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Mathematical model of fresh water shortage using the example of the Grozny reservoir

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Abstract. Mathematical models are used in many fields of science and technology, such as physics, chemistry, biology, economics, sociology, etc. In geoecology, they are used to analyze and predict changes in the environment caused by various anthropogenic and natural factors. One of the main tasks of mathematical modeling is the construction of models that most accurately reflect real processes and phenomena. Today, the problem of providing clean water is faced in developing countries, but the day is not far off when developed countries will also face it. Water cooperation and cooperation is one of the most important conditions for the sustainable development of an interdependent world. Water as a strategic resource, the basis of human life and habitat, is becoming a decisive factor in geopolitics. Overcoming natural challenges and man-made threats to preserve water for current and future generations is a vital task facing the international community; a solution can only be found together.

1 Introduction

Geoecology is a science that studies human interaction with the environment. It combines knowledge from geography, ecology, geology, chemistry, physics, sociology and other sciences. The main task of geoecology is to preserve the natural resources and biodiversity of our planet.

The origins of geoecology go back to the past. In ancient times, people were already concerned about preserving nature, but the first scientific research in this area began only in the 19th century. In 1864, the German scientist Ernst Haeckel published his work "General Morphology of Organisms," in which he put forward a theory about the interconnection of all living organisms on Earth.

At the beginning of the 20th century, the French geographer Paul Vidal de la Bleu conducted extensive research into the interaction of humans and the environment. He identified three main types of human impact on nature: exploitative, transformational and regulatory.

In the 1960s, geoecology became an independent science. At this time, the first environmental organizations were created, such as Greenpeace and the World Wildlife Fund. These organizations promoted nature conservation and held protests against the destruction of ecosystems.

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Geoecology is a relatively young science that began to emerge in the middle of the Twentieth century at the junction of such classical sciences as biology and geography. Geoecology - studies and investigates natural processes, phenomena and actions of nature. Geoecology also studies human activity and its impact on nature, on environmental processes that arise and occur due to economic activity.

The impact society has on the environment does not go unanswered. Destructive actions towards nature boomerang back to humans in the form of a polluted environment with its consequences on human health and declining natural resources, which in turn are the central link in the development of mankind.

In 1939, the German scientist Karl Troll conducted a study of landscapes, during which the scientist came to the discovery of a completely new scientific field called geoecology. This direction is being formed at the intersection of physical geography and ecology.

In the 2nd mid-20th century, the world's population faced the possibility of a global crisis leading to catastrophic degradation of the ecosphere, that is, in the sphere of interaction between the geosphere and humanity. The culprit of this process is man and his economic activity.

Geoecology, which studies the ecosphere, was formed as an academic field in 1999. Within the framework of which the concept of geospheres and its integration with the environment was studied. At the origins of this direction was Vladimir Artemyevich Golubev, Doctor of Geologist - Mineralogical Sciences. V.A. Golubev’s scientific interests are the geothermy of large lakes and reservoirs.

But at the same time, the terminology as geoecology did not receive due recognition; in its place at the beginning the term ecosphere was used. In turn, the ecosphere itself, in its understanding, presupposes a special integration of the geosphere and society. This is the area in which the geosphere, atmosphere, hydrosphere, lithosphere and biosphere interact with each other, as well as the place where people live and work.

2 Research Methodology

Mathematical modeling is an effective tool for solving the problem of fresh water scarcity. Hybrid models that take into account both analytical laws and empirical data can be used to predict future water shortages in the region and determine optimal measures for the conservation and use of freshwater.

To build a mathematical model of providing fresh water to the population of the city of Grozny from the Grozny Sea reservoir, you can use geographic information systems (GIS).

First, data about the reservoir needs to be collected, such as its depth, surface area, water volume, etc. This data can be obtained using satellite observations, aerial photography and other methods.

Then it is necessary to determine the need of the city population for fresh water. To do this, you can use data on the city's population and its per capita water needs.

Next, it is necessary to determine the possibility of supplying water from the reservoir to the city. To do this, you can use data on the distance between the reservoir and the city, the presence of pipelines and other utilities.

After this, you can build a mathematical model that takes into account all this data and allows you to determine how much fresh water can be supplied to the city from the reservoir in a certain period of time.

