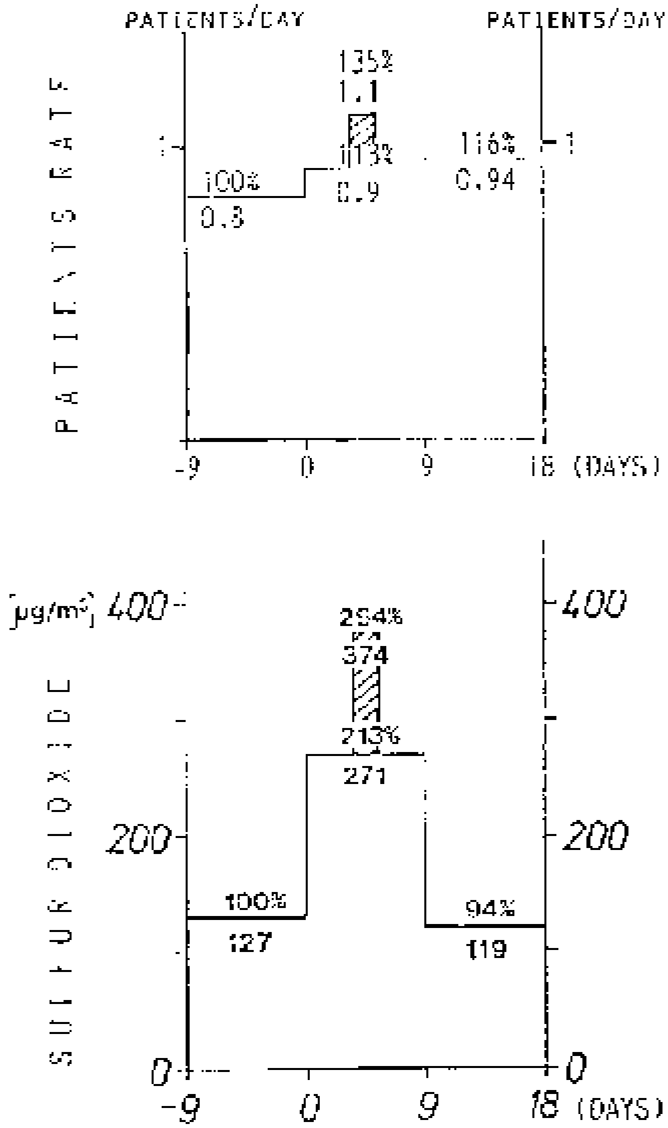



**Figure 8:** Croup Syndrome rate of children before, during, and after epochs of high $SO_2$ concentration Berlin (W) 1979-1982.

