

# Climate Change and the Problem of Malaria in Armenia

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**Abstract**—The data presented in this work show that in Armenia a rise of air temperature is expected in the season, and annual terms. As a result of the noted increase in temperature, a significant growth of vulnerability of the territory of Armenia in relation to malaria is expected. Zoning by the risk of renewed malaria transmission has been performed.

**Keywords**—Armenia, climate change, malaria, zoning of Armenia.

## I. INTRODUCTION

CLIMATE change, particularly warming, has pronounced direct or indirect effects on the human population, and contributes to the spread of many infectious and parasitic diseases [2], [3], [7], [9], [14], [15]. Major global mortality factors, including malaria, diarrhea and malnutrition, depend on climatic conditions [20]. The evidence of a higher incidence of vector-borne diseases, which include malaria, in years with unusually high temperatures confirms the dominant role of the temperature factor in the spread of vector-borne diseases [4]. It was found out that any change in the environment that occurs as a result of natural causes or human activity can alter the ecological balance between the agent of malaria, vectors and population [6], [10], [13].

According to the World Bank, by the end of the twenty-first century, Armenia will be among the five countries of Eastern Europe and Central Asia especially subject to be affected by dangerous hydrometeorological phenomena [19].

The first mention of malaria in Armenia belongs to the ancient period. The prevalence of malaria in Armenia was contributed by both geographical location and climatic conditions of the country. The fact that Armenia was at the crossroads of major trade routes from east to west and from south to north, contributed to entry of different agents of malaria to its territories.

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The negative impact of climate on human health and as a result on the spread of various diseases, in particular such as malaria, is shown by the foremost 5th century Armenian historian Movses Khorenatsi, who describes the involuntary resettlement of the Armenian capital Artashat based in the 2nd century BC to Dvin: "At that time Ares accompanied the sun and blowing hot, infested, malodorous winds. Residents of Artashat, incapable of bearing it, readily agreed to move". Dvin with a population of 100,000, which was situated northwest of Artashat, became the new trade center on the international trade routes [5].

According to the Greek geographer and historian Strabo, the Araks River in the 1st century BC had not a well-defined channel and branched into the forty arms which flew inland swamping large spaces there [17].

In these circumstances, it is no mere chance that the first original medical book written in the Armenian language in the XII century was devoted to the question of febrile illnesses. "The consolation in fevers" is the main work of Mkhitar Heratsi, the founder of the medieval Armenian medicine [11].

Traditions of Armenian classical medicine were continued in the works of the foremost Armenian physician of 15th century Amirdovlat Amasiatsi. The main work of the scientist is the book "The Benefit of Medicine" which served as a practical guide for Armenian physicians until the 18th century. In the book, a considerable space is devoted to descriptions of febrile diseases many of which are detailed descriptions of the various presentations of malaria [1].

Information on malaria in Armenia after the 15th century is scanty. The available literature shows that since the end of 19th century malaria was a true scourge for the Armenian population [16], [18].

A systematic study of the problem of malaria in Armenia essentially began after the organization of Tropical Institute in Yerevan in 1923, which was the first scientific institution in Armenia and the second institution of this profile in the USSR. The institution were responsible for the conduct of scientific research on the diagnosis, clinical progression features, epidemiology, prevention of malaria and other parasitic diseases, development of effective prevention and control measures.

Progress in malaria control became possible due to the development and implementation of scientifically grounded system of anti-malaria activities, including introduction of new methods and tools of malaria control to practice of health care of the republic.

Through the development and implementation of highly-efficient complex activities for malaria control, in 1949 the

quartan malaria was eliminated in the republic. In 1953, tropical malaria was eliminated. At the same time, malaria early was eliminated as a mass disease, and in 1963 the practical elimination of malaria was achieved in Armenia.

