RISK ASSESSMENT OF THE WATER RESOURCES LOSSES OF THE AZERBAIJAN REPUBLIC DUE TO CLIMATE CHANGES

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The main territory of Azerbaijan Republic is situated within arid climate and vast majority of the water resources are involved in the national economic production. Approximately 70% of the water resources are from the transboundary rivers. In states with a current 30% and, as was estimated, more than 40% in the near future deficit of general water resources, the optimal use of fresh surface and groundwater resources great significance and strategic importance for economy of the new independent country in the current situation. As a result, the stress of the potable water resources in various sectors of the national economy, especially in agriculture, which is a major hazard of the countries' food security. This is the reason that currently the interest in the impacts of climate change on water resources in the Republic has developed greatly. The research data demonstrate that the water resources formation in Azerbaijan are very depend on the climate components and highly sensitive to variations in climate. At a time when over the whole territory of the Republic natural conditions are not co-operated to form the potable water resources and other analyses suggest that groundwater resources and water quality could all be significantly affected by climate change over the course of the coming decades. It may be very important factor against sustainable development of Azerbaijan. This paper examines the scientific and technical aspects of evaluating the state of affairs of the water resources management, risk assessment and their degree of vulnerability due to consequences of climate variation in the Republic of Azerbaijan.

Introduction. Currently, importance of potable water resources for the future is one of the vitally important worldwide problem and for Azerbaijan in particular. The provision of safe and sufficient supplies of water is already a problem in many areas of the world and, as populations increase, it is a problem that will continue to escalate. This situation is complicated by the climate change, intensive industry development and anthropogenic impact on the environment. As a result, the need in freshwater, the vital strategic resource in the world, increases every year dramatically. Such problem, in turn, can lead to serious economic damage and social instability. This confirms that the potable water plays the leading role in the development of any society. The water supply deficit is not just increase humanitarian problems it is almost always a reason for the political problems also.

Even energy-rich countries can not survive without sustainable water supply. As a consequence, the management and sustainable development of water resources for states' population and national economy is the key component for state sovereignty and for the Republic of Azerbaijan in particular. The climate change predictions and scenarios, made by scientists from different countries, show how it may lead stress of the fresh water resources. In Azerbaijan – in the state with major deficit of the water resources, this situation definitely will lead the water crisis. Therefore, analysis of the role of the climatic factors and impacts of climate change (based on different scenarios) on groundwater resources within Republic can be of great interest and helpful to identify a range of alternative water management scenarios, likely involving integrated "conjunctive" use of ground and surface water supplies and "recharge management", through which long-term sustainability of urban water resources can be achieved.

Problem definition. The Azerbaijan Republic is located on the western side of the Caspian Sea, in the arid climatic zone and feels deficit of general water balance (in terms of a transboundary water inlet) for almost all fields of the economy development including potable water supply for the population, agricultural and industrial production as well. Most of the territory is located in the regions with light precipitation and high evaporation, where agricultural production is not possible without artificial irrigation (Fig.1). Consequently, the country's sustainable food production (food safety) and sustainable economic growth fully depend from the sustainable water supply. At the same time, the scientists' longtime and short time forecast scenarios show effect of the climate change on a reduction in precipitation. Further aggravation of the water balance deficit will inevitably lead to problems in the economic and social spheres of the country.

Fig. 1. Review map

The modeling studies show a high sensitivity or total dependency of the water resources formation from the climate data variations in the different regions of the World (Arnell and Liu 2001; Kundzewicz et al., 2007; Roos, 1987; Barnett et al., 2005; Zhang et al., 2007; Barnett et al., 2008).

In 1987 Gleick More established that the climate changes impact upon the stability of the water supply system in California and extreme high demand of the water supplies in the dry summer months (Vanrheenen et al., 2004).

A series of studies in 2011-2012 (Papalexiou et al., 2011; Papalexiou, Koutsoyiannis, 2012), which are conducted based on the statistical analysis of 15137 records around the World of the maximum long-term daily precipitation, have allowed to establish different distribution laws. And these laws are used for statistical evaluation and analysis of the average values of different regularities and risks. There is a clear relationship between the density distribution parameters and recording length. Only very large samples can reveal its true distribution and the actual behavior of extreme precipitation.

