Ecological and Toxicological Analysis of Iodine Content in Mongolian Soils

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Man-made environmental pollution, low iodine content in soils and waters leads to the spread of endemic goiter in animals and humans. The main sources of iodine in the body are food and drinking water, which determines the high dependence of the health of the population that consumes local food on the level of iodine in the soils and natural waters of agricultural landscapes. The article presents the results of cartographic analysis of thematic maps of Mongolia, medical data and data on the content of iodine in soils obtained from open sources. For the Ulaanbaatar region, the authors also used their own field and analytical data on the content of iodine in drinking water obtained in 2015-2017. The hypothesis about the influence of geographical and edaphic conditions on the causes of iodine deficiency in various parts of the country was tested. The average content of iodine in the soils of Mongolia ranged from 0.5 to 3 mg/kg, while the most iodine-deficient areas were identified for the southern and partially Eastern aimags (territories) of the country. The data obtained deserve attention and consideration when organizing the prevention of iodine deficiency in Mongolia.

1. Introduction

Iodine belongs to the chemical elements that are actively involved in the metabolism of biological systems. Low iodine content in the environment leads to the spread of diseases, especially endemic goiter in animals and humans [1].

In the modern world, iodine deficiency is a global medical and social problem of modern society. According to the World Health Organization (WHO), territories with a low content of iodine in the biosphere are significantly distributed on Earth. As a result, more than 1.5 billion there is an increased risk of insufficient iodine intake among the world's inhabitants, 655 million have endemic goiter, and 43 million have mental retardation [2,3].

With a long-term insufficient intake of iodine in the body, a complex chain of compensatory processes is activated, designed to support the normal synthesis and secretion of thyroid hormones. Chronic iodine deficiency in the human body is often a hidden cause of many diseases [4].

Given that the main source of iodine is the world's oceans, the population of inland areas suffers the most from iodine deficiency. One of these regions, for geographical reasons, is Mongolia. Up to 80% of their population lives in conditions of iodine deficiency [5]. Based on the results of research,
the government of Mongolia adopted a resolution on the fight against iodine-deficient diseases (IDD), and also developed and approved a national program (1996, 2001) for the fight against IDD and their prevention, which emphasizes the relevance of this problem for Mongolia [6].

The purpose of our work was to identify the causes of geographical and edaphic nature that affect the uneven distribution of iodine deficiency in different regions of Mongolia. The work is based on cartographic analysis of thematic maps of Mongolia, medical data, and data on the content of iodine in soils and surface waters for drinking purposes obtained from open sources. We also took into account the data of the government of Mongolia on the prevention of iodine deficiency [6,7]: introduction of iodized salt in the diet of the population, informing the population about the need for iodine prevention, etc. For the Ulan-Baatar aimag, the authors’ own field and analytical data on the content of iodine in drinking water (19 sources), obtained as a result of expedition research in 2015-2016, were also used.

2. Materials and methods

The current work is based on maps of the Atlas of the Mongolian People's Republic in 1990 [8] and a modern data source (national Atlas of Mongolia 2006) [9]. It should be noted that there were no significant changes in the structure of the studied parameters (soil cover, rocks, climate, etc.) during the period from 1991 to 2006. All the maps used in the work of the MNR Atlas (1991) were scanned by us and saved with a resolution of 96 dots per inch and a size of 1601x767, in the "JPG" format. A total of 9 Atlas sheets (15 maps in total) were scanned, including: soil map, vegetation map, Quaternary sediment map, average annual precipitation map, prevailing wind map, and many others.

The maps were uploaded to MapInfo professional, version 7.8 (product number: MIPWEU0780626719). The maps were linked to four points with known coordinates. Three of them were located along the borders (Eastern (coordinates 49°50’44"N; 116°42’50"E.), Western (coordinates 49°10’2"N; 87°48’48"E), southern (coordinates 41° 40’ 25"N; 105° 00’E)) and the city center of Ulaanbaatar (coordinates 47°54’27"N; 106°52’59"E). All maps were linked in the Gauss–Kruger projection (Pulkovo, 42).

