THE ŁÓDŹ ATLAS

Sheet X: Climate

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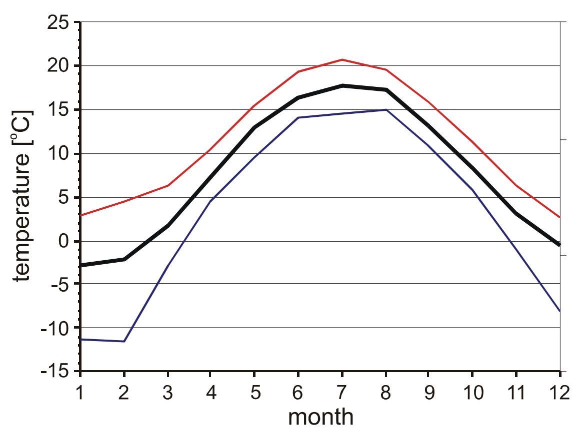

Fig. 1. Mean annual course of temperature (black line) in Łódź in the years 1951–1990. Marked are the highest (red line) and the lowest (blue line) temperatures of each month in the 40-years' period (W i b i g, F o r t u n i a k).

From 1931 till 1998, the average annual temperature in Łódź was 7.9°C. The highest value of 9.6°C was recorded in 1989, whereas the lowest – 6.0°C – in 1956. Usually, –the highest temperatures are observed in July, with the average value of 18.0°C. July of 1994, with the average of 21.5°C, was the hottest month, whereas July of 1979, with the average of only 14.6°C, was coldest. However, the highest average temperature of 21.7°C in the above mentioned period was recorded in August of 1992. January is usually the coldest month, with the average temperature of –2.9°C. January of 1963, with the average of –11.8°C was the coldest period, whereas January of 1975, with the average of 3.1°C was the warmest one. The lowest average temperature of –12.3°C was observed in February of 1956. The absolute minimum in Łódź was recorded on 17th January, 1963, when the temperature dropped to –31.1°C, while the absolute maximum was on 29th August, 1992 with the temperature of 36.8°C.

The annual precipitation in Łódź is typical of the continental climate (fig. 2). Between 1951 and 1998, the month with the highest average precipitation was July, in which the highest overall monthly precipitation was 86.4 mm. The lowest precipitation fell on February, when the monthly average was only 27.9 mm. In the period under discussion, overall monthly precipitation exceeded 200 mm three times (in July of 1957 – 258.1 mm, July of 1997 – 256.3 mm, and June of 1980 – 229.5 mm). The driest months were: October of 1951, with the overall monthly precipitation of 0.5 mm, February of 1976 (1.1 mm), and September of 1951 (3.2 mm). In Łódź, the frequency of days with precipitation (fig. 3) ranges from 49.4% in August to 76.6% in February. Such days are recorded most often in the period November – February, whereas late summer and early autumn (August-October) are much drier periods. Daily precipitation of less than 1 mm occurs most often in winter (47.0% in February, 42.8% in January) and least often in summer (19.5% in July and 20.2% in August). Days with precipitation between 1 and 10 mm are recorded more regularly throughout the year, however predominantly in December (31.5%) and less frequently in October (20.1%). Days with precipitation above 10 mm mainly occur during the summer season (8.3% in July, 6.8% in June and 6.3% in August) and rarely in winter (0.8% in January and 0.9% in February).

The average annual precipitation between 1931–1998 was 560.6 mm. The highest was recorded in 1931 – 780.6 mm, and the lowest in 1959 – only 363.9 mm. Precipitations in Łódź during the summer half-year from May to October (average 354.6 mm) are usually higher than in the winter half-year between November and April. The lowest precipitation of 193.2 mm was recorded in the summer half-year of 1983, while the highest (551.7 mm) in the summer half-year of 1998. In the winter half-year between November and April, the average precipitation reaches 210.1 mm, with the lowest overall precipitation value recorded in the season of 1958/59 (120.9 mm) and the highest in 1937/38 (353.6 mm). The highest overall daily precipitations were observed in 1939 (103.5 mm), 1980 (99.8 mm) and 1957 (82.4 mm).

