DOI: 10.2478/jwld-2014-0001

© Polish Academy of Sciences, Committee for Land Reclamation and Environmental Engineering in Agriculture, 2014
© Institute of Technology and Life Science, 2014

JOURNAL OF WATER AND LAND DEVELOPMENT
J. Water Land Dev. 2014, No. 20 (I–III): 31–37
PL ISSN 1429–7426

Available (PDF): www.itep.edu.pl/wydawnictwo; http://www.degruyter.com/view/j/jwld

Received 05.11.2013
Reviewed 29.11.2013
Accepted 14.01.2014

A – study design
B – data collection
C – statistical analysis
D – data interpretation
E – manuscript preparation
F – literature search

Seasonal variability of basic pollution parameters in atmospheric precipitation in Strzelin

Bartosz JAWECKI[1) ABCDEF], Ewa BURSZTA-ADAMIAK[2) ABCDEF]

[1)] Wroclaw University of Environmental and Life Sciences, Institute of Landscape Architecture, pl. Grunwaldzki 24a, 50-363 Wrocław, Poland, e-mail: bartosz.jawecki@up.wroc.pl
[2)] Wroclaw University of Environmental and Life Sciences, Institute of Environmental Engineering, pl. Grunwaldzki 24, 50-363 Wrocław, Poland, e-mail: ewa.burszta-adamiak@up.wroc.pl

For citation: Jawecki B., Burszta-Adamiak E. 2014. Seasonal variability of basic pollution parameters in atmospheric precipitation in Strzelin. Journal of Water and Land Development. No. 20 p. 31–37.

Abstract

Electrical conductivity and pH are the basic indices of rainfall pollution, constituting the basis for evaluation of the general nature of rainwater. This article presents an analysis of these two parameters in samples of rainfall collected in the years 2008–2010 (in the heating season and outside it) in three measurement sites P1, P2 and P3, located in the city and commune Strzelin (Lower Silesian Voivodeship).

Preliminary results show a high variation of pH and electrical conductivity of rainfall occurring in the analysed area. Approximately 30% of the samples were characterised by a pH that allowed to qualify them, according to JANSEN *et al*. [1988], as normal rainfall. A similar share in all the collected samples represented rainfall of pH < 5.1 that was classified as slightly, considerably and highly acidic. The problem of acid rain occurred in the analysed area mainly during the heating season, when rainfall of pH < 5.1 accounted for a considerable share in all rainfall samples collected in the said period. The electrical conductivity of most samples fell below 60 $\mu S \cdot cm^{-1}$, which allowed us to classify them as slightly polluted rainfall (site P2), considerably polluted (site P3) and highly polluted (site P1).

Key words: *bulk precipitation, electrical conductivity, pH, Strzelin*

INTRODUCTION

The quality of precipitation is a significant indicator of the extent of atmospheric air pollution. Measurements that allows us to draw conclusions as to the general nature of rainwater include the analysis of pH and electrical conductivity. In the atmosphere that is free from anthropogenic pollutants, the values of rainfall pH are 5.5–5.6. When the value of pH in precipitation decreases to ~5.0, it is assumed to be acidic precipitation, often referred to as "acid rain". [PĘCHERZEWSKI 2003]. According to some authors [SINGH *et al.* 2007; WALNA, SIEPAK 1995; 1999], pH 5.6 is considered a threshold value, below which the rainfall is characterised as of acidic nature.

The problem of acid precipitation is important due to a series of negative consequences resulting from the influence of such rainfall on terrestrial and aquatic ecosystems. The most important effect is the dying of forests, nutrient outwashing from above-ground plant parts, soil and surface water acidification and the destruction of construction materials of various types of structures [BŁĘDZIŃSKA 2004; MENZA, SEIP, 2004; POTTER 1991; SAPEK 2013]. The value of pH in precipitation is influenced mainly by gases emitted to the atmosphere by humans (including sulphur, nitrogen and carbon oxides) as a result of the combustion of coal and other energy carriers, industrial production and the use of mechanical vehicles.

Specific electrical conductivity, as the second determined parameter, is an indicator of the total amount

© Polish Academy of Sciences (PAN) in Warsaw, 2014; © Institute of Technology and Life Science (ITP) in Falenty, 2014

Unauthenticated | 89.73.89.243
Download Date | 5/15/14 12:23 PM

of ions dissolved in water. It evidences mineral pollution of water. The value of electrical conductivity in rainfall depends on the volume, intensity and frequency of rainfall occurrence, on the character of inflowing air masses, the type of atmospheric circulation and the direction of wind that determines the influence of local sources of air pollution [BOCHENEK 2005].