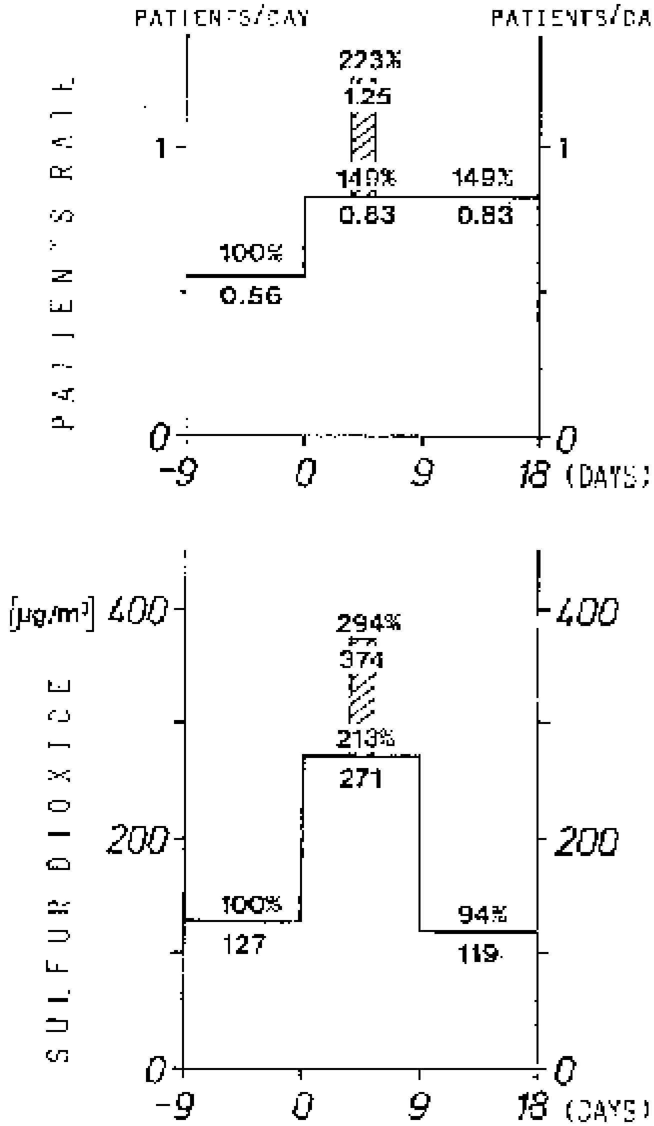



**Figure 9:** Obstructive respiratory tract diseases of children from The Neukolln and Rittberg Children's Hospital before, during and after periods of high $CO_2$ concentration Berlin (W) 1979-1982.