To do this, you can use special GIS programs that allow you to build mathematical models based on spatial data. In this case, we will use the MS Excel spreadsheet processor.

3 Results and Discussions

Thus, the use of geographic information systems makes it possible to more accurately determine the possibilities of supplying fresh water to the population of the city of Grozny from the Grozny Sea reservoir and make effective decisions on natural resource management.

This mathematical model is being built to calculate the supply of fresh water to the population of the city of Grozny from the Grozny Sea reservoir in the event of an environmental disaster.

Solution:

The purpose of the model is to calculate the supply of fresh water to the population of the city of Grozny from the Grozny Sea reservoir in the event of an environmental disaster.

The objects of modeling are two components: the reservoirs of the city of Grozny "Grozny Sea" and the city of Grozny.

Development of 1 model.

In order to build a mathematical model, it is necessary to determine the initial data of the task. Let's denote:

V – volume of the Grozny Sea reservoir – 5.3 km3 (5,300,000,000,000 l.);

N – population of the city of Grozny – 328,533 people (as of 2021, which is 21.44% of the population of the republic);

p – water consumption per day per person (on average) 231 liters (For one person over a thirty-day period, the norm is 6.935 m3. If you divide this amount by 30, you get approximately 231 liters of water per day.).

The volume of the reservoir "Grozny Sea" km3 will be converted into liters 5.3 km3 = 5,300,000,000,000 l (1 cubic km = 1,000,000,000,000 l; 1 liter = 0.000000000001 cubic km).

From Result - the number of years for which the population of the city of Grozny uses water from the Grozny Sea reservoir - let us denote g.

So, g=(V)/(N*p*365).

$$g = \frac{5\ 300\ 000\ 000\ 000}{328\ 533 * 231 * 365} = 191{,}3339.$$

Based on the obtained calculation results, we can say that with the conditions that we introduced into the mathematical model, the population of the city of Grozny, in the event of a geo-ecological disaster and the absence of other water resources, can live 191 years using drinking water from the Grozny Sea reservoir.

Development of 2 models.

To build the second mathematical model, we will use the same initial data as model 1. Let's denote:

V – volume of the Grozny Sea reservoir – 5.3 km3 (5,300,000,000,000 l.);

N – population of the city of Grozny – 328,533 people (as of 2021, which is 21.44% of the population of the republic);

p – water consumption per day per person (on average) 231 liters (For one person over a thirty-day period, the norm is 6.935 m3. If you divide this amount by 30, you get approximately 231 liters of water per day.).

The volume of the reservoir "Grozny Sea" km3 will be converted into liters 5.3 km3 = 5,300,000,000,000 l (1 cubic km = 1,000,000,000,000 l; 1 liter = 0.000000000001 cubic km).

To convert cubic kilometers to liters, you must use the inverse formula:

1 cubic kilometer = 1,000,000,000 liters

Thus, to convert cubic kilometers to liters, you need to multiply the number of cubic kilometers by 1,000,000,000. For example, 0.005 cubic kilometers = 0.005 * 1,000,000,000 = 5 billion liters

From Result - the number of years for which the population of the city of Grozny uses water from the Grozny Sea reservoir - let us denote g.

So, g=(V)/(N*p*365).

$$g = \frac{5\ 300\ 000\ 000\ 000}{328\ 533 * 231 * 365} = 191{,}3339.$$

Only in this method of constructing a mathematical model will we convert the numerator and the result obtained in the denominator into cubic kilometers.

5,300,000,000,000 litas = 5.3 km3

27,700,259,895 liter = 0.0277002599 km3

To convert liters to cubic kilometers, use the following formula:

1 cubic kilometer = 1,000,000,000 liters

Thus, to convert liters to cubic kilometers, you need to divide the number of liters by 1,000,000,000. For example, 2 billion liters = 2 / 1,000,000,000 = 0.000002 cubic kilometers.

$$g = \frac{5{,}3}{0.0277002599} = 191{,}3339.$$

Based on the obtained calculation results, we can say that both models work properly and produce the same result.

