Climate Change: Implication for Food-Borne Diseases (Salmonella and Food Poisoning Among Humans in R. Macedonia)

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Additional information is available at the end of the chapter

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1. Introduction

Using the classic epidemiologic triad (host, agent, and environment), it is clear that climate, which impacts all three sectors of the triad, can have a dramatic effect on infectious disease. Evidence of the impact of climate change on the transmission of food and waterborne diseases comes from a number of sources, e.g. the seasonality of foodborne and diarrhoeal disease, changes in disease patterns that occur as a consequence of temperature, and associations between increased incidence of food and waterborne illness and severe weather events as "in reference [1,2]. There are also theoretical and unintended consequences of global climate change on food safety. Climatic factors influence the growth and survival of pathogens, as well as transmission pathways as "in [3]". Higher ambient temperatures increase replication cycles of food-borne pathogens, and prolonged seasons may augment the opportunity for food handling mistakes - in 32% of investigated food-borne outbreaks in Europe "temperature misuse" is considered a contributing factor [4].

Climate change associated diseases are estimated already to comprise 4.6% of all environmental risks. It has been estimated that climate change in the year 2000 contributed to about 2.4% of all diarrhoea outbreaks in the world, 6% of malaria outbreaks in certain developing countries and 7% of the episodes of dengue fever in some industrial countries. In total, the estimates show that mortality due to climate change has been 0.3%, whereas the related burden of disease has been 0.4% [5]. Climate change is linked to human health in a complex manner. There are direct impacts, such as diseases and conditions that may result in morbidity or mortality related to extreme temperatures, and other, more indirect health effects such as diseases related to consumption of contaminated drinking water, foodborne or vector-borne diseases and zoonoses, or health conditions related to lack of food and water. There are projections regarding the expansion of diseases from the southern to the northern latitudes, especially re-emerging diseases that had already been eradicated, such as malaria, yellow fever, etc. Changes have also been detected in the distribution of rodent borne diseases, such as the hantavirus disease and leptospirosis. Geographical, weather and environmental changes are likely to affect the vectors of disease and to have a corresponding impact on the distribution of diseases such as leishmaniasis, Lyme disease, tick-borne encephalitis, malaria (in endemic regions), dengue, etc. An increased burden of disease related to drinking water and food may be expected due to inadequate distribution at a global level and the projections for decreased availability of drinking water and food production (cholera and food poisoning). Exposure to extremely high temperatures may lead to cardiovascular or respiratory diseases, whereas extreme disturbances in climate conditions (floods, warm winds) may lead to injuries, choking, respiratory disorders, diarrhoea, etc. Increased temperature and floods are the cause of` an increase in water contamination and resulting food- and waterborne diseases. Climate change is also likely to have an impact on the distribution of aeroallergens, especially pollen, and thereby cause changes in the distribution of allergic diseases. On the positive side, health conditions related to extreme low temperatures will decrease [6,7]

Weather effects, especially related to temperature, act in an indirect manner as regards transmission of infectious diseases. Temperature may affect both the causes of infectious diseases and their carriers (vectors) or water supplies. The link between weather impacts and infectious diseases has led to the development of scenario models to predict the expansion of infectious diseases due to climate change. Changed lifestyles, food production, modern urban planning, climate change and variations in the quality of the environment increase the danger of expansion of zoonoses.

Before the prospect of anthropogenic climate change emerged, epidemiologists were not greatly interested in climate-health relations [8]. Modern epidemiology has focused mainly on studying risk factors for noncommunicable diseases in individuals, not populations. Meanwhile, there have been occasional studies examining deaths due to heatwaves, some epidemiological studies of air pollution incorporating temperature as a covariate, and a continuation of the longer standing research interest in meteorological effects on microbes, vectors, and infectious disease transmission. Overall, the health risks of climate-related thermal stress, floods, and infectious diseases have been the most amenable to conventional epidemiological studies. Can current effects be estimated, if not yet directly observed? The current burden of disease attributable to climate change has been estimated by WHO as part of the Global Burden of Disease (2000) project as "in reference [5]", as a comprehensive standardised risk assessment exercise that underwent critical review. The estimation of the attributable burden was a statistical exercise that entailed three steps: (i) estimation of the baseline average annual disease burden in 1961–90; (ii) specification (from published work) of the increase in disease risk per unit increase in temperature or other climate variable; and (iii) estimation, by geographic region, of the current and future global distributions of population health effects of the change in climate. The extent of climate change (relative to the 1961–90 average climate) by the year 2000 is estimated to have caused in that year around 160 000 deaths worldwide and the loss of 5 500 000 disability-adjusted life-years (from malaria, malnutrition, diarrhoeal disease, heatwaves, and floods). This exercise was conservative in several respects, including being limited to quantifiable health outcomes. Nevertheless, is it reasonable to attribute a proportion of global deaths from malaria, malnutrition, or other such outcomes in 2000, to the global warming that has taken place since around 1975? The fact that equivalent estimations are routinely made for other such relationships involving a disease with known multivariate causation—eg, the proportion of all stroke deaths in 2000 attributable to hypertension—suggests that, in principle, wherever a well documented exposure-effect relation exists, the incremental change in health outcome can legitimately be estimated for an incremental exposure (eg, temperature) [8]. Climate change is perhaps the most significant environmental problem which mankind will face in the coming century. Efforts to reduce the extent of climate change are of course important, but it is likely that we will have to deal with at least some impacts on health. Climate change is linked to human health in a complex manner. There are direct impacts, such as diseases and conditions that may result in morbidity or mortality related to extreme temperatures, and other, more indirect health effects, such as diseases related to consumption of contaminated drinking water, foodborne or vector-borne diseases and zoonoses, or health conditions related to lack of food and water. Cimate change will have consequences for the health of Macedonian citizens as well. In 2006 a report on the Vulnerability and Adaptation of Climate Change in Health Sector has been published [9]. This report was the first of its kind in the country, insofar as it sought to provide quantitative estimates of the possible impacts of climate change on health.

