A FA NEURAL NETWORK –BASED APPROACH FOR HUMAN EXPOSURE ANALYSIS IN URBAN AREAS

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Abstract

Environmental pollution of urban areas is one of key factors process. To find a compromise among many criteria, factor analysis extended by neural network models has to be carried out. Factor analysis based neural-network approach was applied to characterize chemical composition of human teeth investigated by PIXE, RBS and XRF techniques. The approach developed in this study enabled the separation between essential mineral teeth components and the pollutants deposited in teeth tissues during the human life. The three independent sources of metals incorporated in human teeth were found. The first class, representing about 48% from the variance of the concentration data, was characterised by pollutant elements from power industry. The second class was loaded with toxic elements of general urban pollution. The third class represented the tooth source as it contained mainly large fractions of the mineral components of the tooth tissue as Ca and K.

Keywords: teeth, analytics, metals, health risks, neural network, factor analysis

Introduction

The incorporation of essential and trace elements in the tooth tissues as well as the easy availability of teeth justify their use as bioindicators of environmental pollution. Due to the hardness of the calcified tissues of the tooth, the trace heavy metal levels of human tooth quantify reliably the cumulative long-term exposure of the living habitat. In this work the investigated group was a segment of urban population residing the all life in the medium industrialized town of Oradea, an area with an important number of different industries and also exhibiting a densely traffic. Human tooth samples were also collected in urban (Oradea downtown) and presumably unpolluted (blank samples) site.

In a previous study accomplished at the EG-5 electrostatic accelerator in FLNP, JINR (Oprea et al., 2007), obtained good results by the PIXE method using H^{+} and $^{4}He^{2+}$ ions, supplied by a standard combination of IBA techniques, as performed on human teeth. In a more recent study (Oprea et al., 2009), characterized the environmental conditions by the distribution of trace elements in human teeth as measured by the x-ray fluorescence method.

In the present work, a synthesis of R-mode factor analysis by neural network modeling results as applied to the concentration data of human teeth as determined by PIXE, RBS and XRF techniques has been reported.

Experimental

Teeth collection and preparation

The teeth used in the present study, donated by the patients of the two private stomatological clinics in Oradea, were prepared prior to be supposed to analytical analyses in a similar manner with the work (Oprea et al., 2007).

A total of 147 teeth were collected from several donors of different age, gender and profession. As control samples were used decayed teeth from five of the donors leaving in a remote area of the same geographical region. The sampled teeth were not treated stomatologically in the past and did not have any composite fillings.

Analytical techniques

The element concentrations obtained by different analytical techniques (i. e. PIXE, RBS and XRF) were used in the present study. The methods used for measuring the teeth content were useful since: they are well suited in terms of the identification and location of inorganic elements in human teeth; RBS is used for the measurement of light elements; PIXE is more sensitive to medium and heavy element and XRF gives better detection limits in determination of more heavy and rare earth elements.

The usual exposure time was 2700 s and statistical error <5% for the main peaks in the spectra were obtained. The hydroxyapatite etalons were measured in the same experimental conditions as the samples in order to assure the quality control of the analytical results.

Neural network applied to factor analysis

The factor analysis was based on correlations between 23 element concentrations (as As, Ba, Ca, Ce, Co, Cr, Cu, Fe, I, In(Cd), K, La, Mn, Mo, Nb, Nd, Ni, Rb, Sn, Sr, Ti, V and Zn) in human tooth used to analyze latent correlation patterns in data, and then syntethesize and simplify the variables into a smaller factor matrix The element concentrations were transformed by means of statistical methods such as basic statistics, varimax method, Kaiser normalization and R-mode factor analysis. In this study, neural network technique was applied to factor analysis in order to transform the factor analysis problem into a multi-dimensional energy function, and then to search for the minimum energy function such that the maximum factor loadings can be determined using neural network simulation. Then the value of the energy function can be reduced until it reaches a stable state. In the supposed neural network approach, the neurons represent factors of the analyzed matrix (Figure 1).

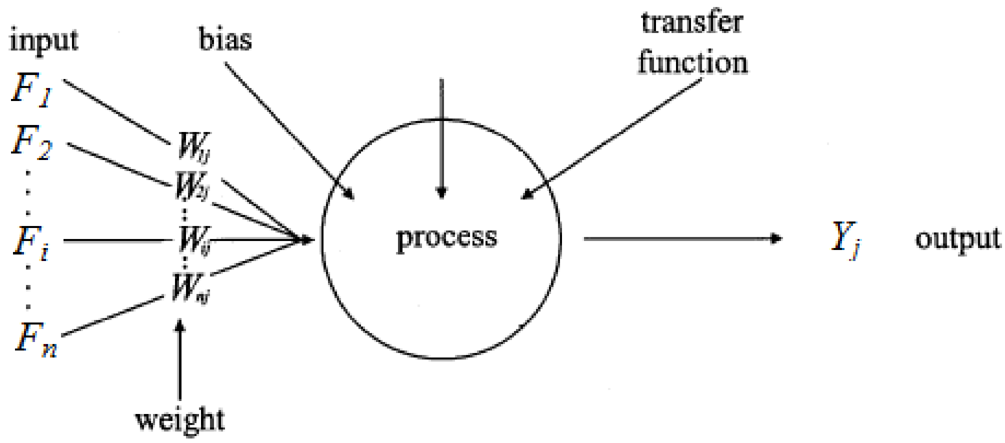

Figure 1. The neuronal simulation

Results and discussion

The content of metals and rare earth was significantly higher in the teeth of urban population compared with that of the control population. The highest levels were measured for trace metals such as Zn, Fe, Cu and Cr. The median values showed the same tendency of asymmetric changes in the favor of high values in the data sets. These metals were also highly correlated pointed for the common sources of their origin in the dental tissue.

