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MATHEMATICAL MODEL TO CALCULATE THE INTERNAL EXPOSURE DOSE FROM THE CHORNOBYL ACCIDENT OF THE UKRAINIAN POLISSYA POPULATION USING ARTIFICIAL NEURAL NETWORKS

During recent years, especially after the Fukushima Daiichi Nuclear Power Plant accident, environmental pollution with radionuclides is alarming the global community. Humans living on radioactively contaminated land inevitably are at risk due to internal irradiation (inside the body) because of radionuclides ingested with food, which can potentially lead to health deterioration of local residents [1; 2]. Therefore, correct estimation of internal exposure doses of a population many years after a large radiation accident is one of the urgent problems of radiation safety and radiation medicine.

It is well known that almost three quarters of the total dose load of the population, caused by the ChNPP accident, consists of ^{137}Cs [3]. ^{137}Cs is rapidly incorporated into biosystems and a highly environmentally persistent radionuclide due to its biological presence in soil, water, and food, which is of particular concern to human health. Thus, ^{137}Cs consumption leads to relatively uniformly absorbed equivalent dose in almost all human body organs and tissues [4]. In some settlements in the Ukrainian Polissya territory, the annual dose of the inhabitants still exceeds 1 mSv/year [5].

Existing internal exposure dose models are not able to respond to population diet changes flexibly and adequately. Due to socio-economic instability and environmental changes, dose exposure varies. Therefore, there is a need to create mathematical support and software for an adequate model of the internal exposure dose many years after the Chornobyl accident. It is expedient to evaluate the exposure dose according to the results of WBC-measurements, which are accurate and reliable because they detect ^{137}Cs actually incorporated by a body from a real diet. The objective of this work was to develop a mathematical model and to create appropriate software to obtain a proper assessment of the internal exposure dose of the Ukrainian Polissya population many years after the Chornobyl accident.

WBC-measurements, carried out by the scientists of the Institute of Agroecology and Environmental Management of NAAS during 2005-2013. The ^{137}Cs activity in human bodies was assessed with the whole-body gamma spectrometer «Scrinnner-

3M» (WBC). The ^{137}Cs intake mode was accepted as chronic for a 365-day intake period with measurement conducted the day after last intake.

Model evaluation was performed on the basis of WBC-measurements of residents of the Vyshgorod district and the Naroditsky district, Kyiv and Zhytomyr regions, respectively.

Comparison of existing methods of modeling the internal exposure dose of the population was conducted using machine learning and data analysis software WEKA [6]. Multilayer recurrent neural network (multilayer perceptron, MLP) was selected for prediction of the internal exposure dose. The software for a mathematical model of internal exposure dose received by the population due to the Chornobyl accident was developed using the Python programming language and the PyQt shell for graphical user interface.

The generated system (Multi-Layer Recurrent Neural Networks) was trained on a sample of 2687 data rows with cross-validation and tested on the 299 data rows sample. When artificial neural network (ANN) parameters were adjusted, allowing the selection of the optimal number of training epochs, the number of data in each package, and the ANN architecture. The hidden ANN layer contains 12 neurons. The next hidden layer has a dropout rate of 0.5, in order to form the unique subsets of the dataset. Since the result is only the internal exposure dose value, the output layer has 1 neuron. The training was held for 16 epochs, and the data were packet-transmitted with 8 data rows. These parameters were also chosen while adjusting the model structure.

The appropriate software was developed both to create mathematical model of the internal exposure dose obtained for a population due to the Chornobyl accident, using current data, and to predict the dose value using the data to be collected in the future. It enables the user either to train the ANN and save the received weights, or predict the internal exposure dose value using an existing file with ANN weights, as well as display the corresponding plots. A simple interface allows the user to display the necessary ANN parameters and to select the further program progress, i.e., training or prediction. The capability of synapse weights preservation for future applying without a training phase, as well as the capability of learning on new datasets is provided. After that, the user can view the constructed error plots obtained after each epoch and compare visually the predicted values with the actual ones.

Testing of the developed software was conducted on two files containing 100 and 200 (Fig.) datasets rows, which were not used in the ANN training. The data are pre-sorted by age in descending order. There is a. In case of values in the set that is significantly different from the others, the so-called outlier, the ANN smooths out this value.

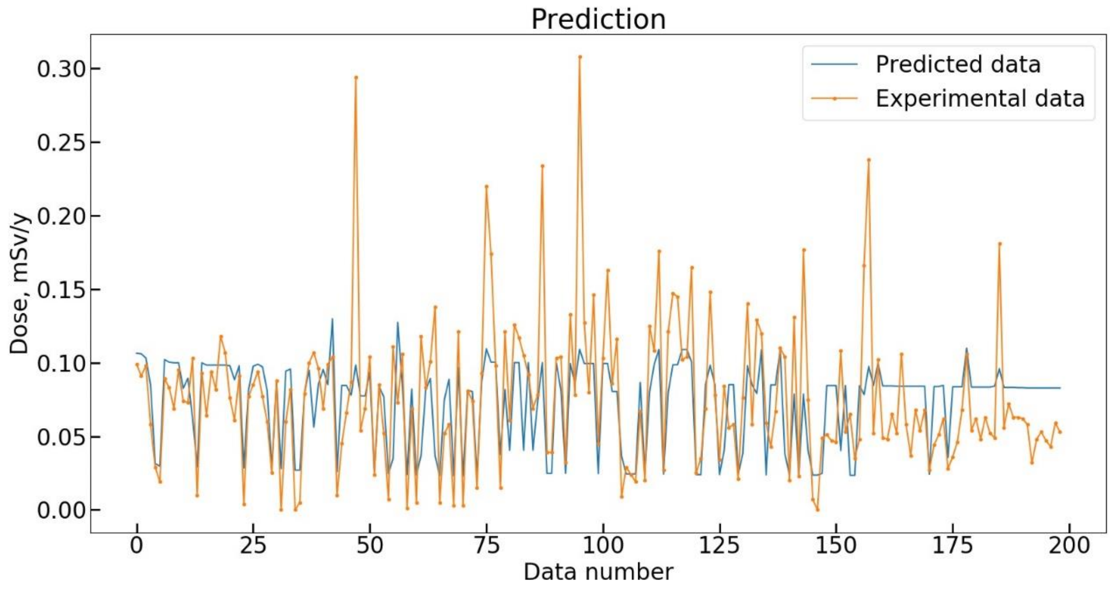

Fig. Comparison of the predicted and real internal exposure dose values for a data set of 200

Source: developed by authors

The ANN has trained better to predict the internal exposure dose for the elderly people (Fig.). This is because the food and behavioral habits of older people are more stable than the younger ones. However, the median absolute error (0.0197633) was lower than the mean absolute error (0.0345). This means that the overwhelming majority of predicted data has an error which is less than its average value. When testing on a dataset of 299, the following indicator efficiency was calculated: the mean squared error (MSE = 0.0036), the mean absolute error (MAE = 0.0346), the median absolute error (0.0197514). The prediction accuracy on the test datasets was 89%.The developed software is unique for the subject domain in question. The high prediction accuracy of the system allowed adaptation to solve problems of this kind precisely. The software allows the user to adjust the ANN parameters and also provides a graphical representation of the error values at each stage. The capability of synapse weights preservation for future applying without a training phase, as well as the capability of learning on new datasets is provided.

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