2. Climate change and food security and utilization

The Food and Agriculture Organization (FAO) defines food security as a ‘‘situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life’’ [10]. This definition comprises four key dimensions of food supplies: availability, stability, access, and utilization. The first dimension relates to the availability of sufficient food, i.e., to the overall ability of the agricultural system to meet food demand. Its subdimensions include the agro-climatic fundamentals of crop and pasture production [11] and the entire range of socio-economic and cultural factors that determine where and how farmers perform in response to markets.

Climate change affects agriculture and food production in complex ways. It affects food production directly through changes in agro-ecological conditions and indirectly by affecting growth and distribution of incomes, and thus demand for agricultural produce. Impacts have been quantified in numerous studies and under various sets of assumptions [12].

Depending on the SRES emission scenario and climate models considered, global mean surface temperature is projected to rise in a range from 1.8°C (with a range from 1.1°C to

2.9°C for SRES B1) to 4.0°C (with a range from 2.4°C to 6.4°C for A1) by 2100. In temperate latitudes, higher temperatures are expected to bring predominantly benefits to agriculture: the areas potentially suitable for cropping will expand, the length of the growing period will increase, and crop yields may rise. A moderate incremental warming in some humid and temperate grasslands may increase pasture productivity and reduce the need for housing and for compound feed. These gains have to be set against an increased frequency of extreme events, for instance, heat waves and droughts in the Mediterranean region or increased heavy precipitation events and flooding in temperate regions, including the possibility of increased coastal storms [13]; they also have to be set against the fact that semiarid and arid pastures are likely to see reduced livestock productivity and increased livestock mortality. In drier areas, climate models predict increased evapotranspiration and lower soil moisture levels. As a result as "in [10]", some cultivated areas may become unsuitable for cropping and some tropical grassland may become increasingly arid. Temperature rise will also expand the range of many agricultural pests and increase the ability of pest populations to survive the winter and attack spring crops.

Global and regional weather conditions are also expected to become more variable than at present, with increases in the frequency and severity of extreme events. By bringing greater fluctuations in crop yields and local food supplies and higher risks of landslides and erosion damage, they can adversely affect the stability of food supplies and thus food security.

Climate change will also affect the ability of individuals to use food effectively by altering the conditions for food safety and changing the disease pressure from vector, water, and food-borne diseases.

The main concern about climate change and food security is that changing climatic conditions can initiate a vicious circle where infectious disease causes or compounds hunger, which, in turn, makes the affected populations more susceptible to infectious disease. The result can be a substantial decline in labor productivity and an increase in poverty and even mortality. Essentially all manifestations of climate change, be they drought, higher temperatures, or heavy rainfalls have an impact on the disease pressure, and there is growing evidence that these changes affect food safety and food security

Extreme rainfall events can increase the risk of outbreaks of water-borne diseases particularly where traditional water management systems are insufficient to handle the new extremes [11]. Likewise, the impacts of flooding will be felt most strongly in environmentally degraded areas, and where basic public infrastructure, including sanitation and hygiene, is lacking. This will raise the number of people exposed to water-borne diseases and thus lower their capacity to effectively use food.

Vulnerability refers to the degree to which a system or societies are susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity [12]. Since impacts and adaptive capacity of systems may vary substantially over the next decades and within countries, vulnerabilities can be highly dynamic in space and time. Consequently, there is a strong need to build resilient agricultural systems that have a high capacity to adapt to stress and changes and can absorb disturbances. Impacts of climate change on food security are global and local. Climate change will affect agricultural food systems in all countries, including exporters and importers as well as those at subsistence level. Many impacts, such as increased land degradation and soil erosion, changes in water availability, biodiversity loss, more frequent and more intense pest and disease outbreaks as well as disasters need to be addressed across sectors. To describe the effect of climate change on a more global scale, the World Health Organization has released data regarding the estimated effects on human health as of the year 2004. What is readily apparent from these data is that developing regions of the world have been disproportionately affected by climate change relative to developed regions. This imbalance stands in stark contrast to the imbalance in greenhouse gas emissions, which are almost entirely attributable to developed countries, and countries with rapidly developing economies. The WHO report also includes estimates of the future global burden of disease that will result from climate change. It is predicted that by 2030 there will be 10% more diarrhoeal disease than there would have been with no climate change and that it will primarily affect the health of young children; indeed, the impact on children might well be amplified by the effects of such diseases on malnutrition, development and cognition. If global temperatures increase by 2–3°C, as expected, it is estimated that the population at risk for malaria will increase by 3–5%, which means that millions of additional people would probably become infected with malaria each year [14].