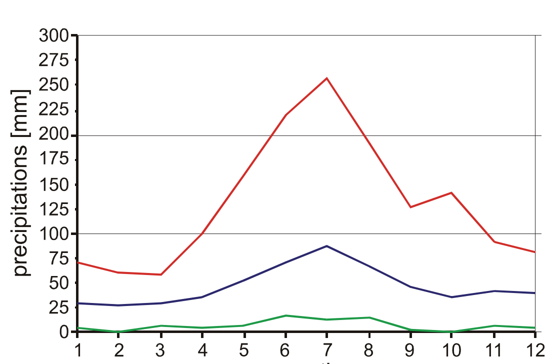

Fig. 2. Annual course of mean monthly precipitations (blue line) in Łódź in the years 1951–1990. Marked are the highest (red line) and the lowest (green line) overall monthly precipitations recorded in the 40-years' period (W i b i g, F o r t u n i a k).

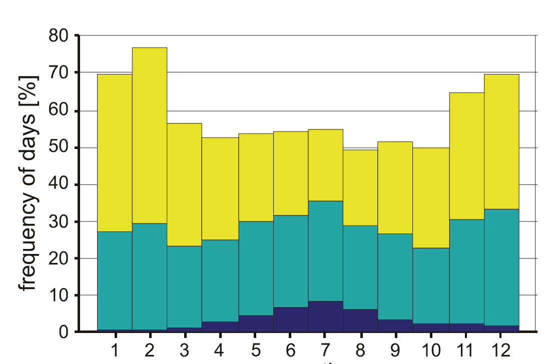

Fig. 3. Frequency of days with precipitation < 1mm (yellow), 1–10 mm (light blue) and > 10 mm (dark blue) – 1951–1990 (W i b i g, F o r t u n i a k)

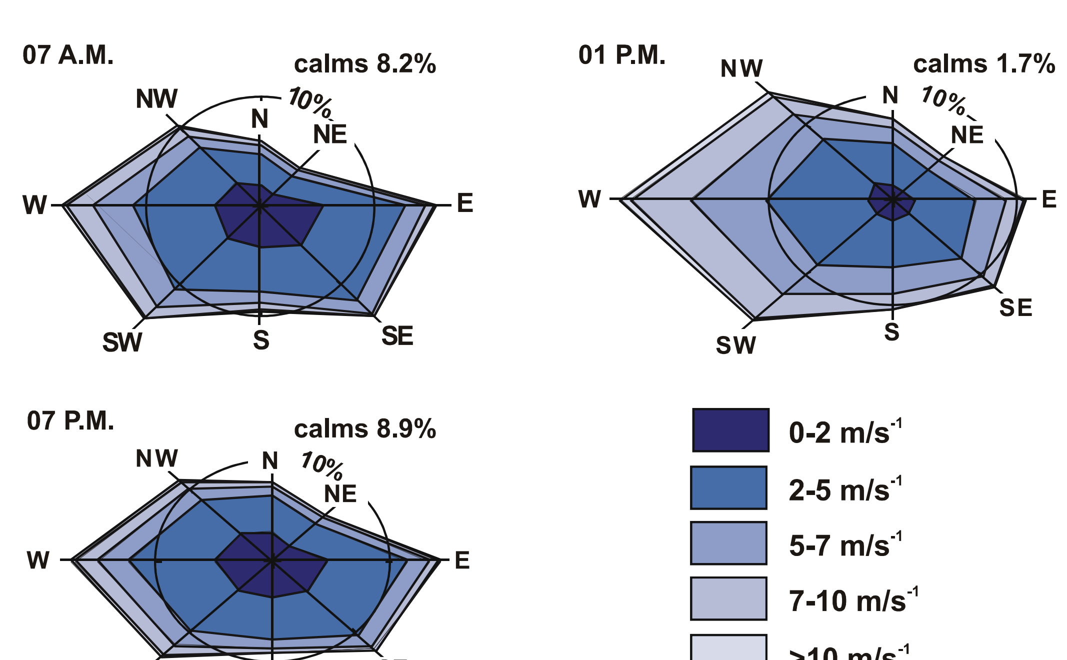

Fig. 4. Frequency (in %) of winds from various directions and in various wind speed brackets – 1951–1990 – recorded at 7.00, 13.00 and 19.00 hours (F o r t u n i a k, W i b i g)

