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RAFAŁ JASIŃSKI*

THE TYPES OF SEASONAL CHANGES IN DAILY CONCENTRATION OF SOME AIR POLLUTANTS IN THE REGION OF UPPER SILESIA AGGLOMERATION

Different types of daily concentration of some chosen air pollutants in Upper Silesia agglomeration region were presented. By means of a contiguity-enhanced *k*-means clustering algorithm it was possible to create different clusters that represent average daily pollutant concentrations. Then, the periods in which individual types of daily pollutant concentration occurred in 2001–2003 were investigated. All cases, assigned to each cluster, that occurred at particular monitoring stations were arranged in a chronological order. The research was conducted for the concentrations of sulfur dioxide and particulate matter consisting of the particles of the diameters smaller than 10 μm (PM10). The clusters obtained represented different types of daily changes in air pollutant concentrations in the region of Upper Silesia agglomeration. These cluster and individual daily changeability of pollutant concentration are characteristic of consecutive seasons of a year. The method used is therefore suitable for investigating the types of individual daily changes in pollutant concentration throughout a year.

1. INTRODUCTION

The concentrations of air pollutants usually differ, depending on the time of day. The curves representing daily concentrations are characteristic of individual air pollutants; however their shapes depend on a seasonal changeability of the factors influencing these concentrations [1]. This is connected with a great number of cyclic factors affecting the concentration of air pollutants. These are both systematic changes of meteorological or emission conditions associated with the time of a day and also with periodic changes related to the season of a year [2].

A contiguity-enhanced *k*-means clustering algorithm perfectly suits the purpose of defining different types of the changes in daily concentrations of air pollutants. That is one of the methods of the statistical analysis of clusters [3], [4]. In the method, the cases are transferred from one group (cluster) to another to achieve the most signifi-

* Częstochowa University of Technology, Faculty of Environmental Protection and Engineering, ul. Dąbrowskiego 69, 42-200 Częstochowa, Poland.

cant results of variance analysis. The clustering procedure begins with determining *k* random clusters, then the cases are transferred from one of these clusters to another to minimize the changeability inside the clusters and to maximize the changeability of particular clusters. The results of *k*-means clustering method give the opportunity to identify all the elements of each cluster and also the Euclidean distance of each element from the centre of an appropriate cluster [4].

2. CHARACTERIZATION OF THE DATA USED AND METHODOLOGY

The investigation was made for the concentrations of SO_2 particulate matter consisting of the particles of the diameters smaller than 10 μm (PM10). Mean one-hour concentrations of the pollutants being registered in years 2001–2003 at 10 automatic air monitoring stations, belonging to the Regional Air Pollution Monitoring System for Upper Silesia Agglomeration, were analysed. These monitoring stations were located in Bytom, Chorzów, Dąbrowa Górnicza, Gliwice, Katowice, Kuźnia Nieborowska, Piekary Śląskie, Sosnowiec, Wojkowice and in Zabrze.

The data were arranged in chronological order to obtain a matrix. The rows of the matrix represent the changes in daily pollutant concentrations in the years 2001–2003 at the particular monitoring stations, while the columns of the matrix are the consecutive one-hour measuring periods of a day. Due to such an arrangement of data each row representing a daily pattern can be treated as the single case in 24-dimensional space of variables.

3 and 4 clusters of SO_2 and PM10 concentrations, respectively, were obtained by using *k*-means clustering method. 24-dimensional centre of each cluster creates a single average type of the changes in daily concentrations of air pollutants. Then the elements of each cluster were identified and the periods of the occurrence of the successive types of the daily changes in pollutant concentration in 2001–2003 at particular air monitoring stations were investigated. During the analysis incomplete daily changes were neglected.

3. RESULTS AND DISCUSSION

In figure 1, the types of the changes in daily SO_2 and PM10 concentrations in the region of Upper Silesia agglomeration are shown. In figure 2, all the cases assigned to each cluster that occurred at particular monitoring stations were arranged in chronological order in annual periods. The table shows the number of cases assigned to individual clusters.

The most numerous group of the cases of SO_2 concentrations was assigned to the cluster No. 3 (57.7%) which represented the type of the daily changes in SO_2 concentrations that occurred most frequently. This pattern shows low mean concentration of

SO_2 (about 20–30 μg/m^3) and small daily amplitude of its concentration (figure 1a). This type of the daily changes in SO_2 concentrations mainly occurs in summer, but also during spring–summer and autumn–winter periods (figure 2a). Cluster No. 2 represents the type of the daily changes in SO_2 concentration with a strongly marked daily maximum of an average value of 140 μg/m^3 occurring at 12:00. This type of changes in the region investigated occurred rarely (about 3.8%) and appeared only during winter months (figure 2a). Cluster No. 1 shows the type of the daily changes in SO_2 concentration, which occurred for ca 20.4% of all the days in measuring period, mainly in heating season (from October to March) (figure 2a).