The researchers have different opinions in the recent studies about the issue of the the potential complexity of the water resources adaptation to climate change. Tanaka et al. (2006) used an economic optimization model of adaptation in the context of the California Water Resources.

The analysis results show that the adaptation cost to climate change will be high for the water sector, but small towards to the country's economy and the budget of California as well. However, these optimistic results have received just partial attention, because the prediction result was obtained in a context of the hydrological uncertainty.

Based on the results of the hydrological systems modeling and interactions between climate and hydrological systems, Vanrheenan et al. (2004) came to reach the conclusion that "... in order to achieve and maintenance of status quo... under the altered circumstances of the hydrological climate scenarios, have an impact on the system productivity in future will be almost impossible."

In view of the above and the results of numerous studies, it is a fair assumption to say, that the water resources is the very important subject of study in the context of the potential climate change impact.

Sources of water resources. The particularities of physic-geographical conditions, complexity of terrain and general atmospheric circulation causes the unique natural climatic conditions of Azerbaijan. In Azerbaijan 9 of the world's 11 climate zones, including semi-desert, arid steppe, and mountain tundra are present in the country (Israfilov R., Israfilov Yu., 2011; Israfilov et al., 2006). At the same time the formation of Azerbaijan climate is influenced by cold air masses of arctic (Kara and Scandinavian anticyclones) and temperate (Siberian anticyclones) and maritime (Azores maximum), hot air masses of tropical zones (subtropical anticyclone and southern cyclones), Central Asian anticyclones and local weather conditions.

The total water balance (excluding water resources of transboundary rivers) in Azerbaijan is: precipitation – 427 mm (3696 km^3); river discharge – 119 mm (10,31 km^3), including 69 mm (5,96 km^3) is a direct runoff and 50 mm (4,35 km^3) is a groundwater runoff. The average long-term drainage modulus is 3,78 l/sec.km^2 (drainage coefficient – 0,28). The total evaporation here is 308 mm (26,66 km^3) (Israfilov R., Israfilov Yu., 2010; Israfilov et al., 2006). Over the whole territory of the Republic the evaporation is twice more than discharge and it is significant factor in a predictive modeling of climate change impacts' on groundwater resources in Azerbaijan (Israfilov R., Israfilov Yu., 2011).

Analysis of numerous studies on different aspects of river basins in Azerbaijan (Israfilov R., Israfilov Yu., 2011; Исрафилов, 2014: Оценка экологических…,1992; Хенли, Кумамото, 1984; Хисметов и др., 2009; Gleik, 1987; Tanaka et al., 2006; Dessai et al., 2007 etc.) leads to the conclusion that out of 8350 small, mid-size and large rivers in the Republic with a total flow of 32.2 km^3/year, approximately 70% of the water resources (22 km^3/years) are from 5 of the transboundary rivers (Рустамов, Кашкай, 1978).

Kura with its vast river system is the key water source for the Caucasus. The river flows through the territories of Turkey, Georgia and Azerbaijan Republics. The total length of the river is 1364 kilometer (km) of which 185 km are within the territory of Turkey, 390 km in Georgia and 790 km in Azerbaijan. The total area of the watershed that the Kura River drains is 188000 km^2 (of which 58000 km^2 is in Azerbaijan proper, 34700 km^2 is in Georgia, and 29800 km^2 is in Armenia and 65500 km^2 is in Iran and Turkey). The average elevation of the Kura River upper watershed in the Azerbaijan-Georgia border is 1700 meter. The headwaters of Kura River are a group of streams formed in the Gizil-Gadik Mountain at an elevation of 2700 m in Anatolia area of Turkey.

The second largest river is the Araz (Araks). The river flows through Turkey, Armenia and Azerbaijan territories and falls into the Kura near Sabirabad town. The total length of the river is 1072 km with a total watershed area of 102000 km^2 (of which 18740 km^2 is in Azerbaijan, 22090 km^2 is in Armenia, and 61000 km^2 is in Iran and Turkey).

Ganikh (Alazan) is the third largest river, which flows through the territory of Georgia and Azerbaijan and falls into Mingechevir reservoir (Kura River). The total length of the river is 413 km with a total watershed area of 12080 km^2 with the highest elevation in the watershed at 900 m. The Samur river watershed area is 3620 km^2 and Astarachay river watershed area is 242 km^2. The watershed area of the rivers that flow directly into the Caspian Sea from the Northeast slopes of the Greater Caucasus Mountains and Lyankyaran-Astara zone are 22500 km^2 and 52000 km^2, respectively.