In the last decade, both pollution parameters attracted the interest of many researchers all over the world [CHANTARA *et al.* 2008; MIGLIAVACCA *et al.* 2005; SAKIHAM *et al.* 2008; WU *et al*. 2013]. Such studies are usually conducted in large urban areas. However, in small cities, like Strzelin, little is known about contamination of regional precipitation.

Despite systematic improvement of air quality in Poland, low pH of precipitation still remains a significant issue in some regions of Poland [POLKOWSKA *et al.* 2005; WALNA *et al*. 1998; 2003; WALNA, SIEPAK 1995; 1999]. The objective of this article is to evaluate the general nature of rainwater and to check whether the threats connected with the occurrence of acid rains exist in the study area.

MATERIAL AND METHODS

The tests were conducted in the city and commune Strzelin, located in south-eastern part of the Lower Silesian Voivodeship (Fig. 1). The commune has an area of 171.64 km^2 and is inhabited by 21 661 residents (according to GUS, as of 31.12.2010) [GUS 2011]. The commune is mainly agricultural, while the industry is dominated by food processing and by mining and processing of natural resources [KULIKOWSKI *et al.* 2010].

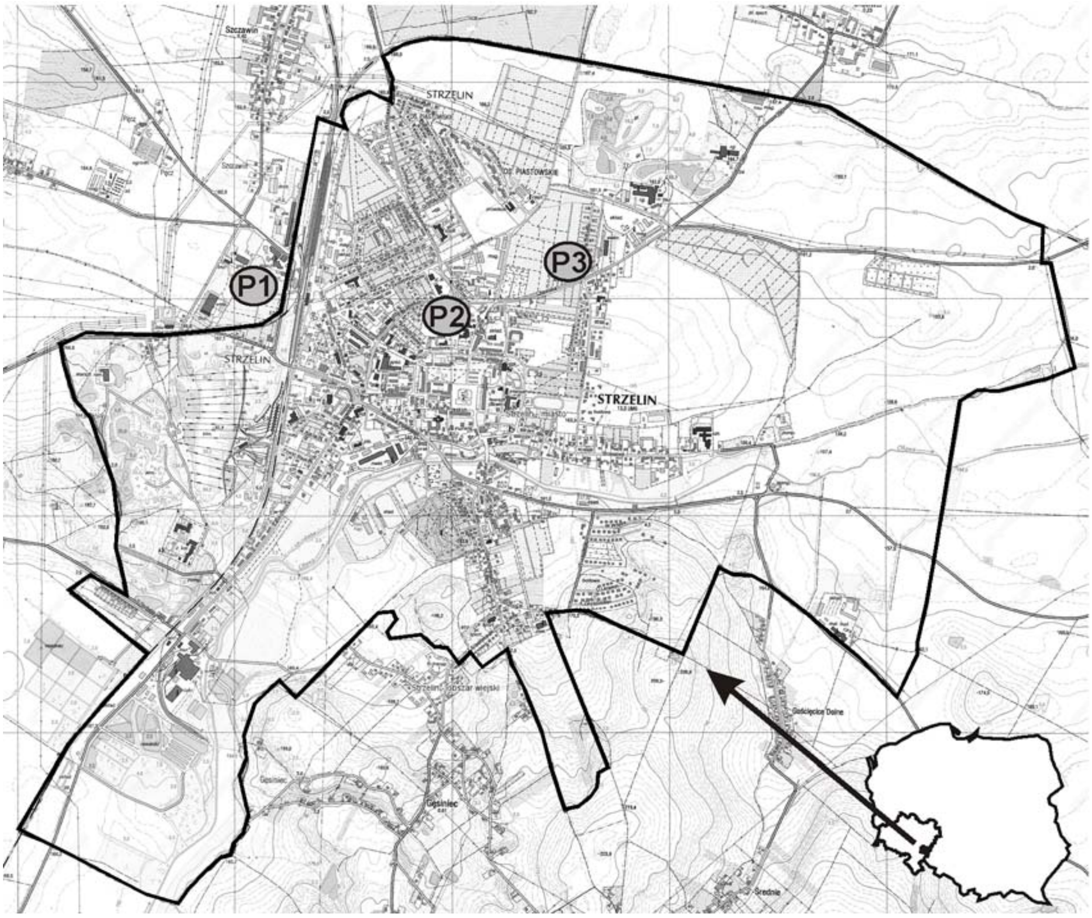

Fig. 1. Location of the measurement sites within Strzelin; source: own elaboration

According to climatic regionalisation of Poland by W. Okołowicz, the commune is located in the Silesia – Wielkopolska climatic region, in a zone highly influenced by the Sudeckie Foothill and moderately modifying oceanic influences, that shape local characteristics of the climate in the area. Thus, the climate is shaped by the same air masses as in the whole Lower Silesia. Average annual temperatures range between 7°C and 8.5°C. The average temperature in July is 17.5°C and in January 1.2–21.8°C. Total annual precipitation is 580 mm. South-westerly, westerly and north-westerly winds prevail in the region and affect precipitation there. The winter period lasts for 14 to 20 weeks, and the summer period from 6 to 10 weeks [KULIKOWSKI *et al.* 2010; OKOŁOWICZ 1973–1978; WIDUCH-HYDRO SA 2003].