During the elimination of malaria, it was repeatedly noted that in Armenia there is a real threat of localized outbreaks of malaria. Due to the proximity of Armenia to Iran and Turkey, the development of tourism in Africa and Asia, regular visits to Armenia of persons from the countries where malaria is a concern, and situation developing in Azerbaijan and Georgia, the threat of introduction and spread of malaria actually increased.

The spread of malaria is determined by several factors, among which migration is of particular importance due to possibility of importation of infection to territories previously improved. Particular threat in terms of local malaria is a delivery of tertian malaria due to the good adaptation of agent to a temperate climate and vector.

Malaria situation in Armenia began to deteriorate in 1994. Analysis of the epidemiological situation in Armenia showed that the imported cases of malaria became a trigger of the epidemic process resulted in a situation that can be defined as a large outbreak of a tertian malaria. In fact, an epidemic outbreak of malaria occurred after the implementation of the program of elimination of malaria in Armenia in 1963 when the source of infection had been really eradicated.

The maximum number of the cases – 1156 – was recorded in 1998, including 542 cases of local origin. More than 89% of the cases were found in Ararat and Armavir marzes located in the Ararat valley, where anophelogenous reservoirs occupy large areas.

In accordance with the basic principles of the WHO strategy "Roll Back Malaria", which became a new milestone in the fight against malaria, with substantial financial, scientific and practical support from WHO, UNICEF, UNDP, the International Federation of Red Cross and Red Crescent Societies, the World Food Programme, World Bank and the governments of Italy and Norway, the Ministry of Health Care has implemented a number of comprehensive anti-epidemic measures in the framework of the regional project "Roll Back Malaria", which resulted in significant reduction of the number of cases. Since 2006, there was no malaria cases of local origin recorded in Armenia.

In 2011 WHO declared Armenia a country free of malaria.

An epidemic outbreak of malaria in Armenia in the 90-ies of the last century was due to environmental factors, socio-economic factors, factors determining the distribution of the vector, as well as factors related to the human organism. Temperature factor is one of the most important factors determining the malariogenecity of a territory [8].

As malaria is limited primarily to temperature, the aim of this work is to study the effect of climate warming on the

malariological environment in Armenia, to zone the country in terms of risk of renewed transmission, to assess the impact of predicted climate change on the level of malariogenecity.

## II. MATERIALS AND METHODS

For a malariological description of territories we used long-term average daily temperatures for 1998-2008 according to Armenian State Service of meteorology and monitoring. We presumed that for objective assessment of climate warming impact on the spread of malaria in Armenia, analysis of temperature data for the last decades with daily resolution was required. Data were collected from 13 meteorological stations. Calculation of the elements of malaria season was made according to Moshkovsky Sh. D. (1950) [12]. 16 °C was taken as a threshold temperature for *P.vivax*, 14.5 °C was taken as a calculated threshold temperature, and 105 °C was taken for the amount of heat required for the maturation of sporozoites for *P.vivax*. Elements of malaria season were calculated according to data from separate meteorological stations. The number of cycles of sporogony and the number of infection cycles, that characterize the capacity of the transmission season in certain areas, were calculated.

To obtain the most detailed information on climate change and to develop regional-scale scenarios, data of PRECIS model (Providing Regional Climates for Impacts Studies) developed at the Hadley Center (UK Met Office) were used, with a horizontal resolution of 25x25 km.

## III. RESULTS AND DISCUSSION

In Armenia in 1929-2011, an increase in annual temperature by 1.03 °C (Fig. 1) and decrease in precipitation by 6% were observed. However, changes in temperature and in precipitation had different trends in different regions and at different seasons.

Over the last 16 years (except 2003) there was a steady increase in summer temperatures, and the summer of 2006 in Armenia was the hottest for the years 1929 to 2011. In Ararat valley, Meghri and north-east of the country an increase in average temperatures in the range of 14-16 °C was noted. Such average temperatures were not observed in 1961-1990. In Ararat Valley there was an expansion of zone up to 14 °C, in Sevan basin it exceeded 5 °C, in Meghri there was an expansion of zone which exceeded 14 °C. Thus, the rise of temperature spread to large territories.