As reported in the references (Хенли, Кумамото, 1984; Tanaka et al., 2006; Gleik, 1987 etc.), the total water resources of Eastern Caucasus rivers flowing into the Caspian Sea within the Azerbaijan Republic including those of Samur and Astarachai Rivers make up 31.5 km^3. Total water resources of the Kura River are 26.6 km^3 and of the Araz River are approximately 10 km^3. Water resources of other rivers directly flowing into the Caspian Sea (Rivers of the Greater Caucasus North-East slope and Lyankyaran-Astara zone) make up approximately 4.67 km^3, of which 2.17 km^3 is from the Samur River and 0.22 km^3 is from the Astarachay River. 25% (7.5 km^3) of total water resources of these rivers are from within the Azerbaijan Republic.

The total exploitation reserves and possibilities for use of fresh and weakly mineralized groundwater fields are 5.1 km^3 (Исрафилов, 2014).

Total surface and groundwater resources for average water year are determined about 37.3 km^3. The approximate volume of mandatory environmental and sanitary passage of the main river basins of the Republic is 6.0 km^3 per year (Imanov, 2000). The remaining water resources (about 31.3 km^3) are the strategic reserves and their sustainable use is a guaranty of the sustainable development of the country.

In total the long-time average annual water resources use about 15 km^3/year, including 2.8 km^3 of groundwater. According to long term average data, about 80% and 15% of the water resources are using in the agriculture and the industry activities respectively and the rest for the needs of public water supply (Алиев, Мусаев, 1991). It is important to note that the volume of water currently used is actually equal to the volume of water being formed within the territory of the Republic. This situation is critical and indicates full dependence on transboundary river flows of Kura and Araz rivers. In this case, almost all water policy of the Republic depends on the quantity and quality stability the of transboundary water resources.

It should be noted that within the Kura-Araz basin the per capita water availability is 6 times in Georgia and is 3 times in Armenia higher than in Azerbaijan.

Water resources contamination. Besides of the general water scarcity the acute pollution of transboundary water significantly increases the tension in the socio-environmental area of the country and generate additional stress on freshwater resources.

Environmental protection and maintenance surface water and groundwater ecology is another urgent problem in the republic. The research results by various investigators (Хенли, Кумамото, 1984; Хисметов и др., 2009; Barnet et al,, 2005; Gleick, 1987; Tanaka et al., 2006; Dessai et al., 2007; etc) show that in the territories of Turkey and Iran environmental conditions of Kura and Araz Rivers are relatively better. The Kura River in the Georgian Varsiya – Akhalkalaki region and Araz beginning from Gumru region of Armenia to Azerbaijan territory are polluted. Wastewaters in Armenia and 36-40% of Georgia are discharged in the Kura River basin. In the Ararat valley sewage from residential areas are transported by pipes to the Sadarak settlement. The annual amount of polluted waters coming from Armenia into Araz River is about 2.6 km^3. Annual wastewater flow into Araz on the average include biogenic elements in the amount of 22-25 thousand ton, pesticide-detergents in the amount of 10-12 thousand ton, organic elements of alloxton type around 60-70 thousands ton and phenols, heavy metals thousands of tons. There is no self-purification process in the river basins. In connection with that physically, chemically and biologically altered and unsafe waters enter into Azerbaijan territory. Pollution of Kura River in the Georgian territory begins from Borjomi valley and continues till Khramchay. The annual amount of polluted waters entering from Georgian territory into Kura River is about 4.2 km^3. Information gathered by specialists (Dessai et al., 2007) wastewater flow into Kura carries on average an annual chlorides load of 60-70 thousand ton, nitrogen compositions 9-11 thousand ton, pesticide-detergents 20-25 thousand ton, organic elements 120-160 thousands ton, phenols 10 thousand ton, metal salts 19-22 thousand tons.