3. Current impacts of climate and weather

Nowadays, a wide range of events shape the behaviour and social interactions of the human host. The spread of childhood communicable diseases mirrors school calendars and community activities. Holidays promote travel and new social interactions, increasing the spatial distribution of disease transmission, even more efficiently vectored through packed planes and other modes of mass transportation. Seasonal shifts in immunity and host susceptibility, exacerbated by increased exposure through crowds during the colder months, will also increase patterns of infectious disease spread [15]. The first detectable changes in human health may well be alterations in the geographical range (latitude and altitude) and seasonality of certain infectious diseases – including vector-borne infections such as malaria and dengue fever, and foodborne infections (e.g. salmonellosis) which peak in the warmer months. Warmer average temperatures combined with increased climatic variability, would alter the pattern of exposure to thermal extremes and the resultant health impacts, in both summer and winter. By contrast, the public health consequences of the disturbance of natural and managed food-producing ecosystems, rising sea levels and population displacement for reasons of physical hazard, land loss, economic disruption and civil strife, may not become evident for up to several decades. New challenges associated with the emergence of large epidemics related to food consumption are arising as a result of globalization, increased trade in food products, increased consumption of fast food, international travel, environmental contamination by human faecal matter in areas with poor sanitation, the increased frequency of natural disasters related to climate change, the introduction of new technologies in food production processes, etc. There are different ways in which weather conditions can affect the incidence of foodborne diseases. Firstly, the prevalence of specific pathogenic organisms in animals may increase with higher temperatures. Secondly, the food cooling chain is harder to maintain in higher temperatures and prolonged warm weather increases the risk of mistakes in food handling. Thirdly, higher air temperatures may speed up the replication cycles of foodborne pathogenic organisms, which leads to a higher degree of contamination. Higher temperatures, in interaction with inadequate hygiene conditions, improper food handling, and lack of hand-washing, may lead to an increased number of epidemics resulting from consumption of unsafe food. In the Republic of Macedonia, foodborne and climate-sensitive pathogenic organisms causing the greatest concern in the context of climate change include the following:

Alimentary toxic infections (ATI) – These diseases were reported throughout the period 1991–2008, with fairly uniform prevalence each year. During the period there were a total of 26 092 cases of ATI, an average of 1450 cases a year. Total morbidity for the entire period was 1304.6 per 100 000, a yearly average of 72.4 per 100 000, with a clear tendency to maintenance. During the period, ATI continually ranked between fourth and sixth among the ten most frequently reported infectious diseases in the Republic of Macedonia, depending on whether ATI epidemics had been more common in any specific year. Syndromes related to ATI tend to be seasonal (with an increase during the summer months), with a few very large outbreaks reported in 2008, connected to specific closed communities and having one common source.

Shigellosis – In the Republic of Macedonia during 1991–2008, a total number of 2652 cases of shigellosis were reported, or 147 cases a year, with a total morbidity of 132.6 per 100 000 inhabitants for the entire period. The trend has significantly decreased over the last eight years, with the average being 35 reported cases each year. This is most likely due to improved access to safe food and drinking water as well as other provisions, proper and hygienic disposal of liquid and solid waste substances, and increased levels of health education and information among the general population regarding hygiene, safe food preparation, etc.

Campylobacter – The risk of infections caused by *Campylobacter* is directly proportional to the increase in temperature. Recent studies show increased incidence of campylobacteriosis at 2–5% per each degree Celsius rise of temperature, based on weekly temperature data. Notwithstanding that it is mandatory to report cases of campylobacteriosis in the Republic of Macedonia, there is currently no reliable information on its distribution, although estimates indicate that its incidence exceeds 18 000 cases annually.

Other foodborne pathogenic organisms causing concern in the context of climate change – These include *Brucella*, *Hepatitis A*, *E. coli* O157 H7 (EHEC) and bacteria causing bacterial food poisoning (e.g. *Clostridium perfringens*). As far as these pathogenic organisms are concerned, the effect of climate change remains within the area of speculation. However, due to their possible sensitivity to climate conditions and their importance for public health in the Republic of Macedonia, they have been included in the programmes for monitoring and prevention of climate-change-related infectious diseases. Such diseases are subject to mandatory reporting under the current legislation. Hepatitis A is constantly present in the Republic of Macedonia and there were 290 reported cases in 2009, 243 reported cases in 2008 and 257 reported cases in 2007.

Waterborne communicable diseases – About 10% of the population in the Republic of Macedonia still lacks access to clean and safe water, be it for drinking or for meeting their basic needs. In addition, there are year-on-year growing trends for certain groups of communicable diseases, especially those associated with contaminated food and water (salmonellas, alimentary toxic infections, shigelloses). Climate change will most probably have an impact on the incidence of waterborne infections, not only as a result of changing average meteorological parameters (e.g. rainfall), but also as a result of the increased frequency of extreme weather events, such as heavy rainfall, flash floods and droughts. Such extreme weather events will have an impact on the available quantity of water, on the quality of the water or on the availability of clean and safe water.

