Method for identifying the interaction of elements in the organism

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Abstract. The statistical method of assessing the influence of elements when identifying the elemental status of the organism is considered. This influence manifests itself in the form of elements - antagonists and elements - protagonists in relation to their concentration in the organism. The influence of the concentration of individual elements was considered, as well as the combined effect at which their combinations were tested while simultaneously exceeding, decreasing or multidirectionally changing the concentration. In the second case, only patients were considered with simultaneous satisfaction of one of the listed conditions. Evaluation of more than 800 patients of the Orenburg region showed the presence of such events with varying degrees of reliability. The final decision on the presence of the identified relationship was made using parametric and non-parametric criteria. The advantage of the developed technique is the possibility of a rather simple algorithmization.

1. Introduction
Bioinorganic chemistry originated in the 2nd half of the twentieth century at the junction of biology, chemistry, medicine, biochemistry, molecular biology, etc. Its formation as a science was prepared by numerous experimental data in the field of classical chemistry, medicine, toxicology and the science of nutrition. Bioinorganic chemistry is a kind of “bridge” between inorganic chemistry and biochemistry [1, 2].

For the human body, the role of about 30 chemical elements is definitely established, without which it cannot normally exist. These elements are called vital. In addition to them, there are elements that, in small quantities, do not affect the functioning of the organism, but with an increase in their concentration are poisons. A characteristic feature of the required element is the bell-shaped dose curve (n) - the response (R, effect).

It follows that the concentration of an element in the body plays a very significant and sometimes catastrophic role, and also that the identification of the biological role of individual chemical elements in the functioning of living organisms (human, animal, plant) is an important task [3].

Along with the importance of the absolute content of each of the elements in the body, the ratio between them is very important. The magnitude of these relationships, in addition to many other reasons, is also influenced by the relationship between the elements, which shows how much they attract each other, displace or neutralize each other. This is especially important when correcting the elemental status of the body. If one element displaces some other, then you must first correct the concentration of this other and only then adjust the first one. On the other hand, if the elements attract each other, it is necessary first of all to increase the concentration of the attracting element.
Finally, due to the large number of elements taken into account, it is most convenient to use a multidimensional coordinate system for the study [4, 5].

2. Theory
The interaction of various chemical elements in the human body has long been occupied by the minds of scientists. It has been established that in addition to organic compounds, 22 inorganic elements (Ca, P, O, Na, Mg, S, B, Cl, K, V, Mn, Fe, Co, Ni, Cu, Zn, Mo, Cr, Si, I, F, Se), which have a significant impact on physiological processes [3]. Moreover, it is known that many elements have a group effect on the body (for example, elements such as Na and K have an effect exclusively in pairs), which provides a basis for the assumption of the mutual influence of elements on each other. In particular, there are a number of theoretical assumptions about the mutual “ousting” and “attracting” of some elements by others (elements are antagonists, elements are protagonists), which predetermines the prospect of further research in this direction [6].

It is necessary to note the non-obviousness of such inter-element influences and the insufficiency of standardized statistical methods for their detection. So, to establish the relationship between some elements, the Pearson correlation coefficient was repeatedly used, which, in most cases, shows a rather weak correlation relationship. The reasons for the low efficiency of this coefficient can be either a non-linear relationship between elements, or an unnormalized distribution of the concentration of elements in the body.

What has been said above predetermines the development of qualitatively new methods that are based on a multidimensional dimension and are independent of the type of distribution law of elements.

3. Model
The model is built from the assumption that an increased concentration of a given element has a more pronounced effect in terms of crowding out the incompatible and attracting kinship and vice versa - reducing the concentration contributes to increasing the concentration of incompatible and reducing kinship elements. However, it is impossible to simply select only those subjects whose concentration of a given test element is above the norm and find out which direction the dependent element is shifting, and then take the remaining subjects whose concentration of the test element is lower. The result will be symmetrical.

