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ABOUT CORRELATION ANALYSIS OF CHEMICAL COMPOUND OF ATMOSPHERIC PRECIPITATION IN THE NORTH OF THE RUSSIAN PLAIN

Dinara Khayrullina

Department of Landscape Ecology, Institute of Ecology and Geography/Kazan Federal University, **Russia**

ABSTRACT

The paper deals with estimation of spatial and temporal variability of magnitude and number of statistically significant coefficients of correlation between components of chemical compound of atmospheric precipitation in the North of the Russian plain. There is direct relationship between magnitude of correlation coefficients and chemical composition of atmospheric precipitation. For example, in space aspect the greatest number of significant correlation coefficients meets on coastal and city continental weather stations. Finally, in temporal (seasonal) aspect this regularity is observed in May, i.e. ion concentration increases in the air during the season of photochemical activity.

Keywords: atmospheric precipitation, aerosols, condensation nuclei, chloride ions, correlation analysis, statistically significant correlation coefficient, weather station

INTRODUCTION

It is known that the ion migration takes place in atmosphere predominantly in bound state in the form of salt aerosols of condensation nuclei [1]. The sources of solutions of these salts are water spray from sea and ocean surface. Sea salts (in the form of aerosols) remain in suspension by evaporation of water splashing into the air, mainly sodium chloride and magnesium [2]. Aerosols can be transferred by winds to considerable distance inland, as long as aerosols are dissolved in atmospheric moisture [3]. So sea component forms chemical composition of atmospheric precipitation (CCP). Chloride concentrations exceed other components concentrations in sea aerosol [1], [2], [8]. For this reason, informative approach is must be based on calculation the degree of relationship between chlorides and other ions in order to identify the degree of pollution by air aerosols and reveal the source their receipt.

The aim of our research is to use correlation analysis to determine the degree of relationship between chlorides and other component of atmospheric precipitation and to try to identify the spatial and temporal variability in this relationship on the basis of long-term observations. Research problems are:

1) reduction of the initial sample data to a normal distribution by taking the logarithm,
2) calculation of correlation coefficients between the components of CCP within and between weather stations and selection statistically significant of them,
3) finding spatial and temporal variability of distribution of values and the number of statistically significant correlation coefficients.

DATA

This paper is based on information about the CCP for period from 1958 to 2007 on 14 weather stations (WS), located in the North of the Russian plain. Incidentally, only four of them have a maximum duration of observation period: Mudyug (1958 - 2007), Ust-Vym (1958 - 2007), Naryan-Mar (1962 - 2007) and Syktyvkar (1971 - 2007). Observation period is from 1990 to 2007 at weather stations Belozersk, Brusovitsa, Onega, Sura and Troitsko-Pechorsk. Observation period is from 1991 to 2007 at weather stations of industrial cities such as Arkhangelsk, Vologda, Severodvinsk and Cherepovets, from 1992 to 2007 - at WS Ukhta.

METHOD

All calculations are carried out in the software package Statgrafics Plus 5.1 and "MS Excel 2010".

Actually, the article based on checking the original data on normal distribution and uses the method of correlation analysis. Statistically, the original data of pollutant concentrations have empirical distribution does not dependent the normal distribution law. It's necessary to lead the empirical distribution of casual variables to a normal concentration distribution. For this reason, all samples should be logarithms [4].

Anyhow, it's necessary to consider degree of relationship between indicators. More specifically, correlation analysis describes this aspect. So correlation coefficient reflects the degree of closeness [5]. Correlation coefficient is more 0.5 reflects direct relationship and less than -0.5 describes feedback.

Besides, the problem of correlation analysis includes estimation of importance and reliability of relationship between indicators. More specifically, P-significance of selected values must be less than 0.05. The level of significance depends on the amount of samples. If the relationship is strong, then it can be detected with high significance when a small sample [6], [7].

So 2016 monthly correlation coefficients compared within each WS, 805 of them are statistically significant (40%). Moreover, 126 of the most significant correlation coefficients (denoted as R) selected for display according to more accurate dependency.

Actually, opportunity appeared to reflect a correlation between chloride and individual components for all components after finding the mean of R values.