Waterborne pathogens include viral (*Hepatitis A*), bacterial (*Cryptosporidiae, E. coli*) and protozoan (*Giardia lamblia*) agents, which cause gastroenteritis. Waterborne diseases may even occur following adequate treatment of water. An example of this is the epidemic of cryptosporidiosis associated with the urban drinking water supply of Milwaukee, Wisconsin, USA in 1989, which resulted in 400 000 cases. Heavy rainfall may contaminate watercourses by bringing human and animal faecal products and other waste substances into surface waters. There is evidence of contamination of the water during heavy rainfall by *Cryptosporidium*, *Giardia* and *E. coli*. Contamination most commonly occurs in the event of high saturation of the soil due to a more efficient transport of microorganisms. Floods and low water levels may both lead to contamination of water and higher disease incidence and mortality due to diarrhoea. Warming and the higher variability of rainfall increase the risk of greater burden of these diseases. Pathogenic organisms identified as relevant for the former Yugoslav Republic of Macedonia in this context include:

Cryptosporidium – This has only recently been added to the list of infections that are mandatory to report; therefore, no details on incidence are available yet. No cases have been registered in the Republic of Macedonia so far.

Giardia lamblia – This has recently been added to the list of infections that are mandatory to report. At the moment no incidence data is available, other than information on laboratory isolates.

Leptospirosis – There is firm evidence showing that leptospirosis is affected by climate conditions. In the Republic of Macedonia, eight cases were reported in the period 1991–2008. Due to the lack of diagnostic facilities, it is assumed that a large number of cases have not been reported. Regions at high risk might include the rice fields in the region of Kocani, in addition to urban areas, riverbanks and lakes.

Vector-borne communicable diseases – Vector-borne infections are passed onto humans from arthropods or mammals, including rodents. Arthropod vectors, such as mosquitoes and ticks, are cold-blooded and thus especially sensitive to climatic factors. Climate change might have an impact on the distribution and the activity of arthropods. In addition, rodents are reservoirs of a large number of human diseases and the population of rodents is subject to the impact of weather conditions. Warm winters and warm springs may increase the population of rodents, a phenomenon that has been reported over the last few years.

Climate is an important factor for the distribution of vectors, in addition to other factors such as the destruction of their habitats, pest control and the density of hosts. Some vector-borne diseases sensitive to climate change have already been reported in the Republic of Macedonia (e.g. Lyme disease) and 4 human cases of West Nile fever in 2011 [16].

4. Temperature as a function of salmonella food poisoning cases in the Republic of Macedonia

The second largest number of human foodborne diseases is caused by the *Salmonella* spp. bacteria. In 2007, the European Union incidence was 31.1 cases per 100 000 population (151 995 confirmed cases), with eggs being the biggest contributors to these outbreaks, followed by fresh poultry and pork. Higher ambient temperatures have been associated with 5–10% higher salmonellosis notifications for each degree increase in weekly temperature, for ambient temperatures above 5°C. Roughly one-third of the transmission of salmonellosis (population attributable fraction) in England and Wales, Poland, the Netherlands, the Czech Republic, Switzerland and Spain can be attributed to temperature influences. Temperature has the most noticeable effect on salmonellosis and food poisoning notifications one week before disease onset, indicating inappropriate food handling and storage at the time of consumption. Indeed, an analysis of foodborne illnesses from England and Wales showed that the impact of the temperature of the current and preceding week has decreased over the past decades, indicating that the potential risk from elevated temperatures related to climate change can be counteracted through concerted public health action. Thus, regardless of climatic factors, health-behaviour interventions and food-safety regulations should be able to attenuate possible negative consequences on public health. Indeed, bacterial enteric infections have recently started to decrease throughout Europe, in part due to control measures [17,18].

Between 1971 and 2000, the annual mean temperature in the Republic of Macedonia increased by -0.1°C to 0.2°C in comparison to the period 1961–1991. Recorded values for the period 1996–2005 are 1.3°C higher for Demir Kapija and Prilep, 1.4°C higher for Stip and Bitola and 1.5°C higher for Skopje. Significantly higher mean annual temperatures were also recorded in 1999, 2002, 2003 and 2007, with the most dramatic variations of temperature recorded during the summer period. According to climate change scenarios, the average increase of temperature may reach 3.8°C in 2100 and the average decrease in precipitation may be 13% compared with 1970–1990 averages [16].

There are different ways in which weather conditions can affect the incidence of foodborne diseases. Firstly, the prevalence of specific pathogenic organisms in animals may increase with higher temperatures. Secondly, the food cooling chain is harder to maintain in higher temperatures and prolonged warm weather increases the risk of mistakes in food handling. Thirdly, higher air temperatures may speed up the replication cycles of foodborne pathogenic organisms, which leads to a higher degree of contamination. Higher temperatures, in interaction with inadequate hygiene conditions, improper food handling, and lack of hand-washing, may lead to an increased number of epidemics resulting from consumption of unsafe food. In the Republic of Macedonia, foodborne and climate-sensitive pathogenic organisms causing the greatest concern in the context of climate change include the following:

Salmonellosis – Recent studies on foodborne diseases show that disease episodes caused by *Salmonella* bacteria increase by 5-10% per each degree Celsius rise in temperature. During 1991–2008, 6969 cases of salmonellosis were reported in the Republic of increasing trend Macedonia, with total morbidity of 340.3 per 100 000, or an average of 387 cases a year, with an in recent years [19].