As a result, a local geographic information environment "GIS Mongolia-Yod" was created, on the basis of which further analysis of the iodine status of the study area was carried out. Vectorization of raster images was carried out manually. The assessment of the studied parameters of soil, water, precipitation, and climate was carried out within the administrative districts (21 aimags). The choice of an administrative district as the minimum territorial division was determined by the availability of medical data [5.10] on morbidity, excretion, etc., as well as on the coverage of iodine prevention of the population (consumption of iodized salt) by districts.

Most layers of the geographic information environment were created in the form of area contours (polygons), which facilitated further cartographic calculations and corresponded to the goals set. The first layer "GIS Mongolia-Yod", "Administrative borders", and the layer "Hydrographic network of Mongolia" were created in a linear way. The "GIS Mongolia-Yod" layer "Administrative borders" later served as the base layer for checking the accuracy of binding the borders of all other raster images, as well as for performing cartographic calculations.

The GIS calculation was applied to the soil map of Mongolia to assess the iodine availability of genetic soil types within one district (aimag) of the country, to compare the calculated data with information on the incidence of the population and the main parameters of iodine deficiency.

The calculation of the areas occupied by different types of soil was performed automatically in the MapInfo 7.8 program within each contour, the data obtained was typed into the MS Excel 2010 program and translated into fractions of the territory occupied by them within the aimag.

Further, the formula (Korobova and kuvylin, 2004) [11] was used to calculate the potential supply of iodine in this Area:

\[ I = \sum_{i=1}^{n} I_i \cdot S_i \]

where: \( I \) is the area’s iodine supply (in mg/kg, in mg/dm³).
I_i – availability of this type of soil with iodine (in mg/kg, in mg/dm^3),
S_i – percentage of the area of this type of soil within the selected area,
n – the number of polygons on the soil map that fall within the district boundaries.

The principal possibility of spatial assessment of the iodine status of territories based on a combination of experimental data on the content of iodine in soils, soil maps and cartometric calculations was proved earlier [1,6,12].

3. Results and discussion
The basis for carrying out barometric calculations in our study was a 1:1000000 scale soil map created as a result of vectorization of the raster image of the soil map of the national Atlas of Mongolia (Fig. 1).

![Figure 1. GIS "Mongolia-Iodine-2017" Soil map of Mongolia (vectorized and generalized for calculating iodine deficiency, authors).](image)

Vectorization was performed manually, and soil contours were drawn within each administrative district. The area occupied by each contour was determined by the MapInfo 7.8 program. We extracted the information from the object properties section and entered it in the MS Excel 2010 table for subsequent calculations. As the analysis of soil maps for the Western regions of Mongolia are so typical of mountain soils to the North and East chernozems, gypsic kastanozems and leptosols umbric, southern and Central – luvic calcisols, gypsic calcisols, solonchaks and solonets. Thus, the administrative division of Mongolia largely corresponds to its natural physical and geographical boundaries, with a set of certain properties and characteristics, including factors that determine the presence of iodine deficiency (table).
Table 1. The areas of prevailing soil types within the administrative regions of Mongolia.