As a consequence, another technique is proposed - Figure 1.

![Figure 1. The scheme of choosing a statistical array.](image)

In Figure \(X_{1N}\) indicates the concentration rate for the selected element \(X_1\), defined as an arithmetic average, and a cloud of points over all surveyed is represented by an ellipse. Then, all the subjects are selected in excess of this norm, their average value is found for them, and then only the subjects who have already exceeded this average take part in the study. In the same way, the second part of the study is formed for small concentrations of a given element, that is, studies are carried out only for the subjects who fall into the shaded areas.

In this way, you can explore the effect of each element separately. If it is necessary to investigate the combined effects of the elements, it is necessary to select only those surveyed who simultaneously have an excess of the norm in two, three, and so on elements at once. Then follow what are the trends in
changing all the remaining elements. However, it must be remembered that starting with a certain number of simultaneously considered elements, statistical instability will occur due to the fact that the probability of a simultaneous excess of an increasing number of elements decreases each time.

4. Data and methods
The calculations are based on an extensive database formed as a result of a comprehensive clinical and physiological examination and determination of the elemental composition of biosubstrates of 910 people of different sex and age. Hair and nails were used as biosubstrates. Despite the long period of exposure, such biosubstrates have been used for a long time for general measurements and, in particular, there is much experience in detecting and measuring the content of metals in the human body [7, 8].

Determination of the content of chemical elements in biosubstrates was carried out by atomic emission and mass spectrometry. Using the Elan 9000 mass spectrometer (Perkin Elmer, USA), the content of As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, Si, Sn, Ti, V was determined, and the Optima 2000 atomic emission spectrometer V (Perkin Elmer, USA) was used to determine Ca, Mg, P, Zn, K, Na. In total, data were obtained on the content of 24 chemical elements. Absolute concentrations of chemical elements were compared with reference values of the content of chemical elements in the hair [9, 10, 11] and average values of the content of these elements in the hair (25-75 centile interval) obtained during population studies in various regions of Russia [12].

|   | As | Be | Ca | Cd | Co | Cr | Cu | Fe | Hg | I | K | Li | Mg | Mn | Na | Ni | P | Pb | Se | Si | Sn | Ti | V | Zn |
|---|----|----|----|----|----|----|----|----|----|---|----|----|----|----|----|---|--|---|---|---|---|---|---|---|
| As | -  | 0  | 0  | -  | 0  | -  | 0  | 0  | 0  | -  | 0  | 0  | 0  | 0  | 0  | -  | 0  | 0  | 0  | 0  | -  | 0  | 0  |
| Be | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| Ca | +  | -  | -  | +  | -  | +  | -  | 0  | 0  | +  | 0  | 0  | -  | -  | -  | +  | 0  | +  | -  | -  | -  | +  | -  |
| Cd | -  | 0  | +  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | +  | -  | -  | 0  | -  | -  | +  | -  |
| Co | 0  | 0  | 0  | 0  | 0  | -  | -  | -  | -  | -  | 0  | -  | -  | 0  | -  | -  | 0  | -  | -  | -  | -  | -  |
| Cr | +  | -  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | -  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| Cu | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | -  | 0  | 0  | 0  | 0  | 0  | +  | -  | 0  | 0  | 0  | 0  | 0  |
| Fe | -  | 0  | +  | -  | -  | 0  | 0  | -  | 0  | -  | -  | -  | +  | -  | -  | -  | 0  | -  | -  | 0  | -  | 0  |
| Hg | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | -  | 0  | -  | 0  | -  | -  | -  | 0  | +  | -  | 0  | 0  | -  | 0  |
| I  | 0  | 0  | -  | +  | -  | -  | 0  | 0  | -  | -  | -  | 0  | -  | 0  | 0  | 0  | 0  | -  | -  | 0  | 0  |
| K  | -  | 0  | +  | 0  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 0  | -  | 0  | -  | -  | 0  | 0  |
| Li | -  | -  | +  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 0  | -  | -  | -  | -  | -  | -  |
| Mg | +  | -  | +  | -  | 0  | -  | +  | +  | +  | -  | -  | -  | -  | 0  | 0  | 0  | 0  | +  | -  | -  | -  |
| Mn | 0  | 0  | 0  | 0  | -  | -  | -  | -  | 0  | 0  | -  | -  | -  | -  | -  | -  | -  | -  | -  | +  | -  |
| Na | -  | 0  | +  | -  | -  | 0  | -  | -  | 0  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| Ni | 0  | 0  | 0  | 0  | -  | -  | 0  | 0  | 0  | 0  | 0  | 0  | -  | -  | -  | 0  | 0  | 0  | -  | -  | -  | 0  |
| P  | 0  | 0  | 0  | 0  | 0  | -  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| Pb | -  | 0  | +  | -  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| Se | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| Si | 0  | 0  | 0  | 0  | -  | 0  | 0  | -  | +  | 0  | 0  | 0  | -  | -  | -  | +  | -  | +  | 0  | -  | 0  |
| Sn | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| Ti | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| V  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | -  | 0  | 0  | 0  | 0  | 0  |
| Zn | 0  | 0  | -  | 0  | 0  | 0  | 0  | 0  | 0  | +  | 0  | 0  | 0  | 0  | 0  | 0  | +  | 0  | 0  | 0  | 0  |

