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## Overall assessment of drinking water security that reaching the consumers.

**Tunakova YA*, Novikova SV and Gabdrakhmanova GN.**

Kazan National Research Technical University named after A.N.Tupolev - KAI (KNRTU-KAI) Kazan, Russia

**ABSTRACT**

The approach for integral assessment of potable waters with use of methods of the cluster analysis based on assessment of probability of intake of cations of impurity with potable water and probabilities of carcinogenic and not carcinogenic changes in the state of health of the children's population is offered. For further analysis, neural network technique of Kohonen self-organizing maps has been chosen as the most suitable method for clustering. Data tuples have been formed for 11 service areas of children's clinics on the above characteristics. Areas were grouped into 3 clusters for further development of implemented programs to improve the safety of drinking water to consumers. The features of the variability of the factors for each cluster (for the factors considered in an integrated assessment that characterizes the safety of drinking water on the areas of research) are considered

**Keywords:** the drinking water, cancerogenic and non-cancerogenic risks, cluster analysis, integrated assessment

***Corresponding author***

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**INRODUCTION**

According to the State Report "About the state of sanitary and epidemiological welfare of the population in the Russian Federation" in recent years, about 40% of the urban population provided by drinking water poor quality. This is due to many reasons, including poor technical condition of used water networks that enrich the drinking water of metal cations. According to modern approaches, drinking water safety is assessed using cancerogenic and non-cancerogenic risks for health of sensitive population groups due to the consumption of drinking water a particular component composition [1-3]. Thus, we need to take into account a set of influencing factors. This raises the task of developing an integrated methodology assessing the quality of drinking water that reaches the consumers. This assessment is the basis for the development of adequate methods for its post-treatment, to ensure chemical safety.

The following indicators are currently used for the integrated assessment of contamination of drinking water:

1. The indicator of chemical pollution of water (ICP-10) [4]. It is calculated for the ten compounds that exceeded the maximum concentrations of pollutants C above their maximum permissible concentrations (MPC) by formula: ICP-10 = ( $C_1$/ $MPC_1$ + $C_2$/ $MPC_2$ + ... + $C_{10}$/ $MPC_{10}$). However, this indicator unnecessarily summarizes exceedances value, without assessing the degree of adverse changes that occur in the body when you receive ach of the considered pollutants.
2. Combinatorial pollution index [5]. It is a modification of the previous indicator. For the calculation of this index for each ingredient based on the actual concentration is calculated the multiplicity excess ratings of MPC –$K_i$, repeatability of exceedances $H_i$, and estimated total rating – $B_i$:

$$K_i = \frac{C_i}{MPC_i}$$

$$K_i = \frac{C_i}{MPC_i}$$

$$B_i = K_i \cdot H_i,$$

Ingredients for which the total estimated value of the rating score bigger or equal to one, stand out as limiting pollution indexes. But it is not evaluated any individual or aggregate level of negative changes in the human body.

3. Ecotoxicological criteria [6]. Degree of pollution is estimated as the sum of exceedances of pollutants concentrations to their maximum permissible concentrations. However, the level of sulfate ions, suspended solids and total mineralization relates not to the MPC, and to the maximum background values. Then, the excess are summarized. But this approach does not eliminate the shortcomings of the previous two approaches.
4. LHI- criterion (limiting hazard indicator) [7]. This criterion is proposed to assess the cumulative effects of metal cations in the water, except for copper cations. The calculation is carried out according to the formula:

$$\text{LHI} = \sum_i \frac{C_i}{MPC_i}$$

5. Integral indicator of the drinking water quality [8]. The formula for integral indicator calculation:

$$II = \frac{R_{r-o}}{PR_{r-o}} + \frac{R_{n-c}}{PR_{n-c}} + \frac{R_c}{PR_c}$$

in these parts:

- II - integrated indicator of drinking water hazard;
- $R_{r-o}$- overall risk of reflex-olfactory effects;

- $PR_{r\text{-}o}$- permissible risk of reflex-olfactory effects;
- $R_{n\text{-}c}$- total non-carcinogenic risk;
- $PR_{n\text{-}c}$- permissible non-carcinogenic risk;
- $R_c$- total carcinogenic risk;
- $PR_c$- permissible carcinogenic risk.

The formula that governs calculation of this indicator is given in Methodical recommendations MR 2.1.4.0032-11. It has no physical basis, and it is mathematically incorrect, due to a lack of direct linear relationship between indicators and their various contributions to the quality of drinking water and the impact on the human organism. This problem could be solved, at least partially, through the use of additional scaling factors, taking into account the varying degrees of influence factors. However, recommendations for the definition of these factors do not exist.