RESULTS

Sea area is the main source of chlorides therefore R values were calculated separately for coastal and continental WS (fig. 1).

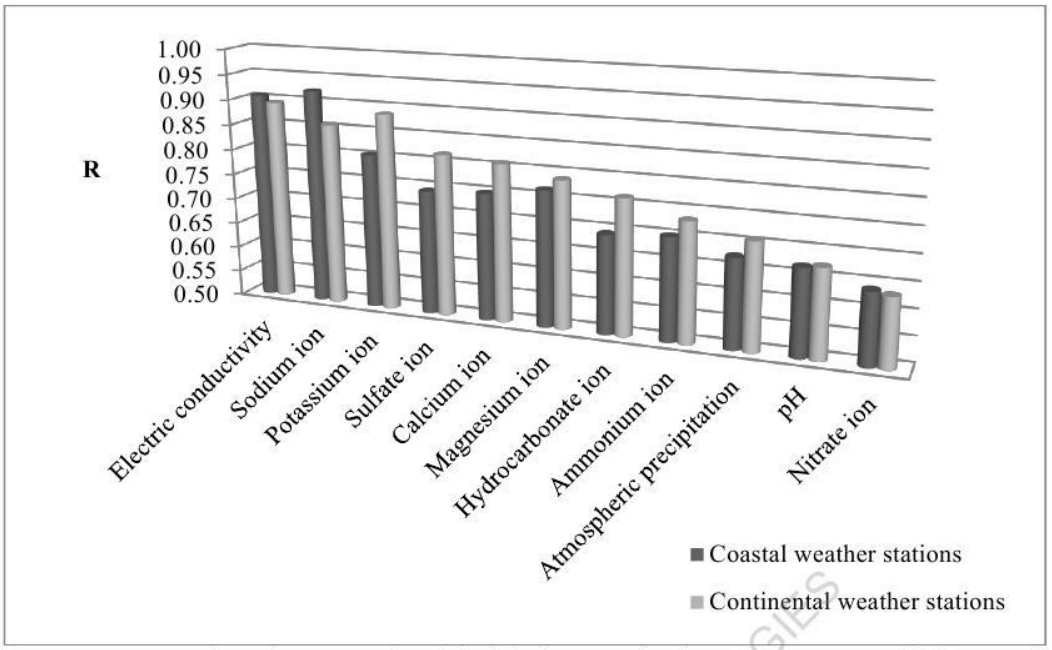

Fig. 1. Mean R values between the chloride ions and other components of CCP on the inland and coastal WS

There is the greatest *R* value between chloride and sodium ions (0.92) in coastal weather stations (Mudyug, Naryan-Mar, Brusovitsa, Onega, Arkhangelsk, Severodvinsk). Besides, high positive correlation coefficients are observed between chloride ions and electrical conductivity (0.91) and also potassium (0.81) and magnesium ions (0.77) (fig. 1).

Primarily, high correlation coefficients between chlorides and sodium, potassium and magnesium ions are related to the high solubility of the salts formed by these components, as well as marine origin of magnesium ions [1]. High relationship between ion content and conductivity connected with direct dependence between chloride content of atmospheric precipitation and mineralization [1].

Interestingly, other situation is observed on continental weather stations. Here there is the greatest relationship between chloride ions and electrical conductivity (0.89), potassium ions (0.88), sodium ions (0.86) and sulfate ions (0.82). Actually, it is caused by industrial enterprises location in this area (fig. 1).

In addition, there is relationship between chloride ions and atmospheric precipitation (0.71).

Chloride ions of atmospheric precipitation fall to the surface with higher rainfall. Presumably, industrial enterprises emit more air pollutants under favorable meteorological conditions.

Naturally, high pH values cause by alkaline environment. Presumably, chloride migration is more related to the migration of H^+ ions in the HCl form. For this reason, coastal WS reveals high relationship between pH value and chloride concentration (about 0.68) (fig. 1).

Anyhow, if dissolved salts in atmospheric precipitation increase then more combinations of statistically significant correlation coefficients can be find.