The results of calculations on determination of the number of possible infection cycles and cycles of sporogony, which were based on the average daily temperatures obtained from 13 meteorological stations located in the territories belonging to different climatic zones, are presented in Table I.

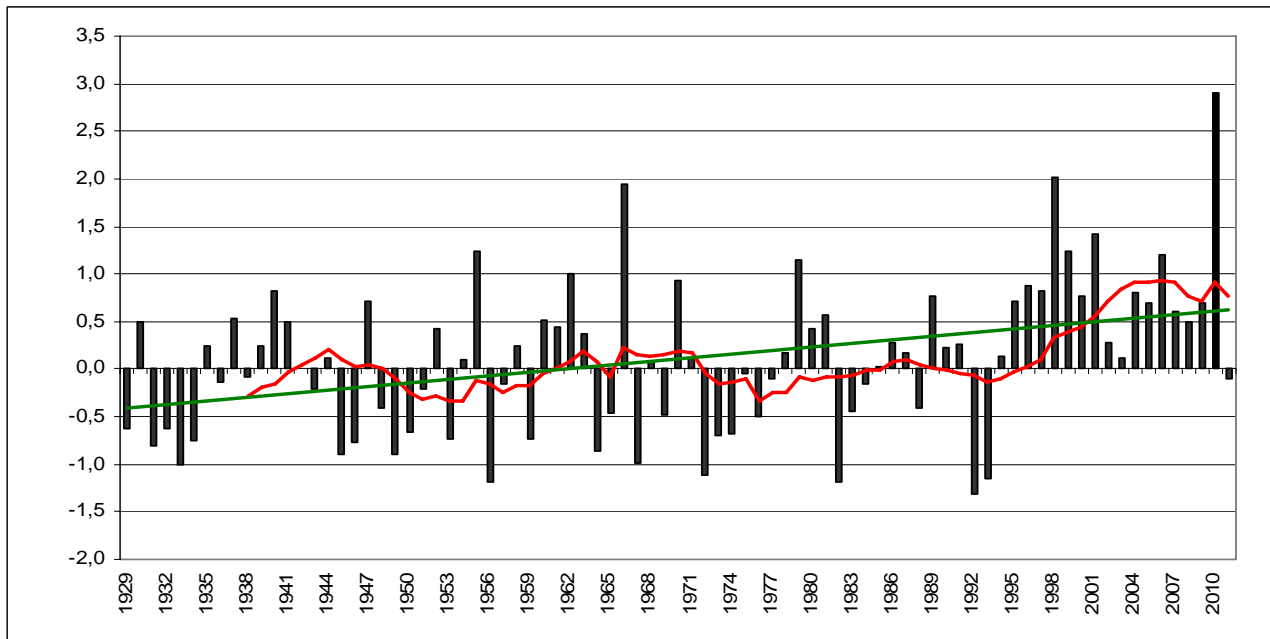


Fig. 1 Deviation of annual temperature in Armenia in 1929-2011 compared with the average values

TABLE I  
POSSIBLE NUMBER OF INFECTION CYCLES AND CYCLES OF SPOROLOGY IN  
CERTAIN TERRITORIES

Meteo Stations	Climatic zones	Cycles	Cycles of sporogony
Artashat	dry semiarid	6, 0	12, 2
Armavir	dry semiarid	5, 2	11, 0
Ashtarak	temperate continental semiarid	5, 2	10, 6
Gavar	wet mountain-steppe	-	1, 0
Martuni	wet mountain-steppe	1, 2	1, 6
Hrazdan	wet mountain-steppe	1, 6	2, 4
Gyumri	dry steppe	2, 5	4, 4
Jermuk	wet mountain-steppe	1, 2	1, 6
Vanadzor	wet mountain forest	1, 3	2, 4
Kapan	warm-temperate forest	5, 0	9, 2
Meghri	dry subtropical	6, 3	13, 8
Ijevan	warm-temperate forest	4, 3	7, 6
Yerevan	dry semiarid	6, 0	12, 0