The characteristic feature of anemometric conditions in Łódź is the predominance of winds from the western sector (particularly W to SW) and from the eastern sector (E to SE). Figure 4 illustrates the frequency (in %) of winds from each direction (wind roses) in breakdown into speed brackets, recorded at three measurement times, i.e. at 7.00, 13.00 and 19.00 hours (an average for years 1951–1990). One essential feature of the wind conditions is their 24-hour variability. In particular, characteristic is the increased frequency of winds with speeds over 5 m/s, and decreased number of calms at the noon measurement time. At night, and at the morning and evening measurement times, the number of calms and the percentage of winds with lower speeds increase. However, it must be pointed out that the diagrams have been prepared based on the data recorded by a station located in an open exurban area (Lublinek airport). Wind speeds are usually significantly reduced in the city.

The general cloud cover (clouds of all types and altitudes) measured on an 11-point scale indicates a clear annual pattern reaching the maximum value in November and December, and the minimum value in August and September (fig. 5). The cloud cover at noon is a little higher than the 24-hour average, particularly in summer, which ensues from the daily course of convective clouds. A typical course of annual cloud cover is also reflected in the annual variability of the number of cloudy days (i.e. cloud cover greater than or equal to 8 on the 11-point scale), with the maximum value in winter November-January) and the minimum value in summer. The number of cloudless days during the year is less varied, with slight rises in autumn and spring.

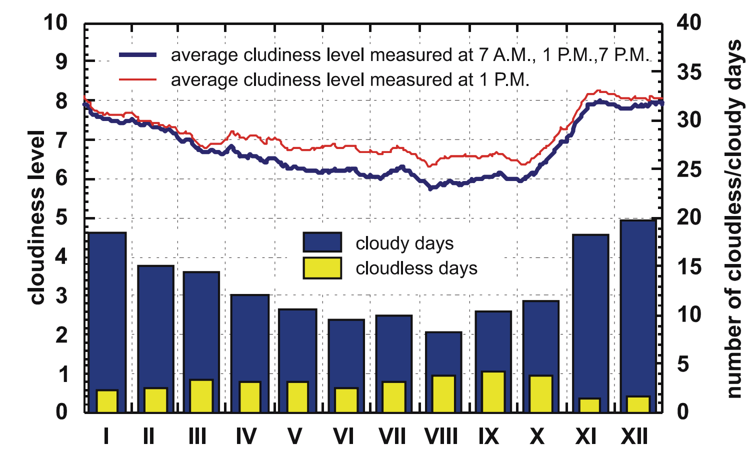

Fig. 5. Annual cloud cover and the frequency of cloudy and cloudless days – in the years 1951–1990 recorded at 7.00, 13.00 and 19.00 (F o r t u n i a k, W i b i g)

The intensity of solar radiation (energy flux value) is the amount of energy received at the Earth's surface within a specified time expressed in watts per square metre (Wm^{-2}). Figure 6 shows the annual pattern of daily maximum 10-minute total solar radiation $\mathbf{I_t}$ values within the range of 305–2800 nm, and ultraviolet radiation $\mathbf{I_{uv}}$ values within the range of 290–400 nm (UVA+UVB), in the centre of Łódź between 1997–2000. In the radiation spectrum there are some characteristic ranges - ultraviolet radiation (<400 nm), visible radiation (400–760 nm) and infra-red radiation (>760 nm). The annual course of solar radiation depends on the height of the sun above the horizon which in Łódź varies from 14.73° in December to 61.73° in June. The highest solar radiation values recorded at the upper atmosphere boundary (51°45' latitude) are 1241.5 Wm^{-2} ($\mathbf{I_t}$) and 111.0 Wm^{-2} ($\mathbf{I_{uv}}$). The highest ten-minute value of the total radiation intensity (1095.0 Wm^{-2}) was recorded on 14 July, 1997, and of the UV radiation (42.4 Wm^{-2}) on 25 June, 1999, during the days with convective clouds (cumulus congestus). High solar radiation values result from the so-called reflection effect, i.e. multiple reflection between the convective cloud base and the Earth's surface. The lowest values of both total and UV radiation intensity were recorded on 24 December, 1997 ($\mathbf{I_t}$ = 26 Wm^{-2}, $\mathbf{I_{uv}}$ = 1.1 Wm^{-2}).