5. Materials and methods

Data on reported cases of Salmonella infection for the period 1998-2008 were obtained from the national surveillance centre, i.e., Institute for Public Health of R. Macedonia for the city of Skopje (capital) and countrywide. Data of average maximum weekly temperature for the same period were obtained from the National Hydrometeorological Office. The following age groups were also modelled: young children (0–6 years), children (7–14 years); adults (15–59 years); and the elderly (60+years). We investigated the epidemiological characteristics of salmonellosis both at the national level and in the city of Skopje using a retrospective research as a method of analysis. We created a Seasonal Index for the same period for monthly distribution of the reported cases for Skopje and for the entire country. The monthly number of reported Salmonella cases for Skopje was related to the average monthly temperature on the same month using Regression statistical analyses. For the analytical approach we made use of Poisson regression model. These techniques helped us in assessing any short-term effects of temperature on the disease. The Statgraphics Centurion software package was used.

For the prediction of the burden of the ambient Skopje temperature in relation with salmonella cases among humans and for determining the current burden for the period 1998-2008 as attributable factor, the following model was used:

5.1. PB=FB-CB

CB_{months} (^{0}C) = MT_{months} (2001…2008) - MT_{months} (1991…2000)

PB-Predicted burden as estimation of difference between future burden and attributable current burden; **FB**-Future burden of the monthly mean temperature due to Climate change estimated by scenario , **CB**- Current burden as attributable fraction of the monthly mean temperature due to Climate change, **MT**- Monthly mean temperature

Then the current burden of the weather temperature was compared by forecasting the future burden due to climate change in the period ranging 2025-2050 and 2075-2100 for the central region of Macedonia where the city of Skopje belong. The scenario from the Second National communication on climate change was used [20].

6. Results

Skopje, the capital, is the most populous Macedonian city. According to an official estimate from 2009, 20.5% of the total population registered in the country (2,052,722) lives in Skopje [21].

During the period 1998-2008, nationally, 3,890 salmonella human cases were registered; 1,951 (50.1%) males and 1,939 (49.9%) females. S. Entiritidis with 90% and S. Typhimurium with 8% are predominant serovars causing human infections in the R. Macedonia. 1,085 salmonella cases were reported in Skopje for the same period with an average of 8.2 patients per month (28% of the total national average; about 29 patients per month). Specific morbidity distribution of salmonellosis (rate per 100,000) in Skopje and countrywide are shown as follows (Figure 1).

While a decreasing tendency was registered at the national level, the analysis for Skopje showed increasing tendency of salmonella incidence. The salmonellosis morbidity rate for Skopje in 1998 was 8.3/100,000; in 2000, the rate was 24.6/100,000 and in 2008 was 41.2/100,000.

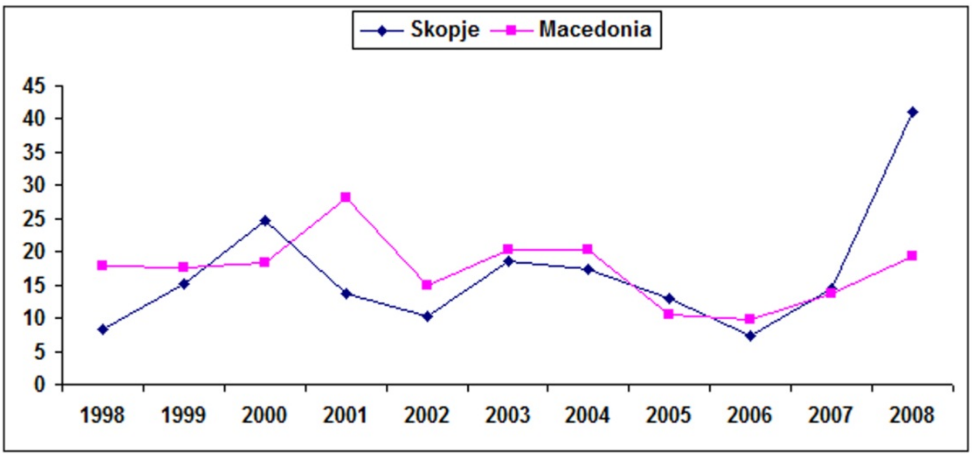

Figure 1. Reported Salmonella cases in humans in Macedonia and Skopje 1998-2008 (Mb/100.000).

Health Indicators	Total	Age groups								
		0 - 6	7 - 9	10 - 14	15 - 19	20 - 29	30 - 39	40 - 49	50 - 59	60 >
Skopje (Number of Salmonella cases)	1085	327	88	96	85	131	81	95	85	97
Specific Mb./ 100 000	142,4	646,1	400,9	239	198,7	141,8	90,3	117,6	108	103,8
Macedonia (Number of Salmonella cases)	3890	1023	334	459	297	416	394	385	272	310
Specific Mb./ 100 000	190,7	622,1	431,6	307	183,2	128,5	131,6	131,3	107,4	97,8

Table 1. Specific salmonella morbidity among humans (per 100,000) by age groups for Skopje and Macedonia during the period 1998-2008

The analysis of specific salmonellosis morbidity by age groups in Skopje showed higher morbidity among 0 to 6 year old children with 646.1/100,000 and lowest among adults from 30 to 39 years old with 90.3/100,000 (Table 1). At the national level, the higher morbidity was registered also among 0 to 6 years old children with 622.1/100,000 but the lowest was recorded among the elderly 60 years and above with 97.8/100,000.