| Administrative district | Area (Km²) | Chernozems | Gypsic kastanozems | Endosol calcisols | Luvic calcisols | Gypsic calcisols | Solonets, solonchaks | Entic podzols and Umbritic leptosols |
|-------------------------|------------|-------------|-------------------|------------------|----------------|-----------------|----------------------|-------------------------------------|
| Dornod                  | 116274     | 31975       | 62376             | 19923            |                | 2000            |                      | 10408                              |
| Hentai                  | 77151      | 17422       | 33501             | 15820            |                | 2500            |                      | 10550                              |
| Suhebator               | 77201      | 2772        | 26063             | 45866            |                | 5650            |                      | 11167                              |
| Dornod Goby             | 108104     | 914         | 23510             | 56140            | 21890          | 5650            |                      | 15753                              |
| UlaanBator              | 71140      | 42260       | 18330             |                |                |                |                      | 3997                               |
| Seleng                  | 42684      | 1454        | 30063             |                |                |                |                      | 3500                               |
| Erdenet                 | 45163      | 6650        | 22760             |                |                |                |                      | 15753                              |
| DundGobi                | 31857      | 4970        | 22890             | 3997            |                |                |                      |                                    |
| OmnoGobi                | 162219     | 4409        | 78320             | 75990           | 3500           |                |                      |                                    |
| Ovor Hangai             | 61509      | 14420       | 27540             | 13020           |                | 6529            |                      |                                    |
| Arkhangai               | 48635      | 8428        | 9587              |                |                |                |                      | 30620                              |
| Bayan Hongoy            | 106451     | 14480       | 32466             | 31530           | 25980          | 1460           | 535                  |                                    |
| Gobi Altai              | 124704     | 28537       | 27822             | 50955           | 640            | 16750          |                      |                                    |
| Huvsugol                | 90256      | 17284       | 10659             |                |                |                |                      | 62313                              |
| Zawhan                  | 66734      | 34530       | 16972             | 8251            |                |                |                      | 6981                               |
| UVS                     | 110013     | 3347        | 64470             | 33986           | 8210           |                |                      |                                    |
| Hovd                    | 66279      | 10570       | 13726             | 15020           | 1048           |                |                      | 25915                              |
| Bayan Ulgi              | 40000      |             |                   |                 |                |                |                      | 40000                              |

The results of the assessment of potential iodine availability in Mongolian soils obtained using the calculation formula were entered into the attribute table of the soil map in the MapInfo program. They were used to create a map of the potential iodine availability of Mongolian soils within the administrative regions, as a result of visualization of these data. V. V. Kovalsky's criteria were used as ranks for assigning a certain color to a contour [13]. The color load of the map was selected according to the increasing risk of iodine deficiency (from green to red) for each of the districts (Fig. 2).
The data obtained show that the highest content of iodine in soils was found in the aimags of Khuvsgul, Selenge and Khentii (more than 4.7 µg / kg), and the lowest in Bayanhongor, Omnogobin, Dundgobin, Dornogobin districts (less than 1.5 µg / kg).

The most unfavorable situation was found in the areas of UVS and Khovd, which does not contradict the available data on the incidence of the population (more than 30% of iodine-deficient pathologies). Omnogobin, Dund-Gobi and Dorn-Gobi are also the leaders in terms of low iodine content in soils. The explanation of high pathologies of the adult and child population in the aimags of Erdenet, Bulgan, and Dornod (12.5-15% of pathologies) is very weakly correlated with the data obtained, which is probably due to some of the factors we did not take into account (altitude, features of iodine prevention, imported products, drinking water from deep horizons with a higher content of iodine, and many others).

It would be desirable to conduct further research based not only on literature and cartographic data, but also on the results of our own field research. Analysis of literature and cartographic data [1,4,5,10] showed a high dependence of the population's morbidity by region on a complex of physical and geographical iodine-deficient factors.

4. Conclusion
1. The highest content of iodine in soils identified in the aimags Khuvsgul, Selenge and Haniska (more than 4.7 µg / kg) and the smallest in Bayanhongor, Omegalsks, Dongobesh, Dorogobush areas (less than 1.5 µg / kg).
2. The most unfavorable situation in terms of iodine deficiency is observed in the UVA, Khovda and Bayan-Ulgey Districts, which may be due not so much to the low content of iodine in the soils, but rather to the large distance from the sea, orographic effect, low Precipitation and the predominance of acidic rocks.
3. The reason for the high pathology of the adult and child population in aimag Erdenet, Bulgan and Dornod (15-30% of pathologies) with a high content of iodine in soils may be a lack of iodine prophylaxis and adequate medical control of the population, lack of awareness, the prevalence of imported food and use drinking water with a low content of iodine and other factors requiring additional research.
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