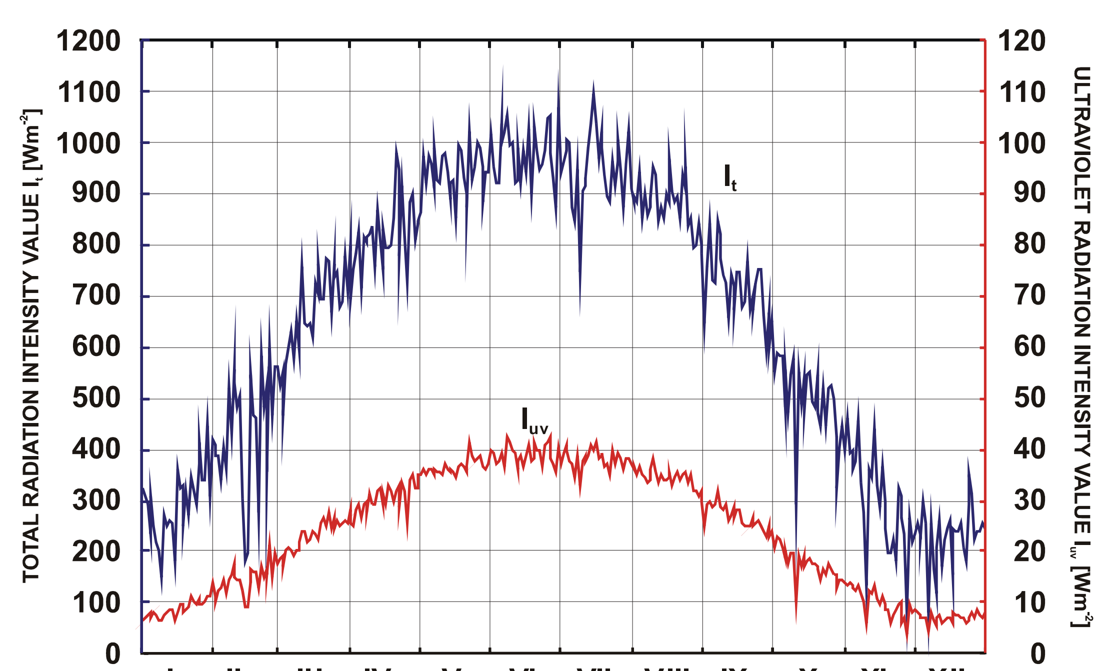

Fig. 6. The annual course of the highest ten-minute total radiation intensity values ($\mathbf{I_t}$) and total ultraviolet radiation intensity ($\mathbf{I_{UV}}$) in Łódź (based on the data for period 1997–2000) (P o d s t a w c z y ń s k a)

Local climatic diversification within the city is mainly caused by an increased absorption of solar radiation by artificial surfaces (roofs, asphalt, pavements). One important factor is the decreased heat loss through evaporation from urban surfaces, as compared to exurban areas, and the fact that the walls of buildings store heat during the day and slowly radiate it during the night. Some important causes of the 'urban heat island' include, e.g. the artificial heat that is released into the urban atmosphere in effect of the use of the various forms of energy (heating, transport, electricity and technological processes in the industry).

Map 1, map 2 present the anthropogenic heat emissions in Łódź in January and July – calculations based on the data for 1985. $\mathbf{I_t}$ is worth pointing out that the amount of heat released into the atmosphere as a result of human activity in winter is greater than the amount of solar radiation reaching the active surface. The total emissions of anthropogenic heat in Łódź are comparable to those in other large cities within the moderate climate zones in Europe and in America. In summer, the anthropogenic heat factor has lower climatogenic effects.

Map 3 illustrates the spatial distribution of the urban wind resistance coefficient (permanent development) calculated for air flows along the east-west axis. The coefficient, expressed in length measurement units (cm), is a measure of the aerodynamic resistance of urban buildings against the air flow and is used for evaluating the influence of the surface on the nature of air flows on the ground level. Generally, it can be said that central urban areas create a dense barrier that obstructs effective and proper ventilation of the city. Some suburban districts of tower blocks, on the other hand, are often exposed to excessively strong winds with unfavourable effects on human organism.