The situation for groundwater is just about the same. In many regions of the republic intensive industrial activity has resulted in different impacts such as water table rise and salinization of soils, contamination and/or decline of the groundwater level, subsidence and landslide processes, etc. Local authorities should need to address these problems urgently. However, in case of contamination of the transboundary aquifers the problem becomes more urgent as it reaches the inter-state level. It is well known that the level of natural protection of the groundwater in the artesian basins is high. But the urgency of the problem may be illustrated by the example of the Alazan-Agrichai transboundary aquifer (its south-east part is located in the territory of Azerbaijan and the north-west part – in the territory of Georgia). More than a million people of both countries live within the region. Their main occupation is agriculture. Moreover, a large Kakhetin-Filizchay (field of polymetallic ores) has been exploited for more than 30 years in the area. Intensive contamination of the environment since the time the territory was part of the USSR has resulted in serious pollution of the water resources. Water sample form the ground and surficial sources in the territory of Georgia and Azerbaijan contain nitrates, heavy metals and some radioactive elements in amounts that exceed acceptable existing standards. At present this is an international problem and it should be solved by collective efforts of Azerbaijan and Georgia. The above-mentioned examples demonstrate the urgency of the protection of the water resources in the regulation and use of the transboundary aquifers.

So, without fresh water resources management and sustainable development (including intergovernmental agreements and regulations in the field of water resources protection from contamination), Azerbaijan may face very serious situation, that can be reason for country's sovereignty restriction.

The rise of the Caspian Sea level. A serious problem for the coastal areas of the country is the rise of the Caspian Sea level that has a cyclical nature. Based on the National Center on Climate Change data, as a result of the sea level rise (2.5 m since 1977), more than 800 km^2 territory were flooded. Currently these areas are the regions of ecological disaster. As a result, the amount flood damage larger than $ 4 billions. Another cause it is silting channel of the Kura and its delta. So in wet years the river does not provide a gravity drainage into the sea. Flooding along the bed of the Kura-

Araz in 2002-2003, led to the flooding of more than 6 thousand yards and the other infrastructure areas (Последствия изменения климата…, 1997).

The socio-economic and environmental problems of the Caspian Sea coastal areas mainly have caused by the global climate change. The long-term sea level fluctuations observations were between the -20 and -34 m (14 m). Most changes in sea level vary between -25 to -27 m (40%) from 1978 to 1995. Sea level has risen by 2.5 meters and reached -26.42 m. It is the most intense and long-term level rise for the whole period of instrumental observations. And it is associated with an increase in humidity in the river basins and their discharge (10-11%) and a decrease in consumptive river water use (Каспийское море, 1992). As a consequence of flooding 485km^2 of offshore caused considerable damage to facilities and infrastructure over the past 18 years. Currently within the under flooding zone are 50 settlements, 250 industrial enterprises, 10 thousand hectares of irrigated land, recreation facilities for 200 thousand people. On 1994 the total damage to the economic sector was estimated approximately $ 82.0 billion USD (Последствия изменения климата…, 1997).

With climate warming in the coming years, the sea level will vary from -26,0 m to -25,0 m . Analysis of current situation let us make the conclusion that for forecast of climate change impact on coastal areas of the Caspian Sea must be counted the cost with the sea level -25,0 m. (A same level was observed in 1882). In case of the sea level rise for another 150 cm flooding will catch approximately additional 87.7 hectares by 2030-2040. The total 136.2 thousand hectares of the flooded areas are expected and it is 1.6% of the total country's territory. The socio-economic damage to Azerbaijan economy will be 4.1 billion US dollars.

For economy prevention and loss minimization it is necessary to stop the development within flooded and possible flooding areas in case of the see levels -26 and -25 m for the next 30-40 years and reduce the risk of capital and ecological disaster (Мансимов и др., 2000).

Forecast of climate change. Forecast of climate change is given by the study results of the National Center on Climate Change. Along with global warming the regional climate changed is observed in the Republic of Azerbaijan (Мансимов и др., 2000). In recent decades, prolonged drought sharply effects to water flow dwindling of the Kura and Araz rivers. To identify possible climate change within Azerbaijan territory the National Center on Climate Change used long term observation data (about 100 years) of the 16 representative meteorological stations in the region. Based on the results general atmosphere circulation simulation the possible scenarios of climate change have been developed. National experts summed up the results and used the softwares developed at the NASA Goddard Institute for Space Studies (GISS-USA), Canadian Centre for Climate Modelling and Analysis (CCCma), the United Kingdom Meteorological Office (UKMO), Geophysical Fluid Dynamics Laboratory (GFDL-W and GFDL-T, USA).