The sources of air pollution in the Strzelin commune include agriculture, industry (agricultural and

Unauthenticated | 89.73.89.243
Download Date | 5/15/14 12:23 PM

food processing industry, construction and road construction sector, manufacturing of pipes and sanitary systems, mining natural resources), communal management (boiler houses of residential quarters and public utility objects, individual boilers) and transport. The pollutants emitted into the air result mainly from the combustion of gaseous and solid fuels and from the processing of rock materials [JAWECKI 2011; JAWECKI, JAWECKA 2011; KULIKOWSKI *et al.* 2010].

The emission from tall, point emitters have a limited influence on air quality in the town. The main factor influencing the air quality in Strzelin is low emission from communal sources. A high variability and dispersion of emission sources leads to the fact that the air is polluted mainly in the town itself, because of a very high share (over 86%) of coal used for heating. The following types of fuel are used to a lesser extent: natural gas, heating oil, electric energy, propane-butane and biomass from wood [KULIKOWSKI *et al*. 2010].

The measurement sites were located in 3 points of the city (Fig. 1). Point 1 (P1) was located in the area of family allotments situated in the proximity of industrially developed area, granite mining and processing and agricultural land. Point 2 (P2) was located in the centre of the city, in the area of multi-family houses and the main communication route. Point 3 (P3) was located in the family allotments (P3) built up by detached houses. Samples of bulk rainfall were collected to a container of the diameter of 12 cm, placed 1 m above the ground covered by turf. Measurements of bulk rainfall parameters were conducted in 10-day intervals in the summer (May–October) and winter (November–April) periods, which corresponded to the heating season (starting at the turn of September/October, ending in the end of April) and the period outside the heating season (starting at the turn of April/May, ending at the turn of September/October) in the analysed area. If there was no precipitation, the container was filled with distilled water and mixed thoroughly. pH and electrical conductivity of the rainfall samples were determined with multifunctional meter WTW 340i and 350i, with pH-meter Sentix 41 WTW (measurement range from –2.00 to +16.00 pH) and TetraCon 325 WTW conductivity meter (measurement range from 1 to 2 $mS\cdot cm^{-1}$). Measurements were conducted on-site. If this was impossible, the sample was stored in a refrigerator at a temperature of 4–5°C. If ice or snow were present in the containers, the sample was melted in room temperature before the measurement. During the test period a total of 216 samples of bulk precipitation were collected (72 samples from each experimental site).

The data on the amount of precipitation were collected at the precipitation station in Strzelin and made available courtesy of the Institute of Meteorology and Water Management (IMGW) in Wroclaw.

The classification of acidity and electrical conductivity of rainfall was developed based on groups proposed by Jansen [JANSEN *et al*. 1988].

RESULTS AND DISCUSSION

Amount of rainfall

Fig. 2 shows the amount of rainfall in ten-day periods, calculated from the sum of daily rainfall that occurred in ten-day intervals. Due to the measurement period (starting in the summer half year in 2008 and ending in 2010, in the winter half year), the distribution of rainfall was analysed by dividing the data into the said periods. The total amount of rainfall outside the heating season 2009 and in the heating season 2009/2010 was higher than in the preceding periods. This was a result of several major events that occurred in May and June 2009 and in January 2010. The precipitation outside the heating season in 2008 and in the heating season 2008/2009 was much more evenly distributed in time, although its amount was smaller. The ten-day amounts did not exceed 57 mm (outside the heating season 2008) and 35 mm in the heating season 2008/2009.