Water resources occupy a special place on our planet. This is one of the most important elements of human life. And these words must be taken literally, all the physical and chemical properties of water. Exceptions in nature, with the same formula H2O, it can be in 4 states of aggregation: liquid, gaseous, solid and bound. The great Russian scientist Vladimir Ivanovich Vernadsky. At the beginning of the last century, he wrote that water stands apart in the history of our planet. There is no earthly substance, mineral, rock, living body that does not contain it.

Man himself is almost 80 percent water. Water is energy, water is food, water is a system that forms the basic conditions for life itself on earth. This is a strategic resource that determines the sustainable development of all environmental and economic state and social systems of the planet. But how much water is there on earth and how much is necessary for the normal existence of humanity. The total quantity is simply impossible to imagine; it is expressed as a number with 18 zeros and is about 1.4 quintillion cubic meters or 1.4 billion billion cubic meters. The World Meteorological Organization classifies ninety-seven and a half percent of the earth's water resources as salt and two and a half percent as fresh.

One of the main factors in the formation and occurrence of geological crises is the growth of the world's population and its disastrous, careless attitude towards the environment. One of the phenomena of the geo-ecological crisis against the background of the growth of the world's population is the dynamic trend of restrictions on territory and resources.

Taking into account another 2 two and a half billion new inhabitants of the planet, an additional four thousand two hundred cubic kilometers of water will be required to the existing ones. Add almost three thousand cubic kilometers more. This means that humanity will be forced to use those water resources that today maintain the stability of the earth's ecosystem. And low-water-supplied regions will face an increase in a certain deficit due to the growing needs of people and the economy. What are the main global water problems and the risks of threats to sustainable development and international security? A significant number of studies have been devoted to this issue.

Risks can be divided into three main groups: climatic and geographical, and anthropogenic technological. Today we are witnessing how the risks of climate change affecting freshwater resources are significantly increasing as the concentration of greenhouse gases in the atmosphere increases. Data on changes in runoff in certain areas indicate. That in some regions of the world it increases, in others it decreases and changes. And the usual seasonal distribution, which complicates the possibilities of use, increases the frequency and intensity of extreme hydrological events. Both droughts and floods according to materials from the Intergovernmental Panel on Climate Change.

The Grozny Sea is an artificial reservoir that was created in 1959 on the Sunzha River in the Chechen Republic. It is one of the largest reservoirs in Russia and has a surface area of more than 1,400 km².

To make it easier to define the problem, we will make an information window where we will write down the goal of the model being developed: "Constructing a mathematical model for providing fresh water to the population of the city of Grozny from the Grozny Sea reservoir in Excel" (Fig. 1)

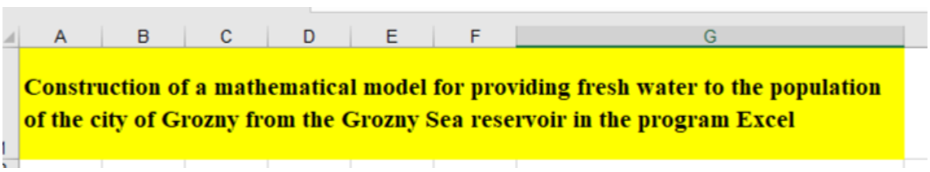

Fig. 1. Information window.

To build a mathematical model, we determine the initial data. To do this, we will create seven columns with separate names:

1. V (km3) - volume of the Grozny Sea reservoir;
2. N (persons) - population of the city of Grozny;
3. p (l) - water consumption per day per person (on average);
4. number of days in a year (constant value);
5. Calculation of water consumption of the city population;
6. Calculation of water consumption of the city population for the year;
7. g (year) - the number of years during which the population of the city of Grozny uses water from the Grozny Sea reservoir.

Each of these columns is named differently according to the information contained in the column (Figure 2).

V (km3) - volume of the Grozny Sea reservoir	N (persons) - population of the city of Grozny	p (l) - water consumption per day per person (on average)	Number of days in a year (constant value)	Calculation of water consumptio n of the city population	Calculatio n of city population consumpti on for the year	g (year) - the number of years for which the population of the city of Grozny uses water from the Grozny Sea reservoir

Fig. 2. Formation of columns

The column "V (km3) - volume of the Grozny Sea reservoir" contains data on the volume of water in its normal state, that is, 5300000000000 km3. Why is it in a nominal state, because the reservoir will add even more volumes of water, and therefore the load on the reservoir dam increases (Fig. 3).

