Development of a geoinformation atlas of the sanitary and chemical state of water sources in the arid region

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Abstract. The paper considers the development of a geoinformation atlas of the sanitary and chemical state of water sources in the arid region on the example of the Saratov region. The atlas summarizes the results of sanitary and chemical monitoring of surface and underground water sources in the Saratov region. Graphs of content of priority pollutants excess, as well as non-carcinogenic risk and hazard index for 2015-2021 are summarized in the form of an information map of a water source linked to its geographical coordinates. The atlas file system includes four blocks, each of which summarizes information about the hygienic condition of one of the types of water sources: springs, wells, small rivers, and sampling points on the Volga River. Atlas data can be derived using landscape models that allow to link the spatial position of a water source with the characteristics of its chemical composition, as well as output data in the form of an altitude diagram. The ratio between sanitary and hygienic indicators in dynamics can also be visualized in the form of diagrams. The atlas may be of interest to specialists in the field of preventive medicine and employees of research organizations dealing with environmental hygiene.

1. Introduction

Thematic mapping based on geoinformation technologies is an up-to-date and informative tool for obtaining, analyzing, and visualizing hygienic monitoring data, which is associated with the possibility of accumulating a large array of data, obtaining ratios between them and their distribution on a cartographic basis. The data system, united by a common theme, is a geoinformation atlas.

GIS platforms allow analyzing health risks caused by air pollution in industrial cities [1]. When creating a geoinformation atlas for hygienic monitoring of water supply facilities, mobile data collection tools are also used [2]. Working with interactive GIS platforms assumes that the representation of three homogeneous subregions is sufficient for effective visualization of natural processes occurring in a certain territory [3]. The use of statistical programming environments, such as S-Plus and XLISP-STAT, with the possibility of adding spatial analysis libraries, allows to create an information map based on the cluster principle. With this approach it is possible to systematize data on various forms of oncology [4]. An epidemiological GIS atlas has been created that systematizes data on the structure, level, and
dynamics of diseases, as well as considering seasonal factors in their spread, as well as methods of anti-
epidemic protection of the population from diphtheria, meningococcal infection, natural focal infections,
tuberculosis [8], an atlas for systematization and study of anthrax foci [9]. The use of geoinformation
technologies in hygienic science and practice makes it possible to display the distribution of diseases,
ways by which one can search for spatial patterns in the distribution to identify the causal factors of the
observed patterns [5]. The prospects for the use of GIS in epidemiological studies consist in the
possibility of compiling morbidity maps in relation to the state of the environment. This makes it
possible to analyze the distribution of environmental factors related to health using interpolation and
modeling [6]. The geoinformation atlas allows to store and analyze large amounts of data, including
structural parameters of the water supply system and compare them with epidemiological databases,
including information about the incidence transmitted through water, which allows to identify cause-
effect and correlation of diseases with the microbiological state of water sources [7].

Geoinformation technologies make it possible to study the dynamics of the sanitary and
epidemiological state of districts both in general and in the projection of municipalities [10]. This
method of data processing allows to summarize information coming from various sources and distribute
it between experts and non-expert users, as well as integrate with the Internet of "smart" things [11].
GIS technologies are used to improve epizootological monitoring, approaches to hazard assessment and
provision of preventive measures against natural foci of tularemia [12], using both traditional
cartography methods and geovisualization approaches [13]. Also for geoinformation analysis in
epidemiology, such approaches as geocoding, distance estimation, mobility in residential premises,
record binding and data integration, clustering, assessment of small territories and stochastic
applications to morbidity are used [14]. When performing a risk assessment, a partial least squares
structural equation model (PLS-SEM) is known, including the geographical coordinates of objects as
hidden variables [15]. The study of spatial trends in cases of diarrhea in children using geoinformation
technologies makes it possible to assess the conditions for reducing mortality at the subnational level,
as well as to identify potential intervention strategies for vulnerable groups of the population [16]. The
Institute of Health Indicators and Assessment (USA) has developed a GIS platform that accumulates
data on the main causes of morbidity: diabetes, tobacco smoking, oncology, hypertension due to their
prevalence in the USA [17]. This tool allows to identify the ratios between the social activity of the
population and the level of common diseases. A similar atlas was created in the European Union [18].
Thus, the most well-known is the Earthquake Emergency Response System (EEMRS), which, by
integrating smartwatch data with a GIS platform, allows to obtain information about the location and
health status of a potential victim [19]. Geoinformation platforms are used for specialized tasks of
parasitology, such as the influence of environmental factors on the spread of parasitic infections. Thus,
in [20] an atlas is described in which the relationship between temperature, the presence of water bodies
and the transmission of schistosomiasis in dynamics is realized.

The purpose of our work is to develop a geoinformation atlas reflecting the sanitary and chemical
indicators of surface and underground water sources in the Saratov region. To achieve this purpose, the
data of sanitary and chemical monitoring of drinking water of underground and surface water sources,
conducted in 2015-2021 at the Saratov Medical Scientific Center of Hygiene of the Federal Scientific
Center for Medical and Preventive Technologies of Public Health Risk Management of the Federal
Service for Supervision of Consumer Rights Protection and Human Well-Being, were systematized.