The trend analysis of the results in Azerbaijan shows that temperature of the air has increased about 0.5-0.6°C and warming value about 0.3-0.6°C in the last 100 years.

In all the country's natural zones the warming was indicated. Maximum warming observed in the Greater Caucasus, the Kura-Araz lowland (0.50-0.65°C); minimum in the mountains of the Lesser Caucasus and the coastal areas of the Caspian Sea (0.14-0.20°C). Decreasing in long-term atmospheric precipitation imperceptible (Мансимов и др., 2000). According to modelling results mentioned above, in case of increasing twice the amount of the CO_2 concentration in the atmosphere, the average temperature will increase about 4,11-5,82°C before the end of the next century. The results of the GISS and GFDL-W modelling is almost same (4.2-4.4°C). According to results of the UKMO and GISS modelling, in case of increasing twice the amount of the CO_2 concentration in the atmosphere, the average annual precipitation will increase about 4-12%. However, simulation in the CCCM and GFDL-T models shows precipitation reduction in the same territory about 1-19%, simulation in the GFDL-3 model shows minor changes in the reduction of precipitation (Table 1).

To cover the full range of possible climate changes within the territory of Azerbaijan, it was necessary to consider scenario for the minimum possible warming value. That scenario was simulated and developed by Azeri experts (Мансимов и др., 2000) and took due account of any regional peculiarities and climatic characteristics and the global background as well as. By the result of this scenario, in case of increasing twice the amount of the CO_2 concentration in the atmosphere, the average temperature will increase about 2,0°C and the average annual precipitation will be stable or a little bit lower then background value.

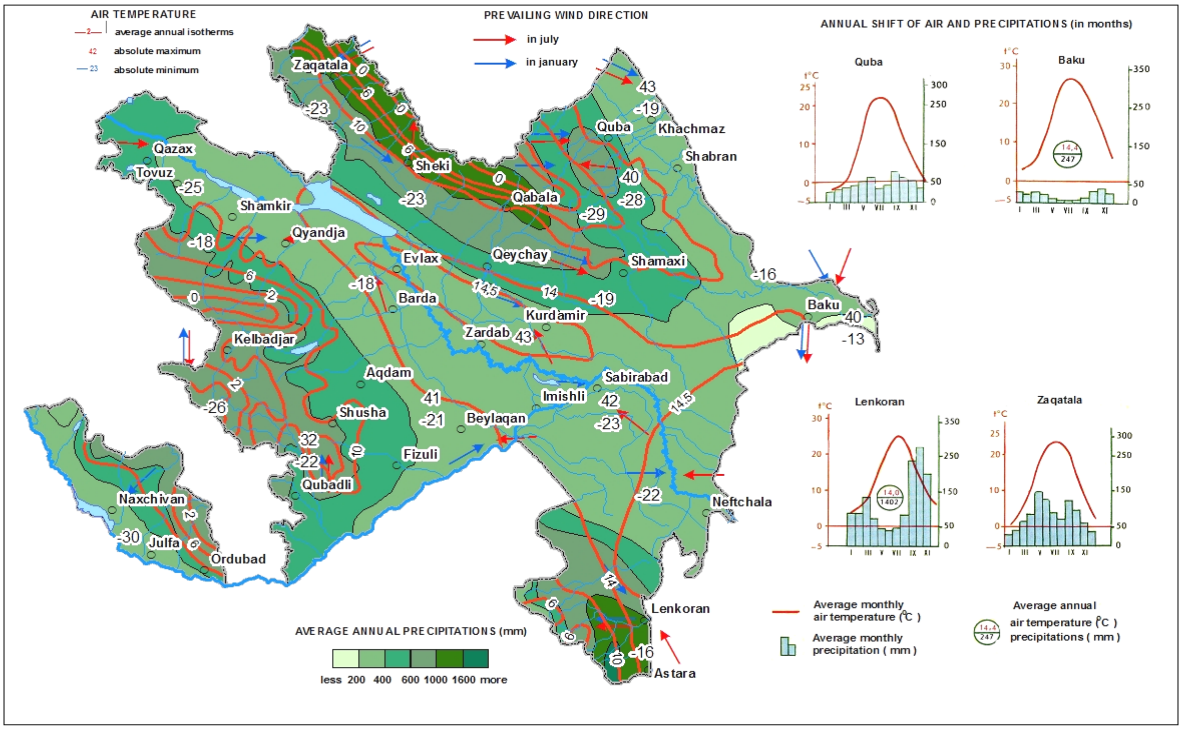

Fig. 2. Climate map of Azerbaijan

Table 1

Expected changes in temperature (dT,°C) and precipitation (R,%) in Azerbaijan in comparison with the background rate (Мансимов и др., 2000)