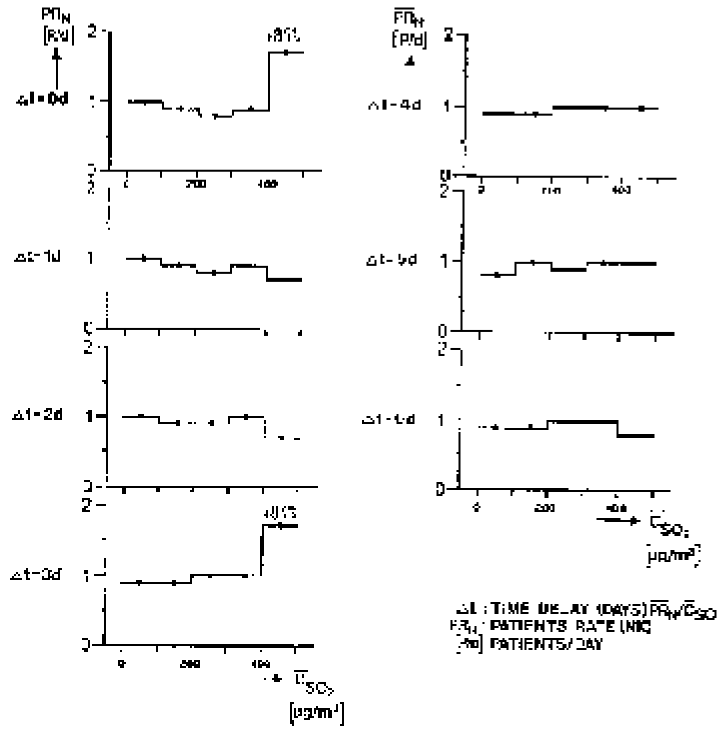



**Figure 10:** Croup Syndrome rate during and after days with sulphur dioxide load.

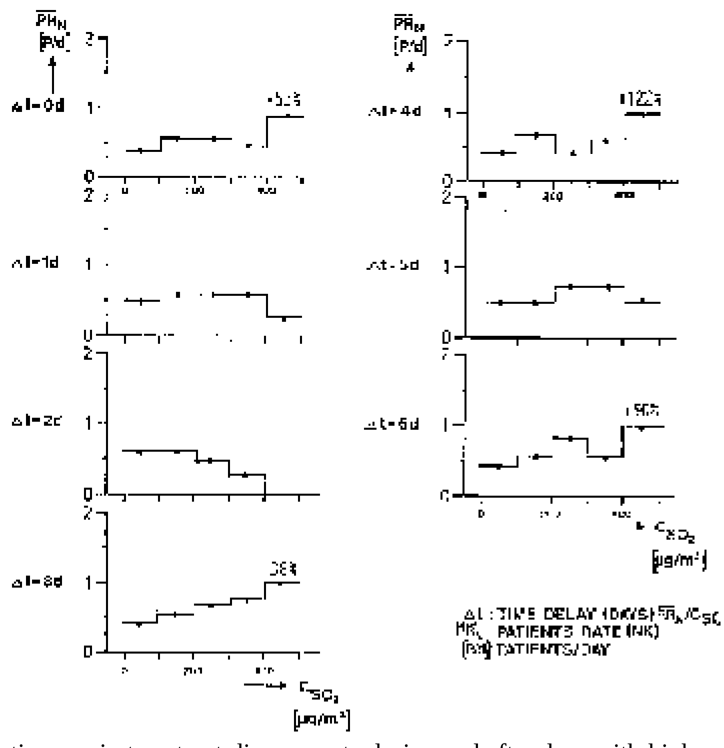
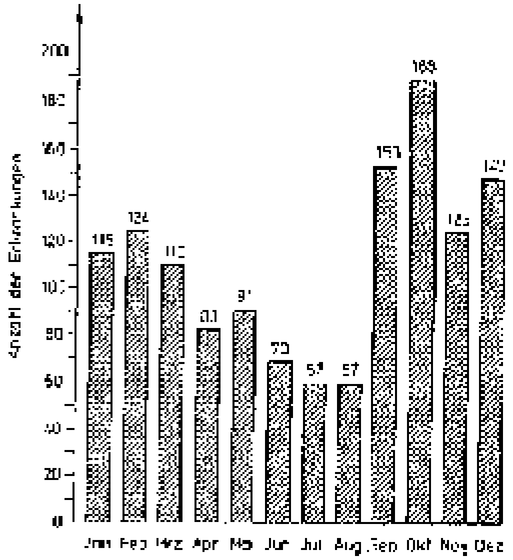
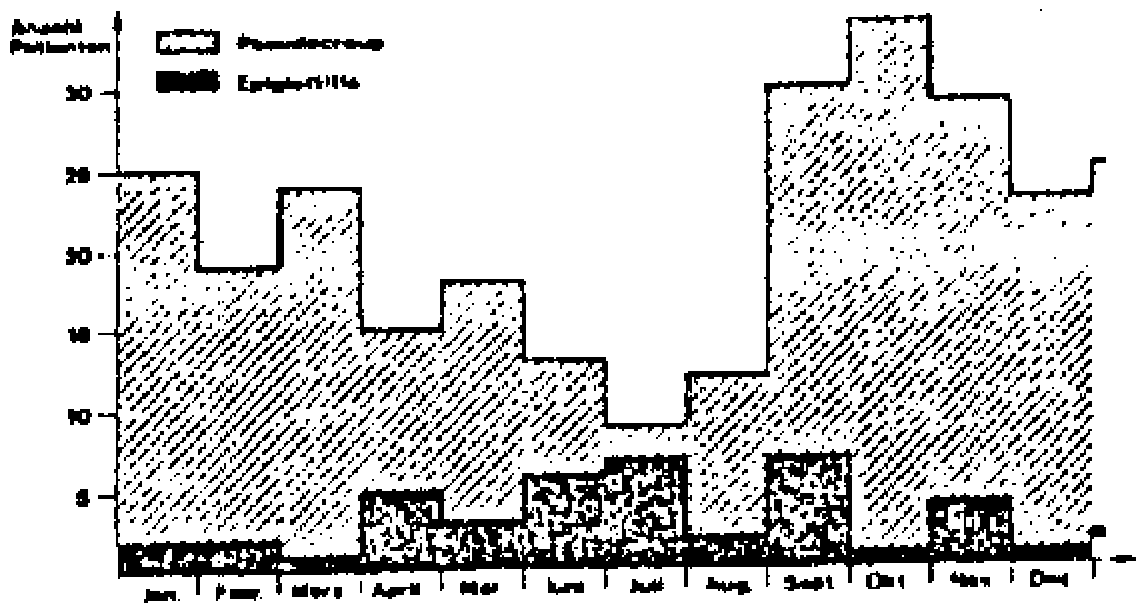



**Figure 11:** Obstructive respiratory tract diseases rate during and after days with high sulphur dioxide load.


Jan Feb Mrz Apr Mai Jun Jul Aug Sep Okt Nov Dez
115
124
110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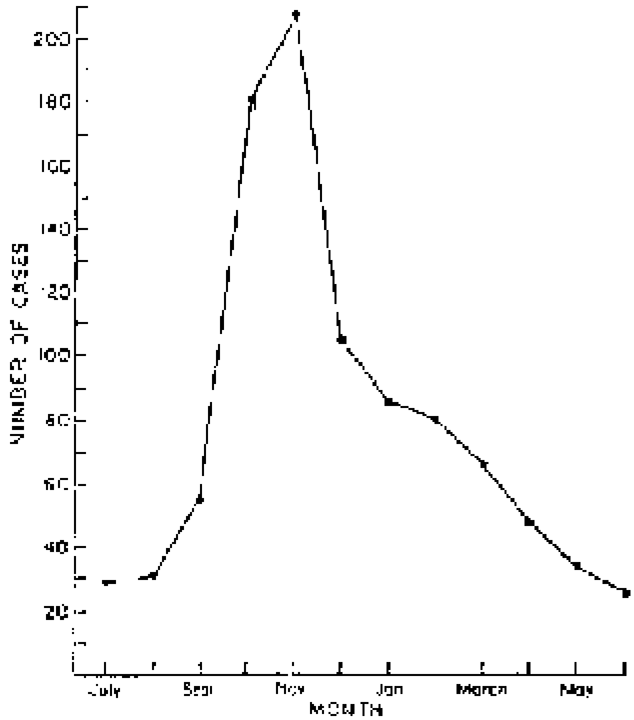