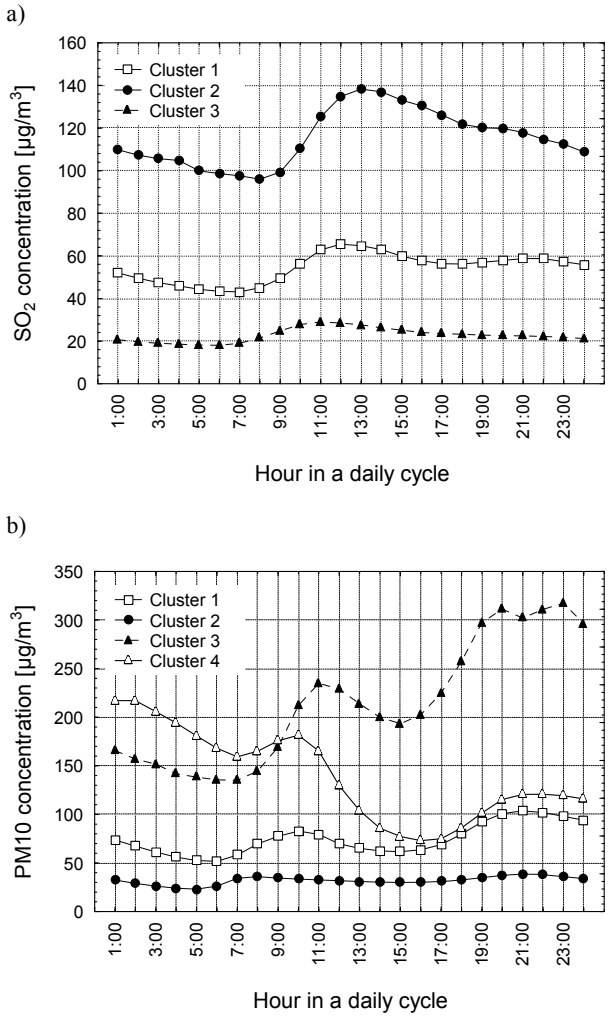
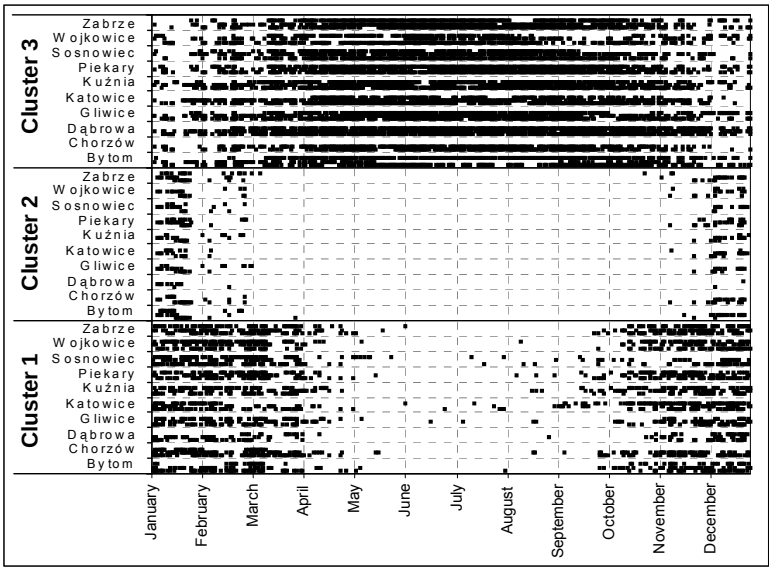


Fig. 1. Clusters representing different types of daily changes in SO_2 and PM10 concentrations

in the region of Upper Silesia agglomeration in 2001–2003:
a) 3 clusters of SO_2 concentration, b) 4 clusters of PM10 concentration

a)



b)