The highest values of the Seasonal Index for Salmonella cases were registered in the summer months, i.e. June with 160.1%, July with 188.6%, August with 171.3% and September with 182.5%. The lowest reported Salmonella cases were registered in February with 20.7% (Figure 2).

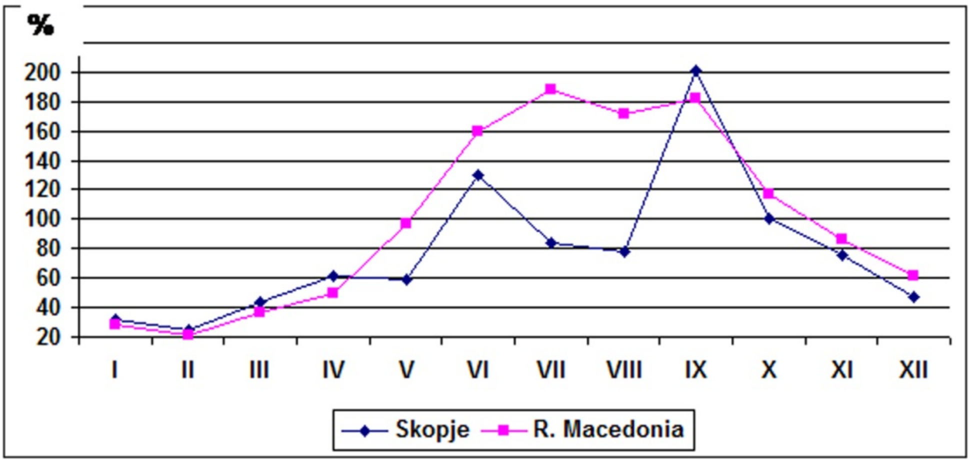

Figure 2. Seasonal Indexes for reported Salmonella cases in Macedonia and Skopje for the period 1998-2008 -distribution by months

Furthermore, in Skopje, the Seasonal Index for Salmonella cases showed two peaks in the summer months (September with 201.6%, and June with 130.5%). The lowest reported Salmonella cases were registered in February with 24.3%. The largest percentage of outbreaks of salmonellosis in the review period, were registered in the months with the highest seasonal index. A total of 42 outbreaks of salmonellosis or an average of 5 outbreaks per year was registered for the same period with a total 6,015 exposed persons. In these outbreaks, according to data obtained from epidemiological surveys, 1,871 persons (31.1% from total number of exposed) were registered as salmonella cases and 608 patients were hospitalized (32.4% from total registered patients). No deaths were recorded in those outbreaks.

The estimated correlation coefficient (0.54), indicates a moderately strong relationship between the monthly number of reported Salmonella cases for Skopje, and the average monthly maximum temperature at $p<0.05$. The 1 month lag time shows Pearson Correlation coefficient = 0.51 and 2 month lag shows Pearson Correlation coefficient = 0.49. Our investigation indicates that higher and sustained temperatures for longer periods of time are likely to lead to increasing cases of salmonellosis. The 1 month lag time of rising salmonella cases suggests that temperatures might be influential earlier in the production phase. The largest increase of air temperature in the next decades for the Republic of Macedonia is expected in the summer season, associated with a strong decrease in precipitation, due to climate change [22]. It is anticipated that there will be a corresponding rise in the incidence of salmonellosis.

The plot of Poisson distribution with 95% Confidence limits, between the monthly number of reported Salmonella cases for Skopje, and average monthly maximum temperature for the period 1998-2008 has been estimated (Figure 3).

The estimated rate ratio for Skopje is 1.052, which means that under conditions of increasing maximum monthly mean temperature of 1°C, salmonellosis incidence will increase 5.2% per month.

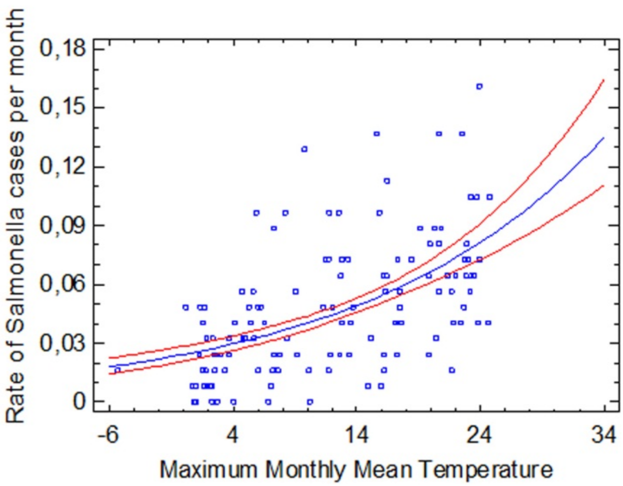

Figure 3. Plot of fitted Poisson Regression Model for Skopje

We detected the current burden of the weather monthly mean temperature for the city of Skopje in particular as follows: January (0,4^{0}C), February (-0,3 ^{0}C), March (2,1 ^{0}C), April (0,5 ^{0}C), May (0,4 ^{0}C), June (-0,5 ^{0}C), July (0,3 ^{0}C), August (0,7 ^{0}C), September (-0.7 ^{0}C) and October (1,1 ^{0}C), November (-0,7^{0}C), December (1,1^{0}C). According to the scenario the largest increase of air temperature in the Republic of Macedonia is expected in the summer season (1,4-5,4°C**).** We projected the changes of future burden of mean monthly air temperature (°C) by seasons using predicted burden as attributive fraction by estimation of difference between future and currant burden for Skopje in 21st Century (Tab.3)