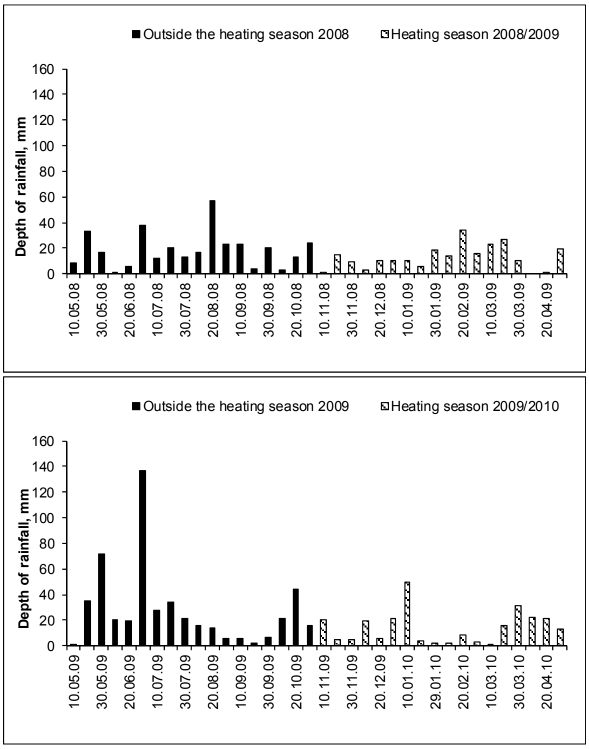

Fig. 2. Ten-day rainfall in the period from May 2008 till April 2010; source: own study

pH of the rainfall

pH of the rainfall collected in the analysed period fell into the range from 3.79 to 8.41 in site P1, from 3.91 to 7.31 in site P2 and from 3.86 to 7.15 in site P3. In spite of the different locations of measurement sites, the values of pH on individual measurement days were only slightly different, and their variation in time was similar in all sites (Fig. 3).The calculated average pH values were similar being 5.72, 5.75 and 5.66 in site P1, P2 and P3, respectively.

© PAN in Warsaw, 2014; © ITP in Falenty, 2014; J. Water Land Dev. No. 20 (I–III)

Unauthenticated | 89.73.89.243
Download Date | 5/15/14 12:23 PM

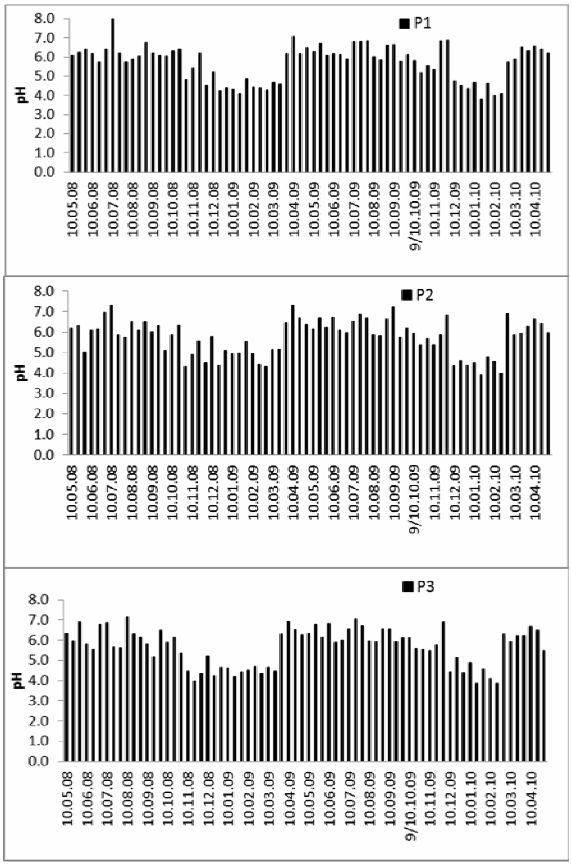

Fig. 3. The variation of rainfall pH during the study period in particular sites; source: own study

If we divide the measurement period into heating season and the period outside the heating season (Fig. 4), the obtained values show a markedly lower pH of rainfall waters in the winter months (mainly in January and February) than in the warm months (April–October). Thus, it can be assumed that air pollution is smaller outside the heating season. Data presented in such a way correspond with findings by numerous authors, confirming the association between air temperature and season and the pH of rainfall [SZWEJKOWSKI *et al*. 2007; WALNA, SIEPAK 1999]. Seasonal fluctuations in pH of rainfall are connected, in the climatic conditions of Strzelin and throughout Poland, with the variability of emission of different types of pollutants resulting from fuel combustion for heating purposes.

In the heating season 2008/2009 in site P1, most rainfall samples were characterised by considerably acidic pH (pH 4.1–4.6), while in the second analysed season 2009/2010 a significant amount of samples (22%) contained rainfall of highly acidic pH. In the periods outside the heating seasons the pH of rainfall was less acidic. Most rainfall samples collected in 2008 had pH slightly above normal (pH 6.1–6.5), those collected in 2009 showed normal pH (5.1–6.1) (Fig. 4).