The most spectacular evidence of the peculiarity of the climate in Łódź is the heat surplus in the city, as compared to the exurban areas. On average, the urban heat island occurs during 75% of nights in a year. Depending on the meteorological conditions, it can either have a 'cellular' (map 4) or extensive form (map 5). The example of 5/6 February, 1996 illustrates the most intense form of the heat island, when the temperature discrepancy between the city centre and the suburban fields near Konstantynów reached 12°C (in winter, with no wind or clouds). Only a few cities in the world have recorded temperature discrepancies this large.

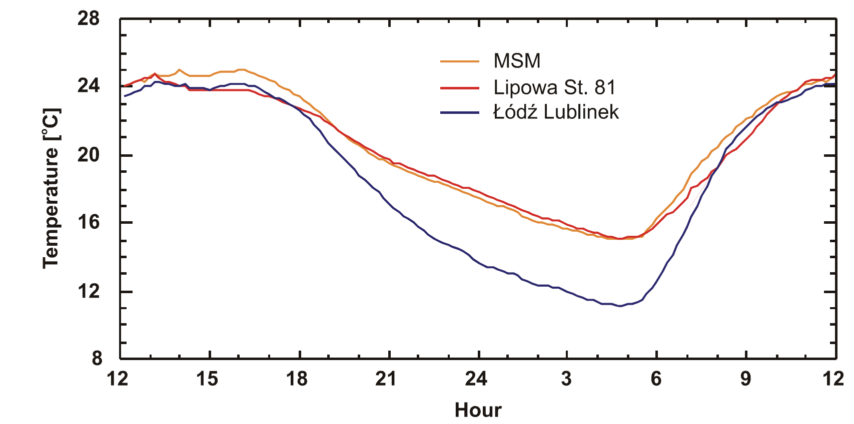

Fig. 7. Mean 24-hour temperature range within and outside the city on windless days with clear skies (average values for 14 days selected from 1997–1999) (F o r t u n i a k, K ł y s i k)

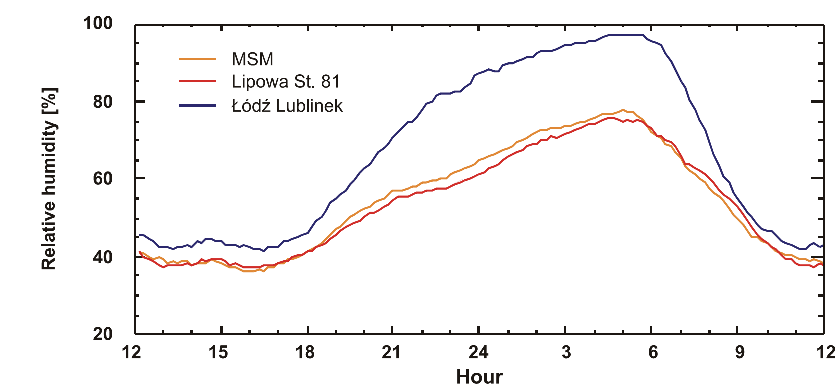

Fig. 8. Mean 24-hour relative humidity within and outside the city on windless days with clear skies (average values for 14 days selected from 1997–1999) (F o r t u n i a k, K ł y s i k)

The urban heat island usually has an extensive form (with low wind speed up to 3–4 m/s) and its intensity reaches 3–4°C (map 5 and fig. 7). The occurrence of a night heat island causes various consequential effects, e.g. a much lower relative humidity in the city (fig. 8). Increased convection is observed over the city during the day, a local urban-breeze may occur, as well as snow cover melts faster, etc. The urban heat also leads to the formation of specific bioclimatic conditions.

Bioclimatic conditions (felt climate) are usually described using various and complex indicators of the influence of weather on human organism. A popular indicator of thermal perception is the equivalent temperature, defined as the temperature that the air would have if at constant atmospheric pressure the whole water vapour had condensed and the heat so released would warm up the dry air. Figure 9 presents the average course of the mean and the highest and the lowest annual equivalent temperature $\mathbf{T_e}$ values as recorded at 13.00 hours in the centre of Łódź in the period 1992–2000. The $\mathbf{T_e}$ indicator was calculated applying Prött's equation $\mathbf{T_e} = t + 1.5{*}e$, where t stands for the air temperature (°C) and e for water vapour pressure (hPa). The wind chill factor ($\mathbf{T_e}$ < 18°C) appears usually in the second third of November and lasts until the first third of April. Between 1992 and 2000, the $\mathbf{T_e}$ indicator values corresponding to the wind chill temperature appeared at the beginning of October and lasted until May. Comfortable temperature conditions (32°C < $\mathbf{T_e}$ < 44°C) usually last from May to mid-September. Increased humidity ($\mathbf{T_e}$ > 56°C) occurs quite rarely and such days are usually observed between May and the end of August. The greatest fluctuations of equivalent temperature, reaching 44°C, are typical of June and November, whereas the lowest, only 33°C, occur in July.