Incidentally, months have been allocated with high frequency of high correlation coefficients occurrence (fig. 2).

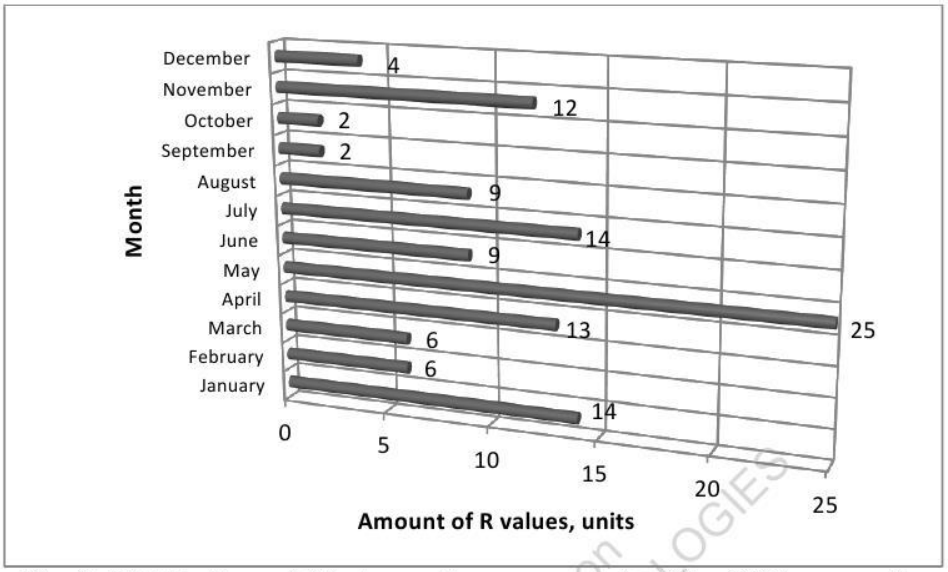

Fig. 2. Distribution of *R* between the components of the CCP on months

There is the maximum number of results *R* (25 units) in May. It is caused by photochemical activity increase in the spring and summer season. So ion concentration is increased during these seasons (fig. 2) [8].

The low amount of *R* found in September - October (2 R) and in February - March (6 R) (fig. 2). It is determined by season change and large amount of atmospheric precipitation. For this reason, the component concentration of atmospheric precipitation decreases.

Besides, number of statistically significant correlation coefficients was calculated for each MS. So the spatial distribution of its values is presented in Figure 3.

Broadly speaking, natural increase in the R values noted in the north-east side (WS Naryan-Mar) and in the south-east of region (WS Cherepovets). Interestingly, there are two local minima in the region of Ust-Vym and Onega. There is a slight increase of significant correlation coefficients number found in the area of Arkhangelsk-Severodvinsk agglomeration.

Moreover, the total number of *R* is much higher on coast of north-east region (WS Naryan-Mar) than in WS Onega. Obviously, Naryan-Mar industry development impacted since 1933. Currently, the city of Naryan-Mar focuses on oil production, energy complex and logging industry.