In site P2, in the heating season 2008/2009, the range of pH recorded in most rainfall samples was 4.6–5.1, which corresponds to slightly acidic pH of

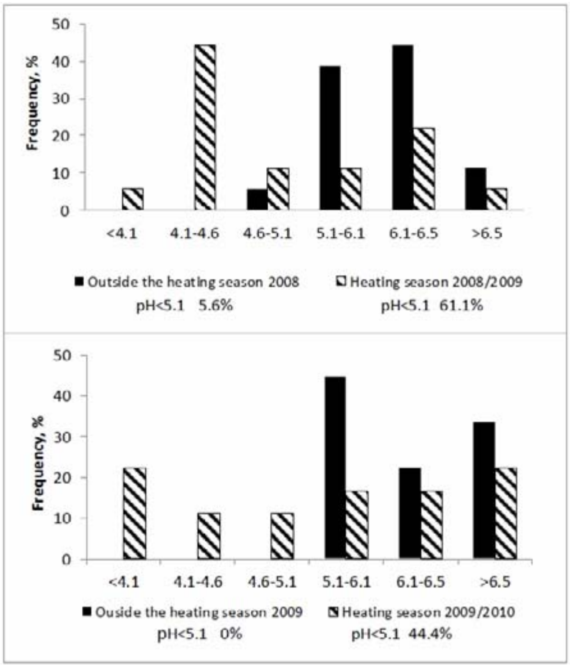

Fig. 4. Histogram of the frequency of samples of specific pH values in site P1; source: own study

rainfall (Fig. 5),while in the subsequent season (2009/2010) most observed events of rainfall were characterised by considerably acidic pH (pH 4.1–4.6). Outside the heating season in the year 2009, the precipitation was characterised by a higher pH than in the preceding year. Precipitation of a pH < 5.1 outside the heating season 2008 accounted for 17% of all events. Outside the heating season 2009, no precipitation of such pH was observed. Noteworthy is a high share (39%) of rainfall of pH > 6.5, which occurred in this site outside the heating season 2009.

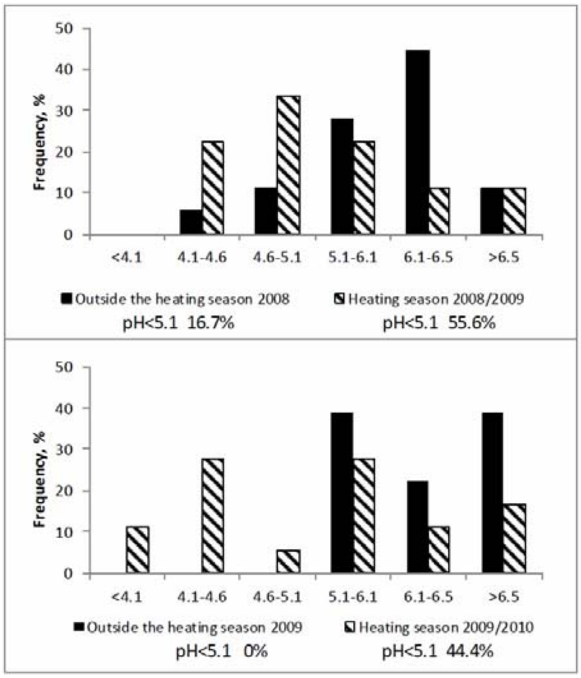

Fig. 5. Histogram of the frequency of samples in specific pH value in site P2; source: own study

© PAN in Warsaw, 2014; © ITP in Falenty, 2014; J. Water Land Dev. No. 20 (I–III)

Unauthenticated | 89.73.89.243
Download Date | 5/15/14 12:23 PM

In site P3 in the heating season 2008/2009 the majority of rainfall had a considerably acidic pH (4.1–4.6), and in the subsequent season (2009/2010) rainfall of a normal pH accounted (Fig. 6). Specific for this location was the absence of rainfall with pH < 5.1 outside the heating season.

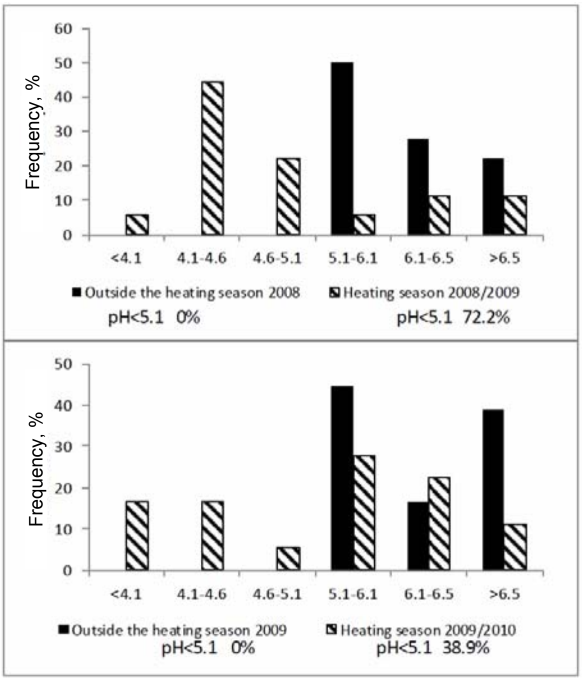

Fig. 6. Histogram of the frequency of samples of specific pH values in site P3; source: own study

For both periods outside the heating season, precipitation of a normal pH (pH 5.1–6.1) accounted for most of the events.