	2025		**2050**		**2075**		**2100**	
	FB	**PB**	**FB**	**PB**	**FB**	**PB**	**FB**	**PB**
Winter	0,8	0,4	1,7	1,3	2,3	1,9	3	2,6
Spring	0,8	1	1,5	0,5	2,2	1,2	3,2	2,2
Summer	1,4	0,17	2,5	2,33	4,1	3,93	5,4	5,23
Autumn	0,9	0,37	1,7	1,33	2,8	2,43	3,7	3,33

Table 2. Projected changes of future burden of mean monthly air temperature (°C) by seasons as predicted burden by estimation of currant burden for Skopje in 21st Century

A projection of the Seasonal Index for the year 2030 in relation to increase of average monthly temperatures under various scenarios for climate change, show that in addition to two peaks in the summer months which were not that significant, there is also a possible peak in the colder months as a result of increase of average monthly temperatures in the future. The largest increase of air temperature in the next decades for the Republic of Macedonia is expected in the summer season, associated with a strong decrease in precipitation. Climate change in the Republic of Macedonia will have an impact in terms of higher air temperatures and reduced rainfall during the summer period. The scenarios show that the total available amounts of water (the river basin of the Vardar river) for the year 2100 will most probably be 18% less than today (estimates vary between 13% and 23%). In addition, more frequent flash flood and floods may be expected. Various parts of the country will suffer different impacts. The regions of the Republic of Macedonia with a Mediterranean climate are likely to experience reduced availability of water, increased number of dry periods and increased health-related impacts resulting from heat waves. Those regions with a continental climate are likely to suffer an increased number of floods and impacts resulting from extreme weather conditions. The local projections of climate change indicate that different climatic regions of Macedonia will respond slightly different on large-scale climate changes. The difference between a strong increase in temperature in summer season and weaker in winter season is not that evident as in sub-Mediterranean climate region where the city of Skopje belong. Although empirical downscaling projections of climate change on a local level contain uncertainties relating to the results, they present a step forward towards the need for implementing adaptation measures now. The Canadian Study showed that, for Alberta, the log relative risk of Salmonella weekly case counts increased by 1.2% for every degree increase in weekly mean temperature [23]. In our Study under conditions of increasing maximum monthly mean temperature for 1°C, the salmonellosis incidence increase for 5.2% per month. Similar higher ambient temperatures have been associated with 5-10% higher salmonellosis notifications for each degree increase in weekly temperature. In other 10 European countries, for ambient temperatures above 5°C, the estimated change in incidence above a common 6°C threshold ranged from 0.3% in Denmark to 12.5% in England and Wales [18]. The strongest effects were found for temperatures 1 week before the onset of illness rather than the longer lag of 1 month found in the Australian study. A significant positive association between mean temperature of the previous month and the number of salmonellosis notifications in the current month, with the estimated increases for a 1°C in temperature ranging from 4% to 10% in five Australian cities were reported [24]. In our Study, food poisoning by salmonellosis, was positively associated with ambient maximum temperature in the previous month, i.e., for each increase in temperature for 1°C resulted in 5.2% increase in salmonellosis notifications in the current month. In the UK, the monthly incidence of food poisoning was most strongly associated with the temperatures occurring in the previous two to five weeks [25]. The time lag of 1 month of rising salmonella cases suggests that temperatures might be influential earlier in the production phase [26]. Roughly one-third of the transmission of salmonellosis (population attributable fraction) in England and Wales, Poland, the Netherlands, the Czech Republic, Switzerland and Spain can be attributed to temperature influences [27]. In our investigation the higher and sustained temperatures for longer periods of time are likely to lead to increasing cases of salmonellosis. Indeed, an analysis of foodborne illnesses from England and Wales showed that the impact of the temperature of the current and preceding week has decreased over the past decades, indicating that the potential risk from elevated temperatures related to climate change can be counteracted through concerted public-health action [28].

7. Conclusion

The climate change process has already started and efforts should be concentrated towards the assessment of the current and future vulnerability of the population in the Republic of Macedonia, with the aim of identifying the necessary interventions and adaptation. The influence of global climate change, including its effects on people's health, can be reduced or avoided by undertaking measures for adaptation. The primary goal of the climate change adaptation measures in the health sector is to reduce the burden of disease, injury, invalidity, suffering and morbidity. The adaptation measures are not solely intended for the health sector, they are also relevant to other fields and sectors such as energy, sanitation and water supply, education, agriculture, economy, tourism, transport, development and housing, etc.