5. Results and discussion
In the first simple study, the subjects were selected with successive successive elements one after another, and for the same subjects, the behavior of other elements was observed with respect to their previously calculated norm for the entire database of available data. The results are summarized in table 1.
In the second case, based on the results of a theoretical study, six essential, that is, vital elements were chosen as supporting elements, and for them the study was carried out according to the procedure described above. The results are presented in table 2.

Table 2. The results of the second study.

| As  | Be  | Ca  | Cd  | Co  | Cr  | Cu  | Fe  | Hg  | I   | K   | Li |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|
| Ca  | -41.4 | -4.5 | -39.9 | -3 | -21.9 | 12.2 | -27.3 | -11.8 | 16.9 | -60.4 | -86.6 |
| K   | 24.3 | 2.9 | -27.4 | 50.1 | 21 | 20.8 | -5.7 | 36.7 | 11.9 | -15.5 | -81.5 |
| Mg  | -39.7 | 2.6 | 65.1 | -37.3 | 0.1 | -18.7 | 11.3 | -16.5 | -15.1 | 29.1 | -58.4 |
| Na  | 21.1 | 7.2 | -7.9 | 39.3 | 28.2 | 22.5 | -3.4 | 28.7 | 21.5 | 36.3 | 69 | 90.2 |
| P   | 0.2 | -6.1 | 0 | -29.4 | 0.2 | 2.3 | 6.9 | 16.3 | -15.7 | 12.7 | 86.8 |
| Zn  | -8.4 | -9.2 | 3.2 | -24.9 | 28 | -0.2 | 6.2 | -6 | 2.4 | 31.9 | -27.3 | -85.8 |

Continuation of table 2

| Mg  | Mn  | Na  | Ni  | P   | Pb  | Se  | Si  | Sn  | Ti  | V   | Zn |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Ca  | 61.7 | 31.6 | -34.8 | 13.7 | -0.4 | -46.6 | -3.4 | 5.3 | 38.5 | 18.9 | -17.6 | 8.1 |
| K   | -23 | -13.4 | 62.8 | 4.1 | 3.6 | 50.1 | 3.8 | -2.3 | -0.8 | -4.3 | 17.1 | -5.9 |
| Mg  | -35.6 | -31 | 18.3 | -0.9 | -41.6 | -4.2 | 5.5 | 40.7 | 14.6 | -10.6 | 5.2 |
| Na  | -2.1 | 8 | -12.8 | 3.7 | 45 | 3.1 | -8 | 13.3 | -18 | 16.3 | -4.6 |
| P   | -2 | -8.7 | 15.1 | -4.5 | -0.7 | 3.9 | -6.7 | 17.6 | -5.8 | -4.9 | 6.8 |
| Zn  | 0.9 | -6.8 | -23.8 | 5.5 | 4.5 | -31.1 | 6.3 | -4.1 | -16.8 | 5.5 | -2.2 | - |