Electrical conductivity

Electrical conductivity, as the second basic indicator of rainfall pollution, was highly variable (Fig. 7). In the analysed period, the values of electrical conductivity fluctuated between 8.1 and 419 $\mu S \cdot cm^{-1}$ in site P1, 6.6 and 338 $\mu S \cdot cm^{-1}$ in site P2 and 10 and 578 $\mu S \cdot cm^{-1}$ in site P3. According to JANSEN *et al.* classification [1988], site P1 with most rainfall samples of conductivity between 30 to 60 $\mu S \cdot cm^{-1}$ was classified as highly polluted, site P2 (15 to 30 $\mu S \cdot cm^{-1}$) – as slightly polluted and P3 (30 to 45 $\mu S \cdot cm^{-1}$) – as considerably polluted. Noteworthy, rainfalls of electrical conductivity <15 $\mu S \cdot cm^{-1}$ were similarly frequent in all sites – 12% in site P1, 11.1% in site P2 and 12.5% in site P3. The same was true for electrical conductivity >100 $\mu S \cdot cm^{-1}$ which occurred in 16% of samples from site P1 and in 13.9% of samples from sites P2 and P3. Most events of rainfall of an electrical conductivity >100 $\mu S \cdot cm^{-1}$ occurred in the heating season 2008/2009.

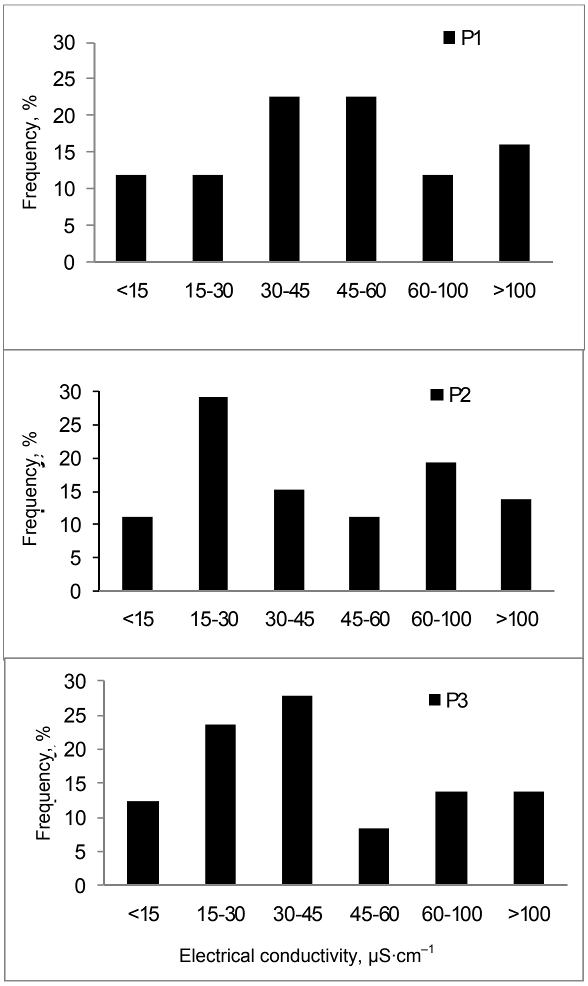

Fig. 7. Histogram of the frequency of samples of specific electrical conductivity values; source: own study

CONCLUSIONS

Preliminary results from the analysis of seasonal variability of pH and electrical conductivity in bulk precipitation samples allow us to formulate the following final conclusions:

1. In Strzelin the majority of rainfall was characterised by normal pH (29.6%), pH slightly above normal (22.7%) and pH above normal (19.4%). Environmentally disadvantageous events of rainfall of a highly acidic pH (pH < 4.1) constituted only 5% of all sampling occasions.

2. The observed high variability in the electrical conductivity of rainfall proves a high variability of pollution. The electrical conductivity of rainfall exceeded 100 $\mu S \cdot cm^{-1}$ only in a few cases (approx. 15%). Most of the rainfall (69% in site P1, 67% in site P2 and 72% in site P3) was characterised by electrical conductivity below 60 $\mu S \cdot cm^{-1}$.