## MATERIALS AND METHODS

In addition to the assessment of the negative impact on the human organism, in the aggregate cationic composition of drinking water, we need to take into account the intake probability of impurity cations in drinking water, as well as assess differentiated by territory. Idea of constructing an analytical calculation model was rejected, because we need to simultaneously consider different size and heterogeneous data into a single integrated assessment. The data have different degrees of effect in each area of research. We have developed an approach, which consists in taking into account all the factors which characterize the safety of drinking water to consumers. This approach is based on a cluster analysis of heterogeneous data.

The proposed integrated estimation is based on the following data: the intake probability of cations and anions with drinking water, the probability adverse carcinogenic and non-carcinogenic changes in the health status of children in each area of research in the city of Kazan. Allocation of research areas is based on service address children's polyclinics. Variability cationic composition of drinking water, which are prepared at the water intake "Volzhsky", is described in detail in [9]. Assessment and ways to improve the physiological usefulness of drinking water are described in [10, 11].

Assessment of the carcinogenic and non-cancer risk to the health of children in each research area in the city of Kazan is given in [12, 13].

The algorithm for calculating and assessing the probability of exceeding the actual concentration over background values for the given list of cations and anions in drinking water samples, as well as a generalized risk calculation algorithm (R), which characterizes the probability of exceeding the metal cation concentrations above background values are described in detail in [14]. Background concentrations are defined as the lower quartile of ranked a number of concentrations values according to areas for research.

As a basis for area zoning children's polyclinics service addresses in the city of Kazan has been selected. This choice is justified, taking into account the effect of the composition of drinking water on children as the most sensitive groups of the population of a megacity. Data tuples have been formed for 11 service areas of children's clinics on the above characteristics. To characterize the quality of drinking water, reaching the child population, data clustering method was chosen.

For further analysis, neural network technique of Kohonen self-organizing maps has been chosen as the most suitable method for clustering. The technique is an adaptive neural network implementation of the algorithm K-means. Areas were grouped into 3 clusters for further development of implemented programs to improve the safety of drinking water to consumers.

## RESULTS AND DISCISSION

As a result of cluster analysis we obtained the distribution areas of research on clusters (Fig.1.)

| Cluster | Area |
|---|---|
| Cluster №1 | 8 |
| Cluster №1 | 10 |
| Cluster №2 | 2 |
| Cluster №2 | 11 |
| Cluster №3 | 1 |
| Cluster №3 | 3 |
| Cluster №3 | 4 |
| Cluster №3 | 5 |
| Cluster №3 | 6 |
| Cluster №3 | 7 |
| Cluster №3 | 9 |

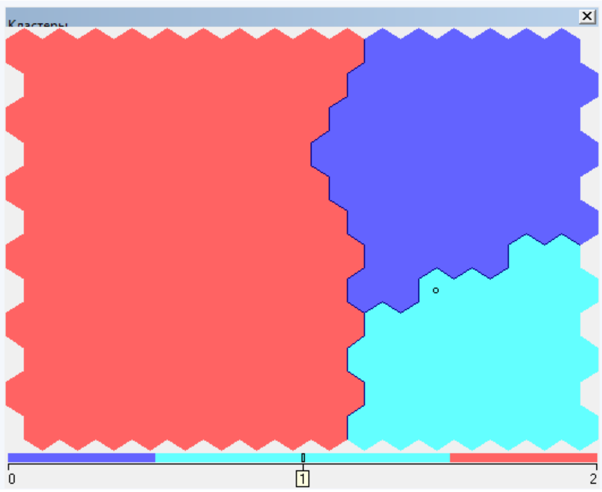


**Fig. 1. Graphical representation formed clusters on the Kohonen map**

Consider the features of the variability of the factors for each cluster (for the factors considered in an integrated assessment that characterizes the safety of drinking water on the areas of research). For this purpose the color visualization of clusters performed for all parameters (Fig. 2-9).