**Figure 12, 13, 14:** Increase in morbidity rate during the autumn period in Germany and the USA.

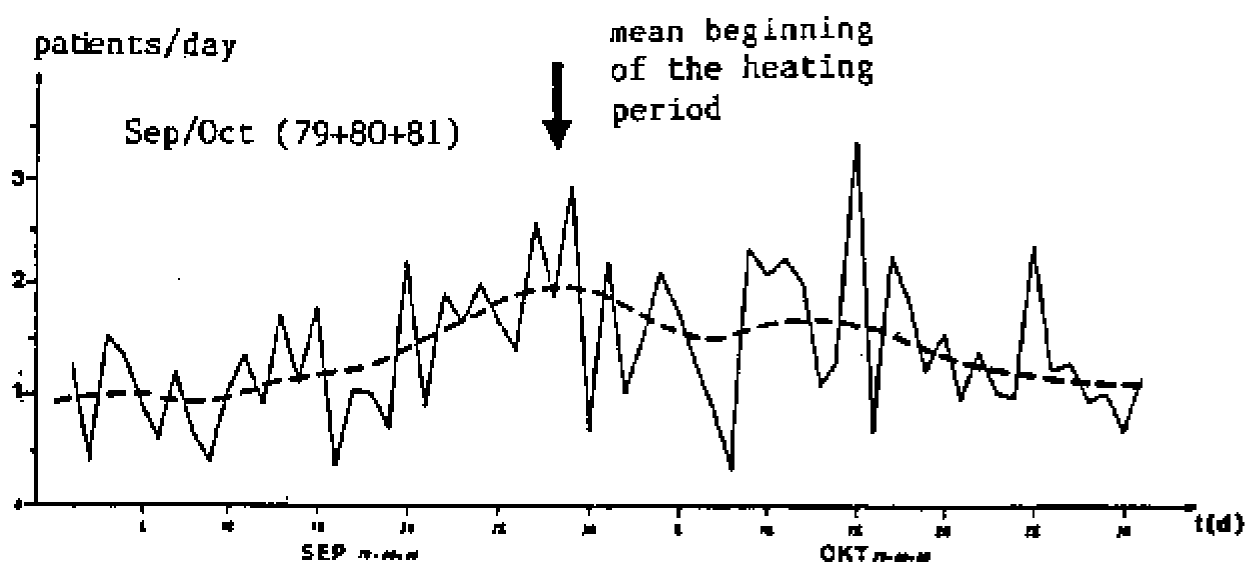


**Figure 15:** Mean daily croup syndrome rate (mean iut of three years) within the Falls 1979-90.

**Table 6**

SAH-Quotient: Mean relative increase of rate of the supply area of the Neukolln Children's hospital in relation to the supply area of the Rittberg Children's Hospital from Summer to Fall level and from Summer to Winter level 1979-1982.

| Croup syndrome | |
|---|---|
| summer → fall | summer → winter |
| 1979 + 11% | 1979/80 + 30% |
| 1980 + 161% | 1980/81 – 8% |
| 1981 + 4% | 1981/82 0% |
| 1979-<br>1982 + 26% | 1979/80<br>1981/82 + 5% |

**Table 7**

SAH-Quotient: Mean relative increase of patients rate of the supply area of the Neukolln Children's Hospital in relation to the supply area of the Rittberg Children's Hospital from Summer to Winter level 1979-1982.

| Obstructive respiratory tract diseases | summer → winter |
|---|---|
| 1979/80 | + 40% |
| 1980/81 | + 93% |
| 1981/82 | + 34% |
| 1979/80-1981/82 | + 53% |

**Comparison of the Supply Areas**

For computing the district-regarded comparison of the Croup Syndrome - and ORTD-PR we used three different mathematical methods:

1. We selected Blume-areas exceeding the respective SAH-average of sulphur dioxide-concentration and investigated their PR. We found four Blume-areas with above-average sulphur dioxide-concentration. Regarding the Croup Syndrome we counted three of these four Blume-areas with coinciding above-average PR, one time under-average PR. In the same way we coincided the PR of the ORTD.
2. In a second step we computed the mean relative increase of the PR of the 75% SAH of the NK children's' hospital in relation to the 75% SAH of the Rittenberg children's' hospital from summer to winter level (SAH quotient) (Tab. 6). The mean SAH of the three-year-examination period indicates a relative increase of the Croup Syndrome of about 26% from summer to fall level in the higher polluted area, from summer to winter level only 5%.
   Regarding the ORTD PR we found no difference comparing the summer-to-fall levels between both supply areas; nevertheless, comparing the summer-to-winter levels we saw a relative increase in the lightly polluted districts amounting to 53% (Tab. 7).
3. Correlating the monthly mean values or PR during the three winter periods and the corresponding air pollution concentration during single measuring areas we found negative (W) or not significant results from Croup Syndrome morbidity but highly significant results for ORTD rate (R+0.69; p

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**Table 8**

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**Summary Croup Syndrome**
Increase of the morbidity rate: at the beginning of the heating period. during and after epochs or in single days with highly concentrated air pollution. (short-term and delayed effects.)
No percentage increase of the morbidity rate in districts with constant above-average air pollution.

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**Table 9**

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**Summary Obstructive Respiratory Tract Diseases**
Remarkable increase:

- on and - with delay - after single days and during and after epochs with highly concentrated air pollution.
- in districts with constant above-average air pollution.

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**Table 10**

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**Conclusions**

Strong relations between air pollution and Croup Syndrome as well as ORTD.
No fixed dose-response interaction between onset of illness and air pollutants because of other co-operating and influencing (natural) environmental factors.
Air pollution can be abolished - the natural environment not.

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**Summary**

- Children are affected with Croup Syndrome mainly at the beginning of the heating period which goes along with a marked variability of the meteorological influencing factors of both the indoor and outdoor complex. During these periods we found a strong relation between the Croup morbidity and the increasing air pollution-concentration (Tab. 8).

- Within epochs which are characterised by constant invernal temperatures as well as by high air pollution-concentration the morbidity rate rose markedly and remained increased even after these epochs. In a similar way the morbidity rate increased on single days with high concentration and - with delay - from the third to the sixth day after the load. These short-term and delayed effects seem to be underlying damages of the respiratory tract mucosa which results in immediate symptoms or in opening the way for infectious agents causing symptoms after the incubation period.
- Areas with constantly high air pollution-concentration are characterised by the same increase of Croup morbidity as areas with lower air pollution-concentration.
- ORTD show a marked increase of the morbidity rate on single days and both during and after epochs of high air pollution-concentrations. Meteorological influences do not seem to affect the morbidity rate in the same way as the air pollutants (Tab. 9).
- Residential areas with constantly high air pollution-concentrations show a remarkably higher percentage of children suffering from ORTD than those with below-average air pollution loads.

**Conclusions**

- Studying the behaviour of the Croup morbidity related to the influencing noxae of both the meteorological and the air-chemical complex we learned that there are no fixed thresholds of air pollution-concentration below which a child certainly does not fall ill. The changing and particularly the rapidity of change of one or the other environmental factors seems to be more affecting than we believed. Therefore, also low level of air pollutants may probably trigger an illness. The photogenic concept of this hypothesis is based on assuming a disarranged adaptability and a progressive irritability of the respiratory tract mucosa. Perhaps this model is underlying even more diseases of the upper and lower respiratory tract of children and adults. (Tab. 10).
- The morbidity rate of ORTD - compared to Croup Syndrome (the more dangerous diseases) - is directly related to short-term and continuously increased air pollution-concentration. Nevertheless, there are other factors like pollen, house dust mite, or weather.
- Ladies and Gentlemen, the natural environmental factors, i.e. temperature, humidity or pollen release, we cannot and do not want to change by human interference. But we are able to abolish air pollution's and to this end we should preserve.

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Dr. **Ulrich Fegeler** studied medicine in the Universities of Bonn and Berlin, and obtained a Doctor of Medicine degree from the Free University of Berlin. As pediatrician at the Red Cross Rittburg Hospital for children he specialised in pediatric cardiology and became Assistant Medical Director in 1985. His publications deal with the effect of air pollution and its role on respiratory diseases in children.