3. Temporal distribution of pH and electrical conductivity shows a noticeable seasonality for all measurement sites. The lowest values of pH in bulk

Unauthenticated | 89.73.89.243
Download Date | 5/15/14 12:23 PM

precipitation and the highest values of electrical conductivity were noted in the heating seasons. The increase in the acidity of precipitation and the degree of mineral pollution in this season is likely to be the result of higher air pollution and lower total atmospheric precipitation in comparison with periods outside the heating season.

4. The character of the area where samples were collected allows us to believe that the main source of rainfall pollution was the emission from communal and residential sector (in spite of agricultural character of the commune), and, to a lesser extent, from the agricultural and food processing industry or from the mining and processing of rock materials.

REFERENCES

BŁĘDZIŃSKA A. 2004. Zależność odczynu wody opadowej pH od wysokości opadów atmosferycznych na stacji Warszawa Ursynów w latach 1998–2003 [The dependence of the pH of rainfall water on the amount of atmospheric precipitation on station Warszawa Ursynów in the years 1998–2003]. Przegląd Naukowy Inżynieria i Kształtowanie Środowiska. R. 12. Z. 1 (28) p. 80–89.

CHANTARA S., CHUNSUK N. 2008. Comparison of wet-only and bulk deposition at Chiang Mai (Thailand) based on rainwater chemical composition. Atmospheric Environment. Vol. 42 p. 5511– 5518.

GUS [Main Statistical Office] 2011. Bank Danych Lokalnych [Local Data Bank] [online]. [Access 10.02.2012]. Available at: www.stat.gov.pl

JANSEN W., BROCK A.A., KNACK J. 1988. Kwaśne deszcze – historia, powstawanie, skutki [Acid rains – history, formation, effects]. Aura. Nr 4 p. 18–19.

JAWECKI B. 2011. The process of creation and the values of the Wzgórza Strzelińskie Natural-Landscape Complex. Infrastruktura i Ekologia Terenów Wiejskich. Nr 11 p. 15–28.

JAWECKI B., JAWECKA B. 2011. Kopalnie w krajobrazie powiatu strzelińskiego – złoża, zasoby i eksploatacja surowców naturalnych [Mines in the landscape of Strzelin County – deposits, resources and exploitation of raw materials]. Infrastruktura i Ekologia Terenów Wiejskich. Nr 1 p. 125–138.

KULIKOWSKI S., CHYLAK A., PRZYSZLAK E., STĘPIEŃ M., KLIMASZEWSKI S., FURDYKOŃ D., JAWECKI B. 2010. Program ochrony środowiska dla gminy Strzelin. Uchwała Rady Miejskiej Strzelina z dnia 28 września 2010 nr XLVI/ 433/10 [Environmental protection programme for the commune Strzelin (typing copy, 175 pages) Resolution of the Municipal Council of Strzelin No. XLVI/433/10 of the 28th September, 2010]. Typing copy pp. 175.

MENZA F.C., SEIP H.M. 2004. Acid rain in Europe and the United States: an update. Environmental Science and Policy. Vol. 7 p. 253–265.

MIGLIAVACCA D., TEIXEIRA E.C., WIEGAND F., MACHADO A.C.M., SANCHEZ J. 2005. Atmospheric precipitation and chemical composition of an urban site, Guaíba hydrographic basin, Brazil. Atmospheric Environment. Vol. 39 p. 1829–1844.

OKOŁOWICZ W. 1973–1978. Regiony klimatyczne, mapa w skali 1:2 000 000. W: Narodowy atlas Polski [Climatic regions, map in the scale 1:2 000 000. In: National atlas of Poland. Warszawa–Wrocław. IG PAN, Zakład Narodowy im. Ossolińskich.

PĘCHERZEWSKI K. 2003. Kwaśne deszcze i zakwaszenie opadów atmosferycznych w rejonie Morza Bałtyckiego [Acid rains and the acidity of atmospheric precipitation in the Baltic Sea region]. Słupskie Prace Geograficzne. Nr 1 p. 133–139.

POLKOWSKA Ż., ASTELB A., WALNA B., MAŁEK S., MĘDRZYCKA K., GÓRECKI T., SIEPAK J., NAMIEŚNIK J. 2005. Chemometric analysis of rainwater and throughfall at several sites in Poland. Atmospheric Environment. Vol. 39 p. 837–855.

POTTER Ch.S. 1991. Atmospheric deposition and foliar leaching in a regenerating Southern Appalachian forest canopy. Journal of Ecology. Vol. 79 p. 97–115.