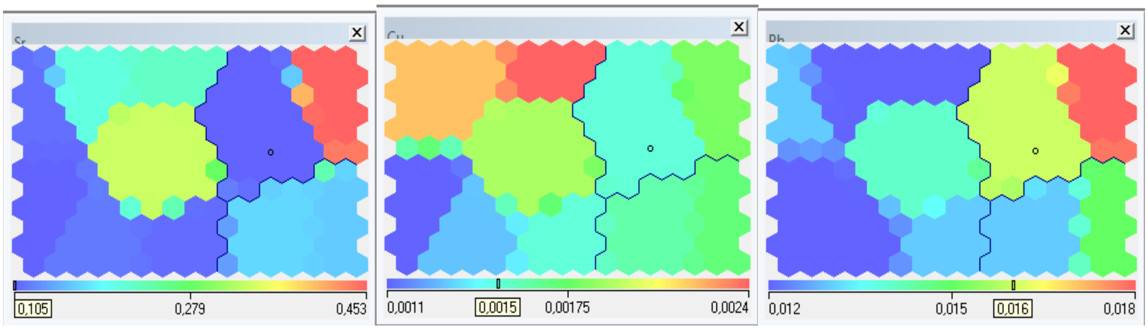


**Fig 2: Visualization cations level of strontium, copper and lead**

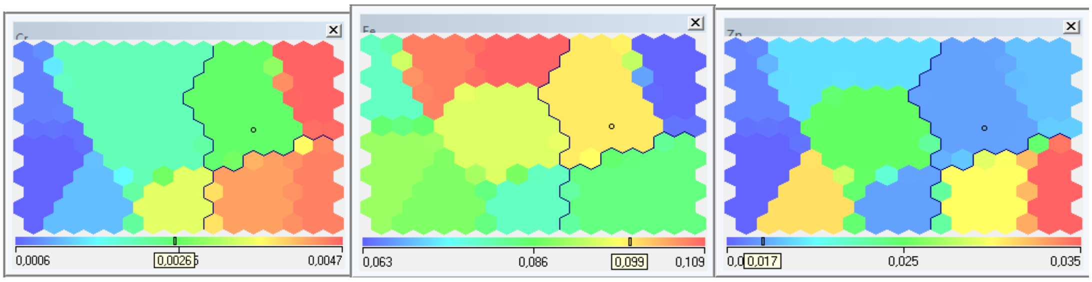


**Fig 3: Visualization cations level of chromium, iron, and zinc**

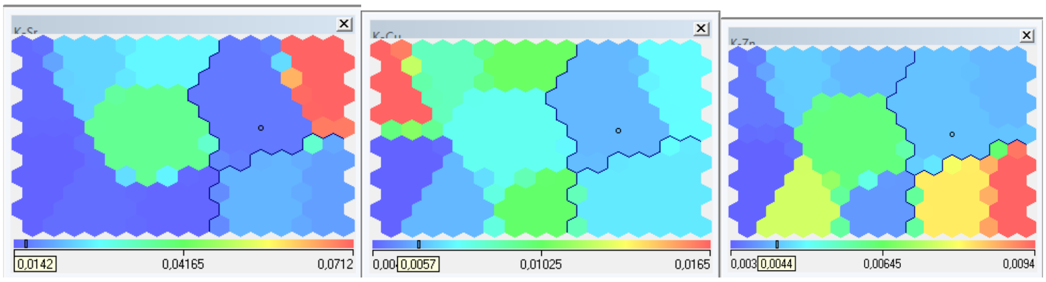


**Fig 4: Visualization of the non-carcinogenic risk level for cations of strontium, copper and zinc**

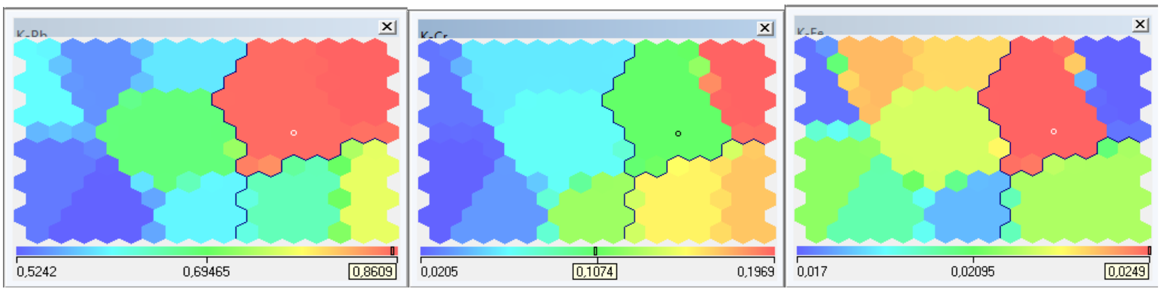


**Fig 5: Visualization of the non- carcinogenic risk level for cations of lead, chromium and iron**

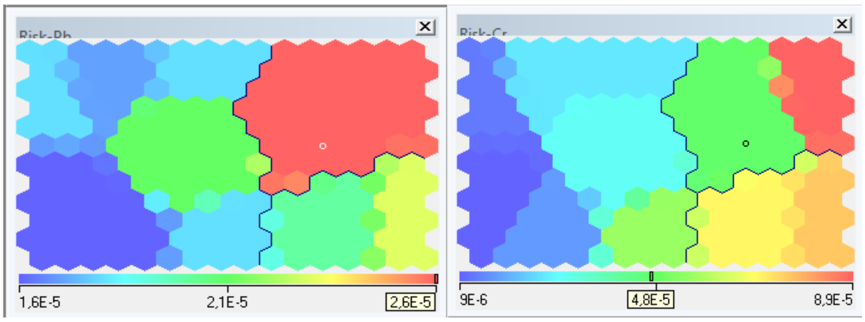


**Figure 6: Visualization of the carcinogenic risk level of lead and chromium cations.**

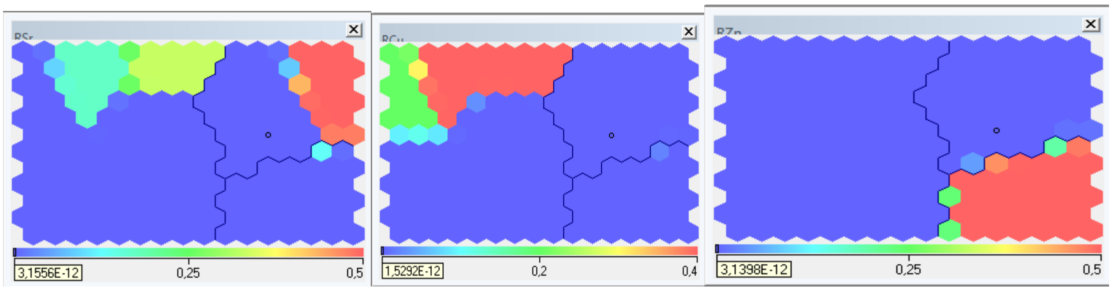


**Fig 7: Visualization of the probability of exceeding the threshold for admission cations of strontium, copper, zinc (as Bayesian probability)**

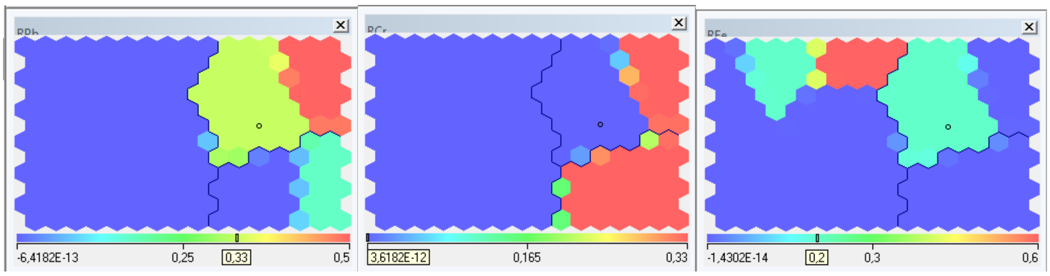


**Fig 8: Visualization of the probability of exceeding the threshold for admission cations of lead, chromium and iron (as Bayesian probability)**

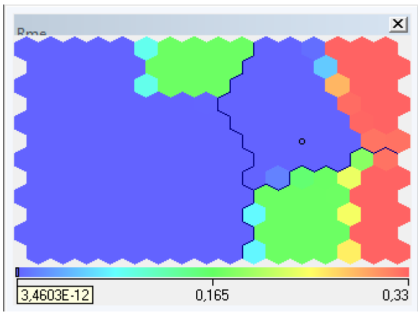


**Fig 9: Visualization probability of polymetallic exceeding the threshold level for metal cations admission in general**

Thus, cluster №1 includes areas that have average or above average concentrations of pollutants, as well as the levels of carcinogenic and non-cancer risk of impurities admission with drinking water. The largest of the observed concentration values obtained for cations of lead, chromium and strontium. Bayesian probability distribution is consistent with the previous results of clustering and complements them: the greatest probability is a typical for cation of lead, strontium and chromium. For other metal cations probability of admission is less.

Areas assigned to the cluster №2, have particularly high concentrations in drinking water cations of chromium and zinc that also introduce non-carcinogenic risk more than average. According to the calculated Bayesian probability, high intake with drinking water should be expected only by cations of chromium and zinc, and the probability of such excess does not exceed 0.5. For all other metal cations probability values are minimal.

Areas assigned to Cluster №2, can be attributed to areas of medium danger of drinking water for the city's population of children. Particular attention should be paid to the purification of drinking water by chromium cations.

In the Cluster №3 entered the zones, which are characterized by low content in the drinking water of metal cations, lower-middle-carcinogenic and non-carcinogenic risk for child health and low probability of increased admission of pollutants from drinking water. The research article is supported by the Autonomous nonprofit organization "Kazan open University talents 2.0".

## CONCLUSION

Integral assessment of chemical safety of drinking water allows you to select the most efficient filters for purification of drinking water to the level of acceptable risk of the filters presented in the consumer market. Assessment of the probability of metal cations intake with drinking water will develop more adequate recommendations in the circumstances for the protection of the child population in the case of the use of poor-quality drinking water.

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