PRECIPITATION CHEMISTRY AND ATMOSPHERIC PROCESSES IN THE FORESTED PART OF CROATIA

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Abstract. The influence of mesoscale weather patterns on the chemical composition of daily precipitation samples is analysed. The data of pH, sulphur from sulphates and total nitrogen are analysed for two rural sites: Plitvice station in forested part of Central Croatia (1981 to 1990) and Puntijarka suburban station on the mountain near Zagreb, the capital of Croatia (1982-1991).

The two prevailing weather types in precipitation days are selected and the comparison of chemical composition of precipitation is made for each of them. The frequency distributions of pH, sulphur and nitrogen show that concentration of major ions in precipitation apparently depends on the regional scale weather type.

It is shown that the seasonal variation of deposition is related to the seasonal variation in precipitation amount. In both weather types Plitvice receives more pollution than Puntijarka that is closer to urban and industrial pollution sources. Both locations are under the prevailing influence of regional pollution sources.

Key words: synoptic weather type, precipitation chemistry, forested part of Croatia

1. Introduction

There is considerable public concern about possible changes in atmospheric composition due to anthropogenic influence. The chemistry of precipitation at remote sites is of interest for several reasons. Chemical composition of precipitation measured at sampling points far from industrial and urban areas is useful as an indicator for the geographical area and it allows us to examine the extent of anthropogenic contamination on meso and larger scales. Precipitation chemistry may change with time in response to changes in emission, meteorological factors, physical and chemical transformation, etc. In this paper meteorological conditions classified in different weather types are used.

The purpose of the paper is to relate chemical composition of daily precipitation samples to prevailing synoptic weather patterns. The analysis is performed for two rural sampling sites: Plitvice, in a forested part of Central Croatia and Puntijarka near Zagreb. The data of pH, sulphur from sulphates and total nitrogen are analysed for the period of ten years (1981-1990 for Plitvice and 1982-1991 for Puntijarka).

2. Data and area of study

Systematic monitoring of forest condition has been carried out in Croatia since 1987. Results obtained by this monitoring showed that the most susceptible area is in the central mountainous part of Croatia, which is the area of exceptional natural value. In this area Plitvice Lakes National Park with area of 195 km^2, established in 1949 and registered as a UNESCO world heritage site in 1979, is under the stress of high acidic deposition (Figure 1). Measurements of chemical composition of precipitation were established in May 1980, and since then, bulk daily precipitation samples have been collected (λ= 15°37.5', ϕ=44°53', h=595 m).

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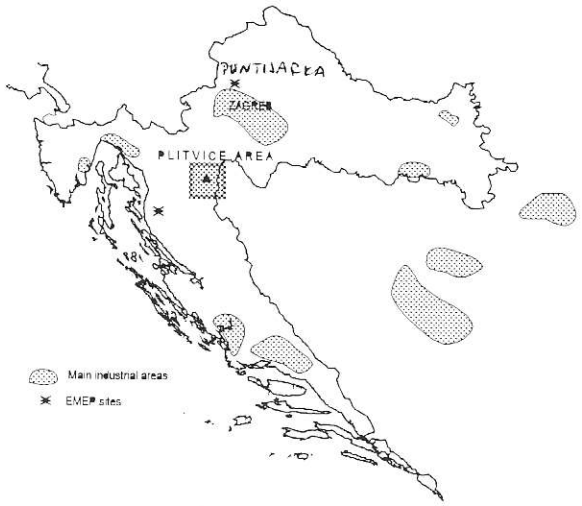


Figure 1. Geographical situation of the area of study and sampling site locations.

Chemical analyses are performed in the central laboratory at Meteorological Service in Zagreb by standard analytical methods.

Puntijarka (λ=15°58', ϕ=45°55', h=988 m) is the rural station situated on the top of Medvednica mountain, about 10 km air length to the north from the centre of Zagreb, the greatest urban and industrial city in Croatia. A ten-year period of data (1981-1990, with exception of 1983 for Plitvice and 1982-1991 for Puntijarka) is used for study of some characteristic features in sulphur (SO_4^{2-}-S) and nitrogen (NO_3^--N + NH_4^+-N) concentrations and pH value of precipitation. In order to relate synoptic scale flow patterns to chemical composition of precipitation the day-to-day weather types have been examined.

3. Precipitation favourable synoptic weather patterns

Since weather is considered to be the ultimate forcing function for many, if not most, environmental processes, we analysed data on precipitation chemical composition obtained in days with different weather patterns. The day-to-day weather at the continental part of Croatia is organised on the basis of mesoscale atmospheric circulation patterns into relatively few types that can provide an environmental baseline inventory specially for the considered region. Daily sampling allowed us to assume a good correspondence between the precipitation sampled and the meteorological situation recorded in the chart for a particular day.