The third study was devoted to assessing the joint influence of elements. For this purpose, the subjects were selected with a simultaneous elevated concentration of calcium and magnesium, potassium and sodium, phosphorus and zinc. The results are presented in table 3.

Table 3. The results of the third study

| As  | Be  | Ca  | Cd  | Co  | Cr  | Cu  | Fe  | Hg  | I   | K   | Li |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|
| Ca, Mg | -54.7 | -5.5 | -48.6 | 20.9 | -19.9 | 21.8 | -27.3 | -17.6 | 37.9 | -57.7 | -84.4 |
| K, Na | 63.5 | 6.2 | -45.3 | 65.7 | -35.2 | 43.9 | -6.3 | 72 | 43.3 | 12.4 | -75 |
| P, Zn | -5 | -6.3 | 1.6 | -3 | -26 | 0.4 | 9.8 | 7 | 27.9 | -13.1 | -2.7 | -85.7 |

Continuation of table 3

| Mg  | Mn  | Na  | Ni  | P   | Pb  | Se  | Si  | Sn  | Ti  | V   | Zn |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Ca, Mg | -44.7 | -25.9 | -34.2 | 3.4 | -46.1 | -11.9 | 7.3 | 98.4 | 23.2 | -15.5 | 7.0 |
| K, Na | -44.7 | -25.9 | -34.2 | 3.4 | -46.1 | -11.9 | 7.3 | 98.4 | 23.2 | -15.5 | 7.0 |
| P, Zn | -1.2 | -7.2 | -4.4 | 4.5 | -19.2 | 6.9 | -5 | -0.5 | -2.1 | -5.1 | - |

As follows from table 1, the most independent - beryllium is neutral to most elements. On the contrary, three elements are most susceptible to extrusion - tin, nickel and cobalt. Finally, magnesium and selenium are among the elements with the highest displacing properties.

Analysis of the results of table 2 shows that among the studied essential elements, calcium is most susceptible to displacement, which is superseded by 14 elements. Among the displacing elements, the most significant are lithium (86.6%), potassium (60.4%), and lead (46.6%).

Zinc is susceptible enough to displacement, which is facilitated by 13 of the elements under study. Lithium (8.5%) and lead (31.1%) have the greatest impact.
Sodium has the most preemptive properties, exerting a preemptive effect on 18 elements. The most affected are lithium (90.2%), potassium (69%).

Finally, table 3 demonstrates that an increased combination of calcium and magnesium is responsible, to a greater extent, for the displacement of lithium (84.4%), potassium (57.7%) and arsenic (54.7%), as well as for attracting tin (98.4%) and manganese (77.8%).

The increased combination of potassium and sodium is responsible, to a greater extent, for the displacement of lithium (75.5%), calcium (45.3%) and magnesium (44.7%), as well as for the attraction of lead (91.1%) and cadmium (65.7%).

The increased combination of phosphorus and zinc is responsible, to a greater extent, for the displacement of lithium (85.7%), as well as for the attraction of mercury (27.9%).

6. Conclusion
Thus, the application of the developed method of identifying the mutual influence of elements in the body allowed to obtain interesting results. This proves, on the one hand, the fruitfulness and effectiveness of this technique, on the other hand, forms the vector of further research, already identified interrelations. According to the results Sodium has the most preemptive properties, exerting a preemptive effect on 18 elements. The most affected are lithium (90.2%), potassium (69%).

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