Scenarios of climate change based on simulation models of:	Time-of-year								Annual	
	Winter		Spring		Summer		Autumn			
	dT°C	R,%	dT°C	R,%	dT°C	R,%	dT°C	R,%	dT°C	R,%
CCCM	4,1	103	5,0	85	7,2	51	4,5	102	5,1	85
UKMO	4,0	99	4,6	107	5,4	90	4,9	118	4,7	106
GISS	4,9	119	3,5	98	4,0	125	5,1	97	4,4	107
GFDL-3	3,2	108	5,4	105	4,4	91	4,3	100	4,3	101
GFDL-T	4,6	115	4,5	100	5,3	66	4,6	101	4,7	98

Assessment of water resources vulnerability carried out based on the statistical models that taking into account peculiarities of runoff formation, depending on the basic parameters of climate. The calculations were performed for the catchment areas of Kura and Araz rivers, and other rivers directly flowing into the Caspian Sea. The long-term assessment of the water resources changes was done by using the results of the scenarios mentioned above and shown in the recent years an imperceptible river flow decline and streamflow redistribution inside a meteorological year. Altitude of the sustainable seasonal snow cover has risen from 1300-1500 m in the 1800-2000 m and snowfall intensity rate decreased significantly.

The water resources forecast by the GISS and GFDL-3 scenarios shows that if the temperature increases about 2.0-4.5°C it will reduce the water flow discharge: up to 15% by the GISS scenario, 20% by the GFDL-3 scenario and 10% – by the artificial scenario. According to the GFDL-3 scenario due to reducing precipitation in summer and autumn seasons that decrease runoff in these seasons and increase the values of the winter and spring runoff (Table 2, 3).

The study results show that in implementing of all three scenarios the water resources will be reduced to 5.7-7.7 km^3. With the current water deficit of about 5 km^3 this value could be rise to 9.5-11.5 km^3, until the middle of the XXI century (Table 3). As a result, the most vulnerable sectors of the economy will be energy, agriculture and potable water supply of the country population.

In this situation, it is necessary to make an additional studies and assessment of the water supply sources and develop a Regular Water Management Information System. At the final stage it is very important to draw up the specific water conservation recommendations for different fields of country's economy for reduce the future impacts of climate change on water resources.

Risk assessment in water resources loss. The above data show that, due to climate change, there is a risk of water resources loss. So, the risk analysis for the large-scale hydrological systems very important when analysing the climate change impact on water supply.

It is becoming increasingly apparent the necessity of application of the probabilistic and statistical methods when analysing source data and risk assessment by climate models. As noted in several studies, for assessing the climate change impacts on the water resources loss it is necessary to pass from the deterministic approach to statistical under uncertainty. N. Stern and C. Taylor (2007) used an integrated assessment model, which explicitly take into account the risk of climate impacts for the global scale of economic evaluation (through conducting active discussion about the importance of risk aversion and the desire to control situation for reduce the risk) (Nordhaus, 2007; Stern, Taylor, 2007; Fishburn, 1977; Anthoff et al., 2009).

Taking into account the strong water stress in Republic, the risk assessment methodology developed before is adapted in this article for current situation in the country. In this case, the risk assume a situation that the value of the water loss leads reduce the water resources in the existing situation of potable water deficit.