Precipitation at the considered sampling sites occurs mainly with two different synoptic patterns. They receive most precipitation (40-45% of total precipitation amount) in connection with frontal passages and orographic lifting of moist air connected with so called precipitation weather type (PWT) (Lončar and Bajić, 1994). This weather type is characterised by strong winds and advection of warm and moist air dominantly from NW, convergence of horizontal air flow and air lifting along the axis or in the centre of cyclonic activity over the western and north-western Europe. Thus, such situations could be considered as favourable for the regional and long-range transport of pollutants.

Radiation weather types (RWT) are characterised by zero pressure gradient field dominantly accompanied by weak winds of variable direction. In such situations local effects prevail and precipitation is mainly convective. Precipitation amount in days with

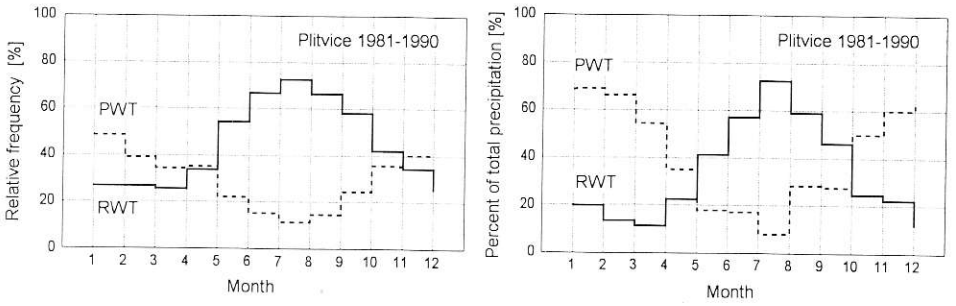


Figure 2. Annual courses of: left - the precipitation (PWT) and radiation (RWT) weather types relative frequencies; right - the percentage of total precipitation amount registered during the PWT and RWT.

radiation weather type is comparable to the amount of precipitation weather type (33-34% of total precipitation).

During winter and spring precipitation preferentially accompanied PWT (Figure 2). More than 50% of total precipitation amount was measured during that weather type. The situation is quite different in summer months when synoptic patterns were classified as radiation weather type with 50-75% of total precipitation amount (in 60% of all days with precipitation). Such seasonal differences in mesoscale weather cause differences in the chemical composition of precipitation.

4. Chemical composition of precipitation

The absolute frequency distribution of pH, sulphate and nitrogen (Figures 3 and 4) for radiation and precipitation weather types shows that chemical composition of precipitation apparently depends on the local weather type. There are evident differences between two stations. It appears that precipitation is more acidic for RWT than for PWT days in the Plitvice area, while at Puntijarka the opposite. The acid precipitation frequency (pH<5.0 according to Charlson and Rhode, 1982) over the period of 10 years is 38% for RWT and 22% for PWT at Plitvice, while 12% in RWT and 11% in PWT at Puntijarka.

Concentrations of sulphur and nitrogen in precipitation are in the high range of values. The fitted log-normal distributions are shifted to the greater concentrations for radiation than for precipitation weather type. Nevertheless, the precipitation volume weighted averages of sulphate concentrations do not differ significantly for those two categories.

The differences between sulphur content in precipitation in two considered weather types are a little bit greater at Puntijarka, but the volume weighted averages of SO_4^{2-}-S and total nitrogen concentrations are smaller at Puntijarka than at Plitvice.

To assess and study the effects on the soil, vegetation and human environment deposition rates of sulphur and nitrogen should to be analysed. In Figure 5 relations between seasonal precipitation amounts and deposition of sulphur and total nitrogen for two considered weather types are presented. Deposition increases with precipitation but not linearly. At Plitvice the differences between radiation and precipitation weather types increase with precipitation amount for sulphur deposition while for nitrogen deposition it is the opposite. Although the deposition reveals a strong relation with precipitation amount, there is a considerable scatter within each subset.