Three independent classes were generated after neural network analysis of factors (Figure 2). A separation of 80.6% was achieved. The first class is mostly loaded with Fe, Cr, Cu and Ni, and accounted for 48% of the total variance in the data set. Overloading the role of Zn, Fe and Cu as dietary supplements, large loadings in the class may indicate the population exposure at the local industry by the specific air emissions from power plants stations of CET 1 and CET 2 in the last 3 - 4 decades, as shown in the work (Oprea et al., 2005) and certified by the earlier published documents (Pacyna, 1984 and Ministry of Waters and Environmental Protection, Romania, 2001). The second class present large fractions of Zn, As, Fe, V and Mn and accounted for 22% from the total variance of the data set. It includes matters as urban related emissions, traffic, etc. The class 3 was mostly loaded with primary elements of tooth tissues as Ca and K and also with the dietary Sr. It accounted for 10.6% of the total variance. This fact may be connected with the interactions of mineral compounds of teeth with bivalent metals, resulting by replacing of them by toxic metals in the intense polluted environments (Wakamura et al., 1998).

Conclusions

Human health risks derived from metal inhalation and ingestion of soil were assessed. With the exception of an increase in the levels of Zn, Fe, Cu and Cr, significant differences in tooth samples from the industrial and the unpolluted zone were not founded. The concentrations of heavy metals measured by PIXE, RBS and XRF methods were analyzed by prediction tools as neural networks and factor analysis. An artificial self-organized neural network confirmed the different origin of the inorganic components in human teeth. The current results suggest that although in general terms the power industry is not a quite relevant metal pollution source for the area, attention should to be paid firstly to Fe, Cr, Cu and Ni and less to Zn, As, Fe, V and Mn.

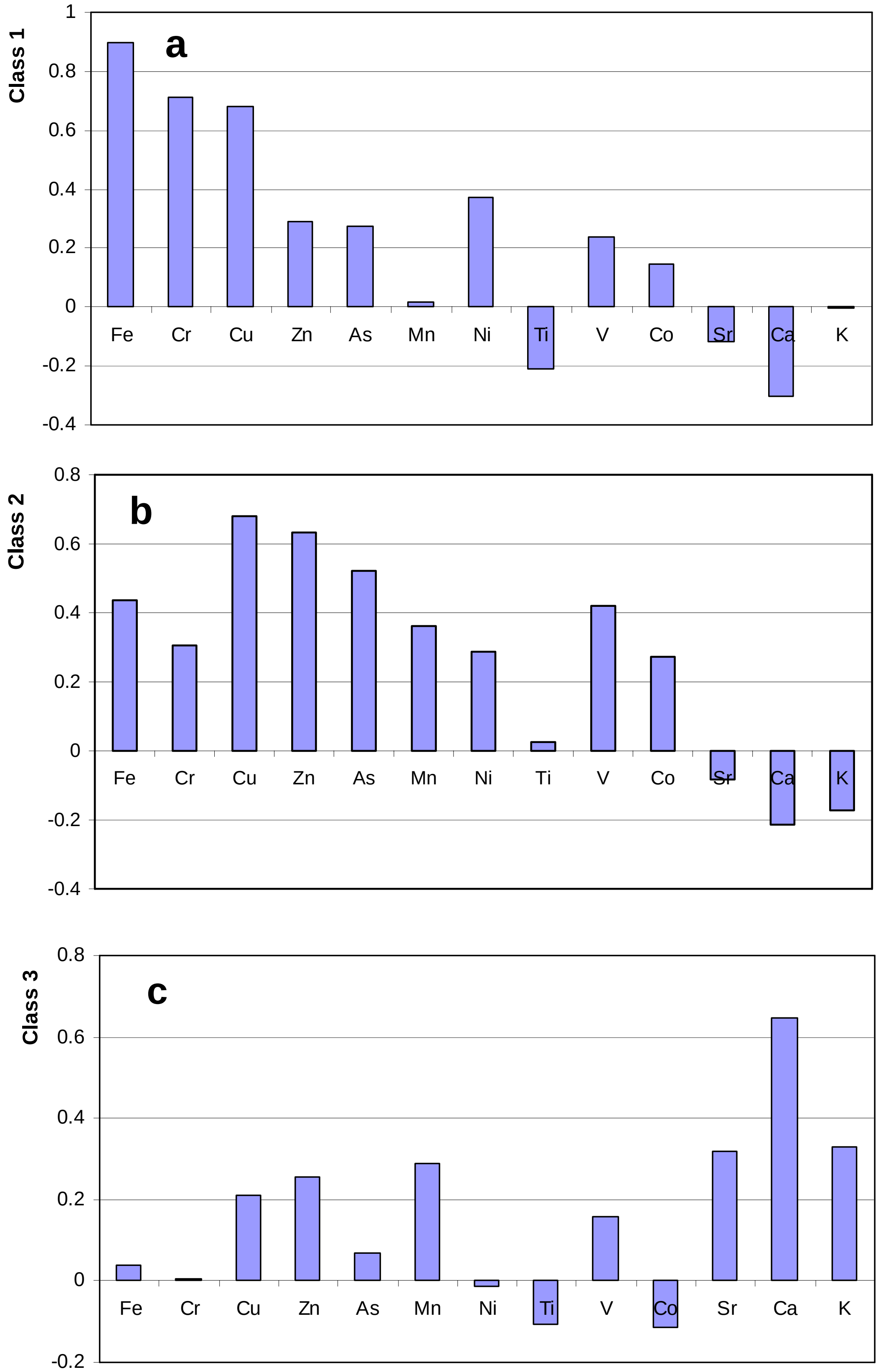

Figure 2. Neural network analysis results (best average values)

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