Table 2

Water resources vulnerability degree due to the climate change forecast scenarios (Мансимов и др., 2000)

Scenarios of climate change by:	Water resources forecast (km^3/year)			General water resources data (km^3/year)	
	Resources	Deficit	Deficit in %	Long-term parameters	Vulnerability degree
GISS	25,0	11,3	45,2	29,3	Highest
GFDL-3	23,5	11,5	48,9	29,3	Highest
Artificial	26,4	9,48	35,9	29,3	Moderate
Background (long-time average annual)	29,3 ~30	5,02	17,1	29,3	Minor

Table 3

Expected water resources and consumptive use of Azerbaijan rivers due to the climate change forecast scenarios (Mansimov et al., 2000)

Indexes	Background	Expected according to scenarios of climate change		
		Artificial	GISS	GFDL-3
Natural (including water intake by transboundary countries)	29,3	26,4	25,0	23,5
Available (including water intake from Samur river)	24,8	22,0	21,2	20,9
Water use	22,8	26,0	26,0	26,0
Regulating releases	6,99	6,47	6,47	6,47
Water deficit with considering releases	5,02	9,48	11,3	11,5

Method used. One of the basic principles of risk assessment was formulated in 1967 by Farmer (Farmer, 1967). According to this principle the frequency (probability) dependence of undesirable situations is formed from their consequences (in this case are the water resources loss).

The first time the author come up with a relationship in the form of a hyperbolic curve between the average amount of radioactive substances emissions into the atmosphere and the event probability, which is called as a boundary, or a permanent risk curve (it is called by the author name "Farmer curve").

This curve divides the coordinate plane into two parts and that allots the areas with unacceptable – high risk (above and to the right of the constant risk line) and the tolerable risk area, located below and to the left of line mentioned above.

Thus, the curve can be used as a safety criteria that defines the upper limit of acceptable probability. According to studies, risk analysis provides:

– probability determination of undesirable events;
– assessment of possible water loss reasons;
– assessment of possible water loss situations.

The first stage allows to identify the risk on a statistical basis using the comprehensive theoretical and experimental approaches, including water-loss data collection, interrogation method and etc. The water loss values were compared on the basis of different climatic conditions. The probability of water losses occurrence was assessed according to their frequency as well.

This results analysis, selected intervals' value, related accident frequency, material expenditures and the estimated risks' values are outlined in the scientific publications by G.M.Efendiyev, K.A.Jafarov (2008); T.V.Hismetov, G.M.Efendiev, K.A.Djafarov, A.A.Abdirov (Хисметов и др., 2009). In the mentioned publications the accident consequences and their risk in the time of borehole drilling were assessed. Same approach is used to assess risk of water resources loss.

The results obtained by such assessment allow to develop the appropriate measures for risk reduction of the water supply in the different fields of economics and water resources protection under the water stress condition. For water loss risk evaluation and classification with involving linguistic categories built a curve of "water resources loss frequency – water resources loss value (Figure 3).

In this case the different risk graduations may occur. The points which are trapped in the unacceptable risk area will not always belong to the same risk category. According to the risks' classification (Table 5), within each of these bands are allocated different risk categories also (Figure 3). The areas, corresponding to certain risk categories with the constant risk curve, are clearly seen here.

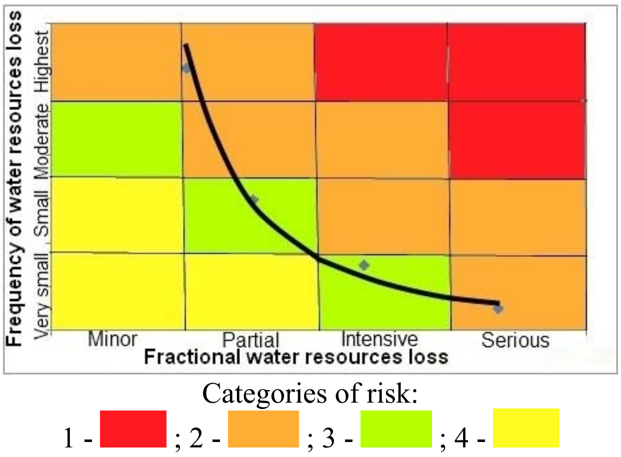

Fig. 3. Correspondence between the categories of relative water resources loss and their probabilities

The information about water resources loss values for different scenarios are divided into the four groups. The different water loss degrees are determined within each group. The appropriate quantitative and qualitative evaluation of the relevant probabilities and consequences are presented.

As the correlation analysis result an analytical approximation of the relationship between the relative water loss and the water losses frequency was determined in the following form:

$$p = 0{,}059q^{-2} \qquad (1)$$

where: p – loss frequency, q – relative vulnerability of water resources loss (consequence). In Table 4 there are estimation results of risk assessment of water resources loss. For that, the parameter $K = q^2$ is multiplying to the losses probability - p. In order to further the water losses risk classification the risk score was calculated for all possible options' combinations and probabilities' consequences. The results are shown in Table 5.