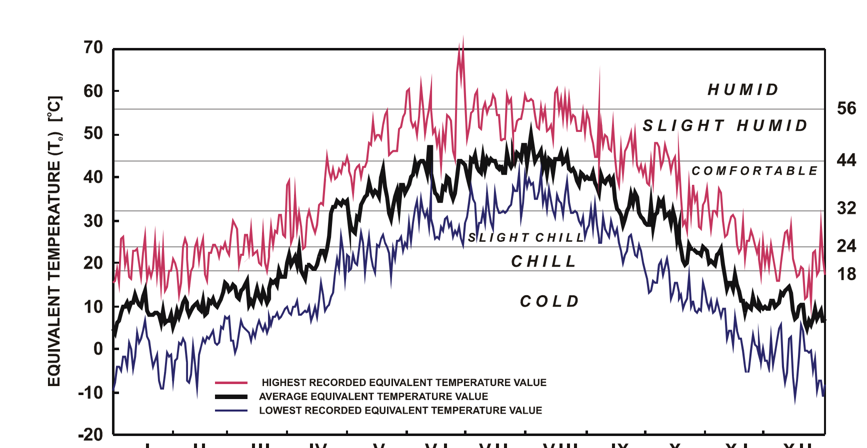

Fig. 9. Annual course of equivalent temperature $\mathbf{T_e}$ [°C] at 13.00 hours at the Meteorological Station in Łódź – 1992–2000 (P o d s t a w c z y ń s k a, K ł y s i k)

Air pollution in the city has adverse effects on the living conditions. Its high concentrations cause respiratory system difficulties, especially in senior citizens and children. Currently, the highest pollution values in Łódź are more often caused by numerous low-level pollution sources rather than large industrial emitters.In busy streets, exhaust emissions add up.

The highest pollution concentrations have always been observed in the city centre, with the annual values of 83 µg SO_2/m^3 (1984), and 128 µg of dust/m^3 (1985), whereas the current admissible pollution concentration levels are 40 and 50 µg/m^3, respectively (map 6, map 7). In 2000, these values dropped to 15 µg SO_2/m^3 and 59 µg of dust/m^3 (as shown in maps 8 and 9). Farther from the city centre, the pollution concentration levels go down to 4–6 µg SO_2/m^3 and 8 µg of dust/m^3. The NO_2 concentration levels do not exceed (apart from the main streets) the admissible daily norm (D_{24} = 150 µg/m^3), and recently even the annual norm Da = 40 µg/m^3 (map 10). The emission measurements carried out for over thirty years by the Environmental Health Department in Łódź and the Environment Protection Inspectorate, as well as some industrial plants, well document the decrease in sulphur dioxide concentrations (fig. 10). Observed are clear annual and daily (or even weekly) courses of the occurrence of 30-minute NO_2 and CO concentrations, with the highest concentration values occurring during the morning rush hours and after sunset (fig. 11, fig. 12). Sulphur dioxide and suspended dust concentrations (with standard grain coarseness below 10 µm) also showed daily variability relative to fuels (mainly hard coal) combustion for heating purposes (fig. 13). One may conclude (fig. 14) that the decrease in the level of sulphur dioxide emissions, particularly noticeable in the last 10 years, is accompanied by increased exhaust emissions. Given the insufficient ventilation in the narrow streets of Łódź, the problem is aggravating.