2. Materials and methods
The atlas is developed based on the QGIS cross-platform geoinformation system (version 3.12.3 with
GRASS 7.8.3). The geoinformation atlas data is structurally organized in the form of a digital
cartographic model, the external interface of which is shown in Figure 1. The atlas consists of four
thematic modules, each of which stores information about the results of sanitary and chemical
monitoring of one of the types of water sources: springs - for springs; Volga - for sampling points located
on the Volga below, above and in the city limits of Saratov; borehole - for wells; small_rivers - for water
sources located on small rivers of the left bank of the Saratov region. Each module is defined by a
system of files: shp contains information about the geometry of the sampling points being studied; dbf file contains attribute data about the sources-name, properties; the relationship between them is carried out using the shx index file; the .sbn and .sbx files characterize the spatial indexing of geometric objects. Since each thematic module corresponds to a single data set, the file system for each of the modules is set separately. Each object that characterizes the sampling point is defined using a set of data reflecting geographical coordinates, the type of marker and its color, as well as attributes. The spatial resolution of the atlas is not lower than the boundaries of urban and rural municipalities, as well as inner-city municipal territories. Information maps of water sources, representing a set of data on excess concentrations of priority pollutants of surface and underground water sources of the Saratov region, as well as the magnitude of non-carcinogenic risks caused by drinking water, were used as files linked to geographical shp-files characterizing the position of sampling points (Figure 2).

![Figure 1. GIS atlas of the sanitary and chemical state of water sources in the Kumysnaya Polyana Nature Park.](image)

3. Results and discussion
The structure of the atlas interface allows processing the data entered by the user and displaying them in the form of thematic maps.

Figure 3 shows a map of the distribution of non-carcinogenic hazard indices of spring water of the Saratov right bank according to sanitary and chemical monitoring data for 2020-2021. The highest value of the hazard index HI is characteristic of springs located in the lower part of the slopes of Kumysnaya Polyana. The reason for this may be that middle waters are enriched with priority pollutants characteristic of arid territories (nitrates, nitrites, ammonium, iron, and manganese) due to ion exchange of middle waters with sedimentary rocks typical of arid zones (dolomites, argillites, limestones, sandstones) and as the distance traveled in the aquifer increases when reaching a natural outcrop in the form of a spring, the final concentration of the pollutants listed above increases.

To visualize the distribution of heights in the territory under consideration, the QGIS2threejs plugin was used. Terrain in the scale range from 1:100000 to 1:2000000 is displayed using SRTM data due to the wide coverage of the territory, openness, and ease of obtaining. The SRTM resolution was 90 m/pixels, which makes it possible to visualize the terrain up to 20 zoom. In our opinion, it would be
promising to apply an approach to the reconstruction of a digital terrain model based on Delaunay triangulation, since it allows to reflect the terrain features that affect the distribution of water sources by height and discard insignificant altitude differences, thereby reducing the volume of the file system.

Figure 2. Information map of a water source containing information about the excess content of priority llutants of regulatory values.
**Figure 3.** The atlas output data in the form of a distribution map of the index of non-carcinogenic danger of springs of the Saratov right bank.

A digital 3D relief model allows to plot the graph of the landscape distribution over heights and, thus, visualize the relationship between the location of springs and indicators of their sanitary-chemical quality. To decrease altitude above sea level, the springs can be arranged in a row: Bogatyrsky (280 m), Serebryany (225 m), Berkutovsky (220 m), Andreevsky (215 m), Poyushchiy (190 m), Chasovenny (180 m), St. Sophia (160 m), Igumnov (135 m), Mochinovsky (120 m) (Figure 4).

**Figure 4.** Altitude Profile.

This atlas is designed to systematize information about the sanitary and chemical state of surface and underground water supply sources in its structural representation, implementing the systematization of data in accordance with the geographical location of the water source. It allows to visualize the dynamics of the processes of changing the hydro chemical parameters of water sources, as well as predict changes in their sanitary and chemical safety.

**4. Conclusion**

The developed geoinformation atlas systematizes the data of sanitary and chemical monitoring of surface and underground water sources of the Saratov region. The indicators of each water source are linked to geographical coordinates and are issued in the form of an information map, which includes information on the exceedances of the content of LOC of priority pollutants, as well as information on the dynamics of the values of the total non-carcinogenic risk and the hazard index. Structurally, the atlas is divided into four modules, each of which includes information about the state of one of the types of water sources: springs, wells, small rivers, and sampling points on the Volga River for 2015-2021. Atlas resources allow to visualize data in the form of 3D landscape models representing the contamination of water sources depending on their position at a given point in the landscape, and also displays its altitude diagram. The dynamics of the sanitary and chemical state of the water source can be presented in the form of diagrams reflecting the ratio between sanitary and hygienic indicators for different years. The Atlas is of interest to employees of the Centers for Disease Prevention and research laboratories studying the effects of the water factor on human health.

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