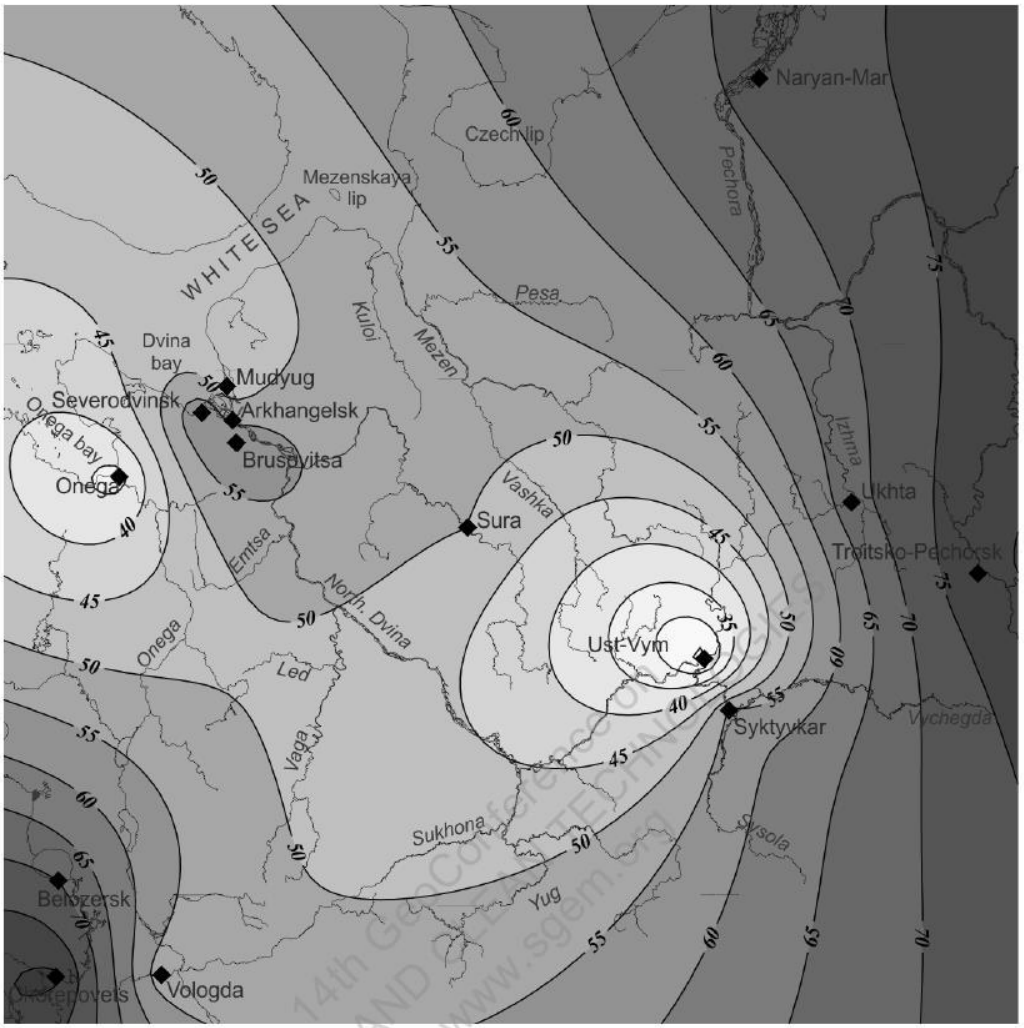

Fig. 3. Spatial distribution of the amount of R found between components CCP in the North of the Russian plain

There is local minima in the central part of the region (WS Ust-Vym and WS Sura) and in the area of Onega. The low number of *R* values observed in MS Ust-Vym (23 units) (fig. 3). Actually, this city is located away from the main sources of atmospheric aerosols (for example, marine waters, industrial enterprises, etc.).

A small number of *R* (33 units) associated with a small number of industrial enterprises in the town of Onega.

Besides, a large number of conjugate ion pairs found in contaminated cities of Cherepovets (81 units), Troitsko-Pechorsk (79) Belozersk (70) and Severodvinsk (60).

More specifically, metallurgical and chemical production developed in Cherepovets.

The logging industry affects the studied parameters in Troitsko-Pechorsk and Sosnogorsk. In addition, the main sectors of the Belozersk economy are wood and food industries. Besides, there is great influence of industrial center of Cherepovets.

Moreover, shipbuilding and mechanical engineering, food and energy industry developed in Severodvinsk [9]. All these anthropogenic aerosol sources increase

mineralization of atmospheric precipitation in cities and their surroundings. Consequently, the probability of finding a larger number of coupled ion pair's increase.

CONCLUSIONS

Finally, correlation analysis reveals values and the number of statistically significant correlations coefficients between ions in direct proportion to its content:

1) marine origin of chloride and sodium ions causes finding the highest relationship between components of atmospheric precipitation especially on coastal weather stations,

2) much more ion conjugate pairs occurs within coastal WS than within continental WS,

3) the greatest amount of significant correlation coefficients are found in May during the spring season of photochemical activity,

4) the most significant correlation coefficients found in industrial cities and coastal areas.

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