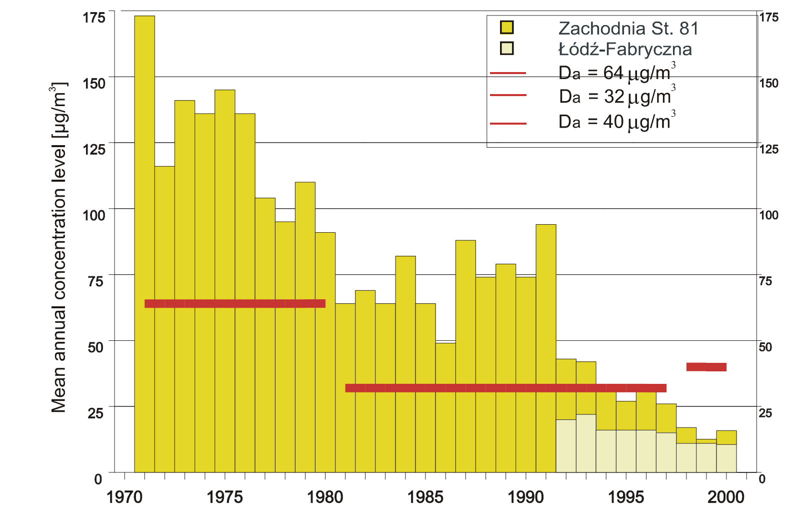

Fig. 10 Mean annual SO_2 concentration levels between 1971 and 2000 at the measurement stations of the Wojewódzka Stacja Sanitarno-Epidemiologiczna – WSSE (Environmental Health Department) at Zachodnia St. 81 and the Wojewódzki Inspektorat Ochrony Środowiska – WIOŚ (Environmental Protection Inspectorate) at Łódź-Fabryczna railway station (R e m b o w s k i, F o k c z y ń s k i)

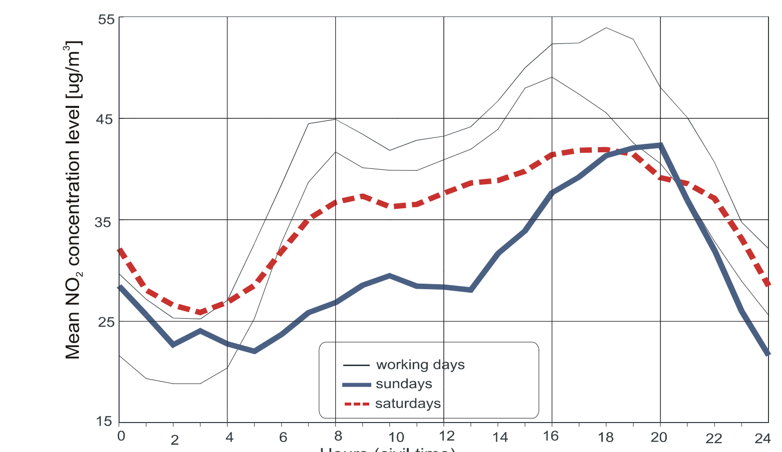

Fig. 11 Mean NO_2 concentration levels (from WIOŚ S60) as per days of the week and time of the day in the half-year from Nov 1998 to Apr 1999, between 120–179 Piotrkowska Street (F o k c z y ń s k i, R e m b o w s k i)