As can be seen from the data in all the territories of Armenia there are temperature conditions that allow the completion of sporogony in the vector. However, the noted territories vary greatly in the number of infection circles, which characterizes the capacity of malaria season. Thus, the

maximum number of infection circles (5 or more) can be completed in Artashat, Armavir, Ashtarak, Kapan, Meghri and Yerevan, located in the warm temperate forest, dry semiarid and dry subtropical climates. Minimum number of circles (up to 2) can be completed in Martuni, Jermuk, Hrazdan and Vanadzor, placed in the wet mountain-steppe zone. From 2 to 5 circles can be completed in Gyumri and Ijevan. In Gavar temperature conditions do not permit the completion of a single circle of infection. The results of calculations of malaria season elements using analysis of temperature data for 1998-2008 with daily resolution allowed to perform zoning of Armenia according to the risk of renewed transmission of malaria, with separation of territories:

- hypermaliarogenic – with high level of risk of renewed transmission of the pathogen (Artashat, Armavir, Ashtarak, Kapan, Meghri, Yerevan);
- mezomaliarogenic – with an average level of risk (Gyumri, Ijevan);
- hypomaliarogenic – with low level of risk (Martuni, Jermuk, Razdan, Vanadzor).

These territories are distinguished by the level of vulnerability, which is determined by presence of local vectors and their ability to support the transmission of malaria, as well as by climatic conditions.

The territory of Armenia, where malaria elimination is achieved, not only can preserve its vulnerability in the long run, but also can be characterized by its increase as a result of climate change and the continued importation of infection.

Based on the modeling of climate change in 2071-2100, scenarios of change of climate parameters were developed, which are presented in Table II.

TABLE II  
ANOMALIES OF SEASONAL AND ANNUAL TEMPERATURE (°C) IN 2071-2100  
WITH RESPECT TO THE NORM OF 1961-1990 (ACCORDING TO REGIONAL  
MODEL OF PRECIS)

Area	Temperature, °C				
	Winter	Spring	Summer	Autumn	Annual
North-East	4	4	4, 5	2	3, 6
Sevan Lake Basin	5	3, 5	6	6	5, 1
Shirak	4	4	4, 5	5	4, 4
Aparan-Hrazdan	5, 5	7	3	5	5, 1
Ararat	4	5, 5	2	3	3, 6
Vayk	6	6	6	6	6, 0
Syunik	2	2, 5	4	3	2, 9
Armenia	4, 4	4, 7	4, 2	4, 3	4, 4

The results show that in Armenia a rise of air temperature is expected in both season and annual terms. This rise will have a maximum value in summer (by 4-6 °C). In Armenia temperature rise differs from region to region: it is expected that in the western and central regions (especially in the Ararat valley) the rise will be higher than in other parts of the country, in the foothills the temperature will raise moderately.

The results of calculations for these scenarios may be essential to prevent the negative impact of the growth of the vulnerability of the territories in regard to malaria. According to this model, on the entire territory of Armenia a significant increase of temperature is expected. This change will be most pronounced in the summer and in some areas will be 5-9 °C. A significant temperature increase is expected in the western and central regions of Armenia, particularly in the Ararat valley. In southern areas, particularly in the foothills of Syunik, a moderate increase in temperature is expected.

As a result of the noted increase in temperature, a significant increase in the vulnerability of the Armenian territory in relation to malaria is expected. In particular, at the expected rise in temperature the completion of infection cycle in Gavar and increase in vulnerability in all hypermalariaogenic territories will be possible. In addition, with climate warming a significant increase in the vulnerability of territories located in mountainous areas is expected, where malaria transmission is restricted by lack of heat. As a result of noted climate change altitudinal limit of the possible vertical spread of malaria can move to a higher altitude.

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