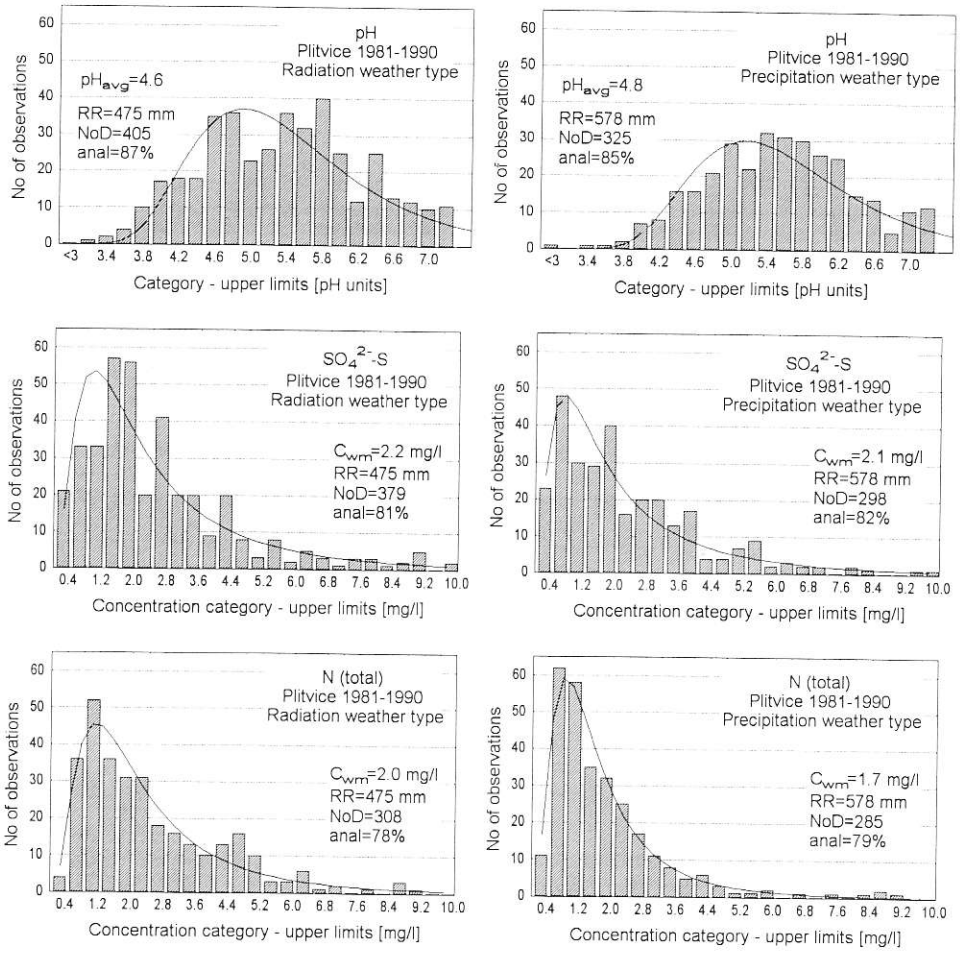
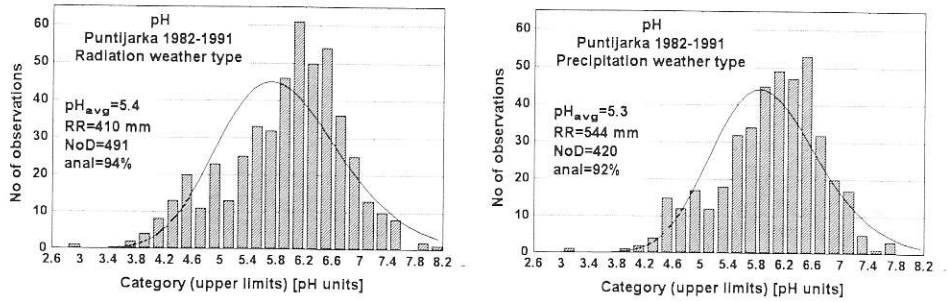


Figure 3. Absolute frequency histograms of pH values, SO_4^{2-}-S and N (total) concentrations with fitted log-normal distribution curve in Plitvice (1981-1990) for radiation and precipitation weather type days. pH_{avg} - the average pH value obtained from precipitation volume weighted H^+ concentration, C_{wm} - the precipitation weighted arithmetic mean concentration, RR - the mean annual precipitation amount, NoD - the number of days with measurements for specific component, anal - the percent of the total precipitation reported analysed for specific component.