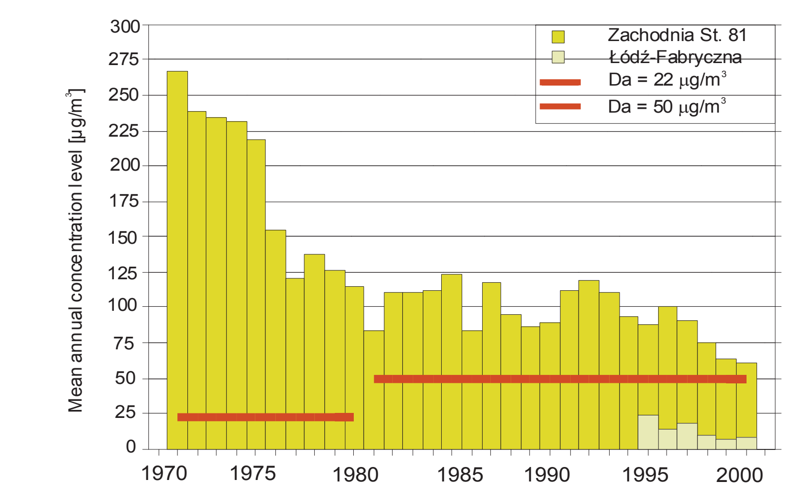

Fig. 12 Mean annual suspended dust concentration levels in period 1971–2000 at the Wojewódzka Stacja Sanitarno-Epidemiologiczna – WSSE (Environmental Health Department) measuring station, 81 Zachodnia Street, and the Wojewódzki Inspektorat Ochrony Środowiska – WIOŚ (Environmental Protection Inspectorate) station by Łódź-Fabryczna railway station
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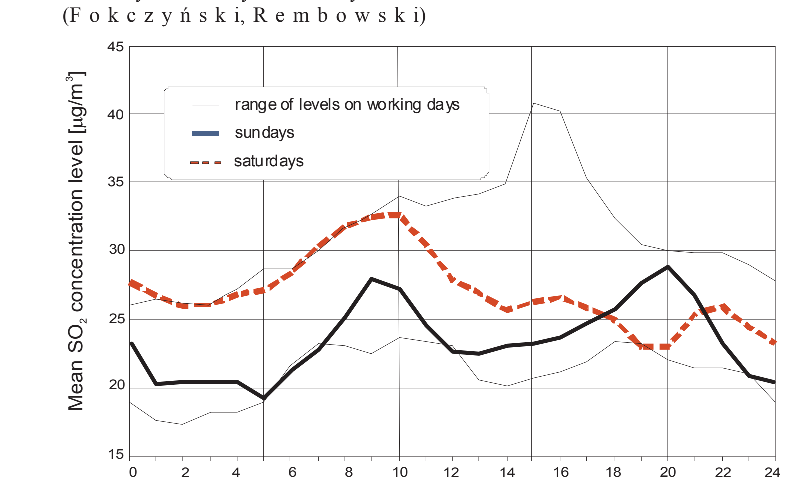

Fig. 13 Mean SO_2 concentration levels as per days of the week and time of the day in the half-year from Nov 1998 to Apr 1999 in Łódź city centre
(F o k c z y ń s k i, R e m b o w s k i)

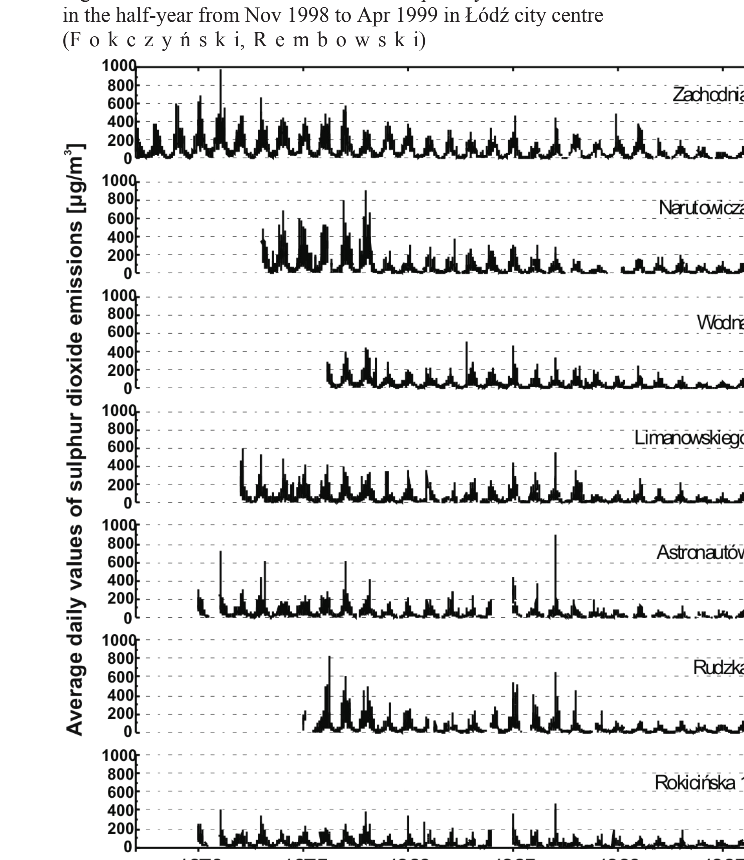

Fig. 14 Long-term course of sulphur dioxide emissions to air in Łódź (selected measuring stations) (F o r t u n i a k, K ł y s i k)