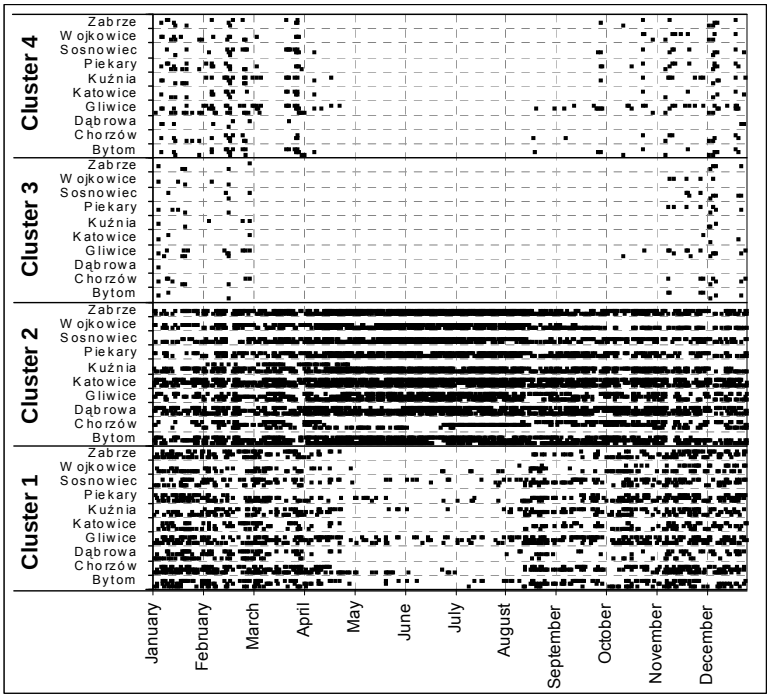


Fig. 2. The arrangement of the cases in particular clusters, depending on the season:
a) clusters of SO_2 concentration, b) clusters of PM10 concentration

Table

The number of cases assigned to each cluster of daily changes in SO_2 and PM10 concentrations

Air pollutant	The cluster number	The number of cases in a cluster	The number of cases in a cluster [%]
SO_2	1	2234	20.4
	2	413	3.8
	3	6315	57.7
	rejected	–	18.1
PM10	1	2189	20.0
	2	6145	56.1
	3	116	1.1
	4	361	3.3
	rejected	–	19.5

In the case of PM10 concentrations, the most numerous group of cases was assigned to the cluster No. 2 (56%). This pattern shows the lowest mean value of concentration (about 20–40 $\mu g/m^3$) and the smallest daily changeability. Such a type of daily changes occurs throughout the year, mainly in summer, at all monitoring stations in the region of Upper Silesia agglomeration.

20% of the given data were assigned to the cluster No. 1, whose daily changes in mean PM10 concentration and changeability were greater compared to the cluster No. 2. In this case, the daily maximum occurred at evening hours. Completely different type of the daily changes in PM10 concentration was assigned to the clusters No. 3 (1.1%) and No. 4 (3.3%). They occurred seldom and almost exclusively during winter period (figure 2b). The cluster No. 3 shows the type of the daily changes in PM10 concentration with the maximum concentration of 300 $\mu g/m^3$ between 19:00–24:00, and in the cluster No. 4 the daily maximum concentrations (about. 220 $\mu g/m^3$) occurred at 1:00–2:00 (figure 1b).

4. CONCLUSIONS

The clusters obtained represent different types of the daily changes in air pollutant concentrations occurring in the region of Upper Silesia agglomeration. They are characterized by an individual daily changeability of concentration levels in consecutive seasons of a year. Therefore the method presented is suitable for investigating the occurrence of individual types of the daily changes in pollutant concentration throughout a year.

Because of a small number of the clusters determined, only basic types of daily changes averaged for the whole agglomeration were obtained. A greater number of clusters offers the opportunity to investigate many different types of the daily changes in air pollutant concentration occurring in different periods of a year. The definition of different types of the standard changes in daily air pollution concentrations is interesting due to the possibility of using them for modelling air pollution concentration levels in different periods of a year.

ACKNOWLEDGEMENT

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SEZONOWE TYPY DOBOWYCH ZMIAN STĘŻEŃ WYBRANYCH ZANIECZYSZCZEŃ POWIETRZA W REJONIE AGLOMERACJI GÓRNOŚLĄSKIEJ

Wyznaczono różne typy dobowych zmian stężeń wybranych zanieczyszczeń powietrza w rejonie aglomeracji górnośląskiej. Korzystając z algorytmu grupowania metodą *k*-średnich, utworzono możliwie odmienne skupienia, które przedstawiają uśrednione dobowe zmiany stężeń. Następnie prześledzono okresy występowania poszczególnych typów dobowych zmian stężeń w latach 2001–2003. Badania przeprowadzono na przykładzie stężeń SO_2 i PM10. Zaobserwowano, że otrzymane krzywe dobowych zmian stężeń różnią się zarówno kształtem, jak i przeciętnymi poziomami stężeń w kolejnych sezonach roku.