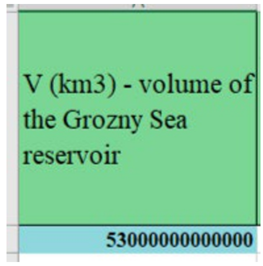

Fig. 3. Column of the volume of the Grozny Sea reservoir.

The first cell of the column "N (persons) - population of the city of Grozny" contains data obtained from the results of the 2021 population census. The data was obtained from open access from the "Cities of Russia" website, and information on the number of city residents per site was obtained from the Federal State Statistics Service. The official website of the Rosstat service is www.gks.ru. The data was also taken from the unified interdepartmental information and statistical system, the official website of EMISS www.fedstat.ru. The website publishes data on the number of residents of Grozny. The table shows the distribution of the number of residents of Grozny by year; the graph below shows the demographic trend in different years.

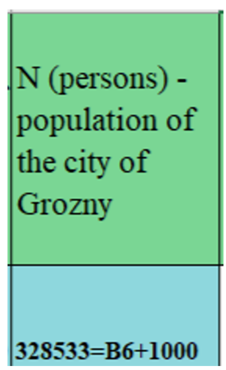

Fig. 4. Population of the city of Grozny.

The column "p (l) - water consumption per day per person (on average)" contains information on the average use of fresh water per person in the amount of 231 liters. On average, one city resident receives 231-250 liters of cold water per day (Fig. 5):

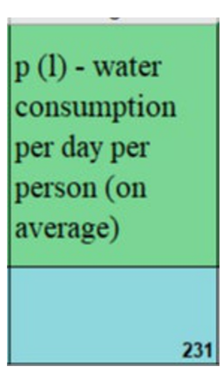

Fig. 5. Average volume of water per person.

The column "number of days in a year (constant value)" contains the given number of days in a year. This information is needed to find out how much water one person will consume per year (Fig. 6).

Number of days in a year (constant value)
365

Fig. 6. Number of days in a year.

"Calculation of water consumption of the city population" in this column, water consumption is calculated based on the formula (Fig. 7):

Np (calculation of water consumption of the city population)=N*p

Calculation of water consumption of the city population
75891123= B7*C6

Fig. 7. Formula for calculating water consumption.

"Calculation of water consumption by the city's population for the year" in this column the calculation of water consumption by the city's population for the year is made, and this calculation is made taking into account the growing number of population (Fig. 8).

NY (Calculation of water consumption by the city population for the year) = Np*Y

Number of days in a year (constant value)	Calculation of water consumption of the city population per a day	Calculation of city population consumption for the year
365	75891123	27700259895
	76122123	27784574895
	76353123	27868889895
	76584123	27953204895

Fig. 8. Construction of a model for calculating water consumption by the population of the city of Grozny for the year.

Based on the results obtained, we build the final mathematical model, calculations for this model will be made in the column "g (year) - the number of years for which the population of the city of Grozny uses water from the Grozny Sea reservoir" (Fig. 9). For this, a formula is developed:

$$g\ (year) = V\ (km3)/NY$$

V (km3) - volume of the Grozny Sea reservoir	N (persons) - population of the city of Grozny	p (l) - water consumption per day per person (on average)	Number of days in a year (constant value)	Calculation of water consumption of the city population per a day	Calculation of city population consumption for the year	g (year) - the number of years for which the population of the city of Grozny uses water from the Grozny Sea reservoir
5300000000000	328533=B6+1000	231	365	75891123	27700259895	191,333945
				76122123	27784574895	=A2/F3
				76353123	27868889895	190,1762151
				76584123	27953204895	189,6025883

Figure 9. Calculation of the number of years for which the population of the city of Grozny uses water from the Grozny Sea reservoir.

4 Conclusions

One of the main factors in the formation and occurrence of geological crises is the growth of the world's population and its disastrous, careless attitude towards the environment. One of the phenomena of the geo-ecological crisis against the background of the growth of the world's population is the dynamic trend of restrictions on territory and resources.

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