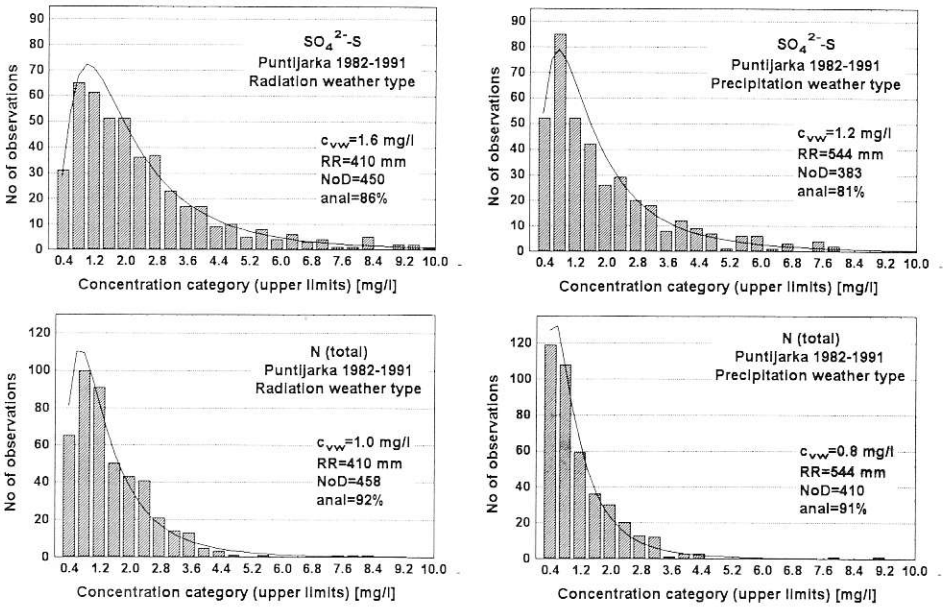


Figure 4. Same as Figure 3 for Puntijarka.

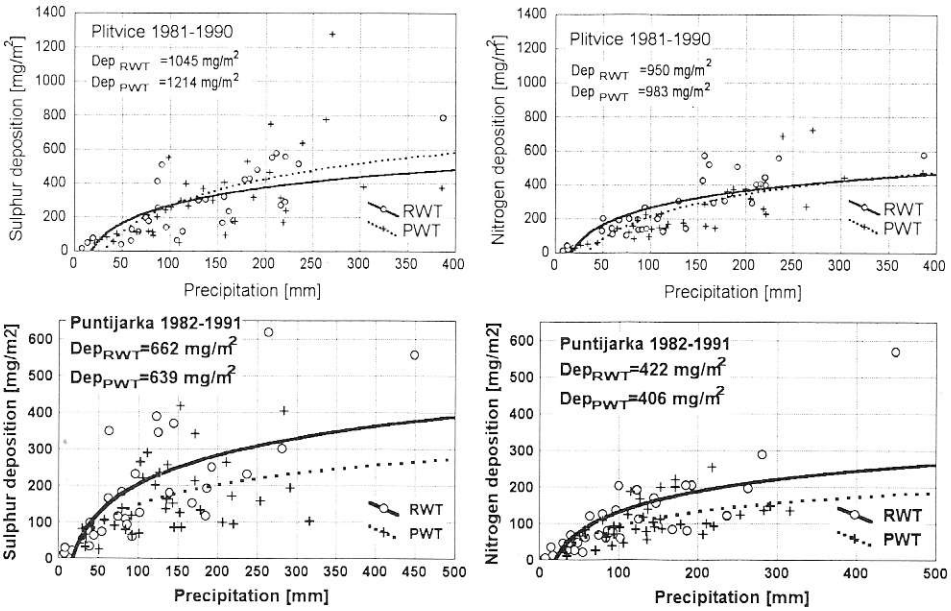


Figure 5. Seasonal sulphur (left) and nitrogen (right) deposition as a function of seasonal precipitation for radiation (RWT) and precipitation (PWT) weather types at Plitvice (1981-1990) and Puntijarka (1982-1991).

Quite different behaviour shows the data from Puntijarka. Both sulphur and nitrogen deposition increase with increasing precipitation amount more in RWT then in PWT. The scatter in seasonal deposition rates is much greater for sulphate than for nitrogen in both weather types. Notice that the deposition of both compounds is at Plitvice almost as twice as at Puntijarka, while the mean total annual precipitation amount is only 20% greater.

5. Concluding remarks

Using the ten year period of data we have analysed the influence of mesoscale weather patterns on the chemical composition of precipitation at two stations in the forested regions: one in central part of the country rather far from local pollution sources, the other in the vicinity of Zagreb, the greatest town in Croatia. The main results may be summerized as follows:

- two precipitation favourable weather types could be separated: *precipitation weather type*, characterised by meteorological conditions favourable for the regional and long-range transport of pollutants and *radiation weather type*, with domination of local effects and convective precipitation;
- prominent relation exists between the chemical composition of precipitation and mesoscale weather patterns;
- the sulphur deposition is more influenced by meteorological conditions than the deposition of nitrogen.

It has been shown that National Park Plitvice is under the stress of acidification even more than rural station close to Zagreb. More than 60% of total precipitation is found to be acidic at Plitvice, while only 31% at Puntijarka. The presented paper indicates that it could be result of regional transport. This should be confirm by further analyses of precipitation chemistry data at other stations. Trajectory analysis and a few individual case studies from regional network stations during well-defined synoptic conditions would undoubtedly be rewarding. Under certain circumstances in radiation weather type the effects of local urban sources become important at Puntijarka. On the contrary, in some situations, specially in winter, mixing height in Zagreb is rather small so urban pollution does not reach Puntijarka (988 m asl) at all (Cvitan, Lončar, 1992).

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