SAPEK B. 2013. Calcium and magnesium uptake with the yield of meadow vegetation in relation to their content in atmospheric precipitation, ground water and soil solution. Journal of Water and Land Development. No. 18 p. 73–83.

SINGH A.K., MONDAL G.C., KUMAR S., SINGH K.K., KOMAL K.P., SINHA A. 2007. Precipitation chemistry and occurrence of acid rain over Dhanbad, coal city of India. Environmental Monitoring and Assessment. Vol. 125 p. 99–110.

SAKIHAMA H., ISHIKI M., TOKUYAMA A. 2008. Chemical characteristics of precipitation in Okinawa Island, Japan. Atmospheric Environment. Vol. 42 p. 2320–2335.

SZWEJKOWSKI Z., SUCHECKI S., DRAGAŃSKA E. 2007. Odczyn opadów atmosferycznych w okolicach Olsztyna [The pH of precipitation in the proximity of Olsztyn]. Acta Agrophysica. Vol. 10 (3) p. 715–725.

WALNA B., DRZYMAŁA S., SIEPAK J. 1998. The impact of acid rain on calcium and magnesium status in typical soils of the Wielkopolski National Park. Science of the Total Environment. Vol. 220. Iss. 2–3 p. 115–120.

WALNA B., SIEPAK J. 1995. Chemizm wód opadowych w Stacji Ekologicznej UAM w jeziorach w Wielkopolskim Parku Narodowym [The chemistry of rainfall waters at the Environmental Station UAM in lakes in the Wielkopolski National Park]. Ekologia i Technika. Nr 6 (18) p. 24–29.

WALNA B., POLKOWSKA Z., MAŁEK S., MĘDRZYCKA K., NAMIEŚNIK J., SIEPAK J. 2003. Comparison of the variability of physico-chemical parameters in precipitation in Poland (1996–1999). Polish Journal of Environmental Studies. Vol. 12 p. 467–472.

WALNA B., SIEPAK J. 1999. Research on the variability of physical-chemical parameters characterizing acidic atmospheric precipitation at the Jeziory Ecological Station in the Wielkopolski National Park (Poland). Science of the Total Environment. Vol. 239 p. 173–187.

WIDUCH-HYDRO SA 2003. Program Ochrony i Zagospodarowania Wód Zlewni Rzek Ślęza i Oława [Programme for the Protection and Water Management of the Waters in catchments of the Ślęza and Oława Rivers]. Typing copy.

WU D., WANG S., XIA J., MENG X., SHANG K, XIE Y., WANG R. 2013. The influence of dust events on precipitation acidity in China. Atmospheric Environment. Vol. 79 p. 138–146.

Unauthenticated | 89.73.89.243
Download Date | 5/15/14 12:23 PM

Bartosz JAWECKI, Ewa BURSZTA-ADAMIAK

Zmienność sezonowa podstawowych wskaźników zanieczyszczeń opadów atmosferycznych w Strzelinie

STRESZCZENIE

Słowa kluczowe: *całkowity opad atmosferyczny, odczyn, przewodność elektrolityczna, Strzelin*

Odczyn i przewodność elektrolityczna należą do podstawowych miar zanieczyszczenia opadów, na podstawie których można dokonać oceny ich ogólnego charakteru. W artykule dokonano analizy tych dwóch parametrów w opadach pobranych w latach 2008–2010 (w sezonie grzewczym i pozagrzewczym) w trzech punktach pomiarowych: P1, P2 i P3 zlokalizowanych na terenie miasta i gminy Strzelin (województwo dolnośląskie).

Wyniki badań wykazują dużą zmienność odczynu i przewodności elektrolitycznej opadów występujących na analizowanym terenie. Około 30% prób miało odczyn, który zgodnie z klasyfikacją JANSENA i in. [1988] pozwalał je zakwalifikować jako opady normalne. Podobny udział opadów w całości zebranych prób stanowiły opady o pH < 5,1, klasyfikowane jako mające lekko, znacznie i silnie obniżone pH. Problem kwaśnych deszczów występował na analizowanym terenie głównie w sezonie grzewczym, w którym opady o pH < 5,1 stanowiły znaczną część wszystkich opadów pobranych w tym okresie. Przewodność elektrolityczna większości próbek wynosiła poniżej 60 $\mu S \cdot cm^{-1}$, co pozwoliło zakwalifikować je do klasy lekko zanieczyszczonych (stanowisko P2), znacznie zanieczyszczonych (stanowisko P3) oraz mocno zanieczyszczonych (stanowisko P1).

Unauthenticated | 89.73.89.243
Download Date | 5/15/14 12:23 PM