The table rows describe the category of the loss degree and the columns represent the quantitative estimation of these events probability (frequency). The category of loss degree (vulnerability) in the table are presented as follows: Very high – more than 10 km^3; high – 5.0 km^3 / year; medium – 2.5 km^3 / year; very minor – less than 1.0 km^3/year.

For the probability (frequency) loss characterization should be used not only quantitative assessment but qualitative as well (Table 6). For the best visual presentation of the losses degree and their probabilities based on table 6 separate risk value is assigned to the each sequence numerals 1 to 16 and table 7 is created.

For example, as can be seen from the table above, a very high level of risk can be identified for the catastrophic water intake as part of frequent and probable events (the coefficient are 1 and 3, respectively), or for serious consequences of the frequent event (the coefficient is equal to 2).

After the quantitative risk assessment (based on the water intake) mentioned above, the table of the qualitative and quantitative risk assessments correspondence is created (Table 7).

Table 4

Data of possible options and combinations of risk impacts (effects) and probabilities

Vulnerability degree (consequences)	Probability categories (frequency) of event			
	Highest (Frequent) (0,60)	Moderate (Probable) (0,30)	Minor (Rare) (0,15)	Very minor (Incredible) (0,05)
Very High (1)	0,6	0,3	0,15	0,05
High (0,7)	0,294	0,147	0,0735	0,0245
Medium (0,45)	0,1215	0,0608	0,0304	0,0101
Very minor (0,3)	0,054	0,027	0,0135	0,0045

Table 5

Qualitative and quantitative assessment of water resources loss probability (frequency)

Category event probability (frequency)	Qualitative assessment	Quantitative assessment
Highest (Frequent)	Events (loss) occur quite often	0,30-0,60
Moderate (Probable)	Possible loss, but in a small volume	0,15-0,30
Minor (Rare)	Event (loss) likely is not happen, but is not excluded	0,05-0,15
Very minor (Incredible)	Event (loss) is very improbable; in this case the situation is not catastrophic	0-0,05

Table 6

Quality line between vulnerability degree and probability (frequency) characteristics of water resources loss

Vulnerability degree (consequences)	Probability categories (frequency) of event			
	Highest (Frequent)	Moderate (Probable)	Minor (Rare)	Very minor (Incredible)
Very High	1	2	4	10
High	3	5	7	13
Medium	6	8	11	15
Minor	9	12	14	16

Table 7

Relation between quantitative and qualitative risk assessments of water resources loss

Relative risk category	Quantitative risk assessment	Qualitative risk characteristics
1	1-3	Very High
2	4-10	High
3	11-13	Medium
4	14-16	Minor

Conclusion. Problems of guaranteed water supply of all social and economic spheres of the national economy, that is, water security, is a basic component of the country's sovereignty and, in particular of Azerbaijan Republic. To meet the needs of conditioned water for all sectors of the Republic economy, there is currently an acute shortage, even taking into account the transboundary waters, coming to us from neighboring states. In fact, cross-border river flow is about 70% of the total river flow. Currently, freshwater resources are in fact limit the development of almost all sectors of the national economy. At the same time, climate scientists predict that climate change scenarios have preconditions to reduce rainfall, both in the near and distant future. Along with the general shortage of the Republic water balance, the main indicator of the tension growth in this area is the severe pollution of transboundary waters. This factor greatly increases the strength of the water deficit of the Republic and calls for effective measures to tackle the problem at the level of interstate relations. Further aggravation of the water balance deficit will inevitably lead to problems in the economic and social spheres of the country. Without water security and its sustainable development the Republic may face insurmountable difficulties in the future, which limit our sovereignty. Therefore, an important task is to assess the degree of risk of water resources loss, based on different scenarios of climate parameters change, transboundary water pollution and other factors. On the basis of probabilistic and statistical analysis, the technique of assessment of water resources loss risk, including the classification of the consequences, their occurrence probability, analysis and risk classification, has been proposed.

The results of evaluation of water resources loss will help to develop priority adaptation measures to minimize the consequences of the water crisis.

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