The incidence of Salmonella cases among humans in the Macedonian population varies seasonally, and may be expected to be change in response to global climate changes. During the review period, the highest values of the Seasonal Index for Salmonella cases were registered in the summer months, i.e. June, July, August and September. An understanding of how specific environmental factors influence human disease may improve disease forecasting; enhance the design of integrated warning systems; advance the development of efficient adaptation action plans; and, underline the need for implementing adaptation measures now.To demonstrate this technique, we conducted a comparative study of seasonality in *Salmonella* cases as reported by the state surveillance system in relation to seasonality in ambient temperature, and found that the incidence in *Salmonella* infection peaked two weeks after a peak in temperature. The limitations of such study are small numbers and under-reporting or late notifications. The results suggest that ambient temperature can be a potential predictor of *Salmonella* infections at a seasonal scale. It is clear that one overall challenge is the generation and maintenance of constructive dialogue and collaboration between public health, veterinary and food safety experts, bringing together multidisciplinary skills and multi-pathogen expertise. Such collaboration is essential to monitor changing trends in the well-recognised diseases and detect emerging pathogens. It will also be necessary understand the multiple interactions these pathogens have with their environments during transmission along the food chain in order to develop effective prevention and control strategies. Reducing the effects of communicable diseases related to climate change requires continuous epidemiological surveillance, as well as preparedness to take immediate epidemiological measures to respond to the threats. Furthermore, consideration should be given to investigating the routes of transmission and improving the safety of drinking water and food, controlling the insects and vectors that transmit disease, as well as providing a rapid response by the public health sector in the event of outbreaks.

8. Action in place

Climate change research needs to be properly coordinated and the benefits optimized to meet the needs of policy-makers in the country. Attention needs to be focused on data that will assist with mitigation of, and adaptation to, climate change and address specific areas of vulnerability. Further, national data are required to show the advantages and acceptability of a variety of technologies related to climate change.

A variety of methodologies of assessments of the potential health effects of climate variability and change in the Republic of Macedonia have been used. Both qualitative and quantitative approaches were used, as appropriate, depending on the data availability, level and type of knowledge.

The National Committee for Climate Change and Health within the Ministry of Health identified the most important climate-sensitive diseases and conditions that will be included in the health vulnerability assessment process.

Before the health impact assessment process started, a management structure was established to supervise each stage of the assessment. Identifying experts from the National Public Health Institute (the leading institution) was useful to ensure that the assessment was supervised through to completion. The Ministry of Health has primary responsibility for assessing and promoting the health of the population. The Second National Communication document was compiled by the Ministry of Environment and Physical Planning, with contributions from a wide range of experts, whose efforts are all gratefully acknowledged.

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A basic assessment was conducted using readily available information and data, such as previous assessment, literature reviews by the IPCC and others and available region-specific health data. Limited analysis was conducted of regional health data, such as plotting the data against weather variables over time. A more comprehensive assessment included a literature search focused on the goals of the assessment, some quantitative assessment using available data (such as the incidence or prevalence of weather-sensitive diseases), more involvement by experts, some quantification of effects and a formal peer review of results. Some comprehensive assessment included a detailed literature review, collecting new data (i.e. mosquito survey in 2010) and/or generating new models to estimate impact, extensive analysis of quantification and sensitivity.

Interactions between weather and climate and health are location-specific – using epidemiological evidence based on local data, if they are available, is therefore important. The first step was to specify the scope of the assessment in the country in relation to climate change and health and community security issues of concern today and of potential risk in the future, both nationally (floods, droughts) and, where applicable, in the geographical region to be covered by the assessment (temperature-related mortality in Skopje, salmonella poisoning distribution in five Macedonian cities), and over time (projection for pollen distribution in future).

Health effects related to communicable diseases in the context of climate change are generally preventable, provided that the health care system is prepared and the population informed. The health care system should strengthen its functions as a leading sector that needs to have the capacity to protect the population and to work together with other government sectors, to establish a proactive, multisectoral and multidisciplinary approach. The activities encompassed by the health care sector should include strengthening the capacities of health care practitioners and strengthening the laboratory diagnostic system for identification and diagnosis; obtaining knowledge; adaptation; and health promotion. Generally, it is expected (with some presumption of uncertainty) that the effect of rapid climate change on human health will be negative. Adverse effects are expected to include:

The variations in rainfall will **most probably** compromise the supply of fresh drinking water, thereby increasing the risk of waterborne diseases.

The higher temperatures and the variability of rainfall will **most probably** reduce food production in the least developed regions, thereby increasing the risk of malnutrition.

Climate change will **most probably** prolong the season of transmission of certain significant vector-borne diseases and will tend to change their geographical distribution, potentially allowing them to spread into regions characterized by lack of immunity among the population and/or lack of well-organized health care infrastructure.

The link between weather impacts and infectious diseases has led to the development of scenario models to predict the expansion of infectious diseases due to climate change. Changed lifestyles, food production, modern urban planning, climate change and variations in the quality of the environment increase the danger of expansion of zoonoses. The health care system has an important role in establishing adaptation, health promotion, prevention and response measures against the health risks related to climate change and communicable diseases, such as:

- strengthening existing public health capacities for early detection and adequate response to communicable disease outbreaks;
- anticipating the consequences of emerging communicable diseases possibly related to climate change; and
- raising awareness among the general population about the possible links between climate change and communicable diseases.

Measures for adaptation to climate-change-related health risks are aimed at reducing the effects of climate change on human health and they can be categorized as follows:

- **primary adaptation measures:** measures aimed at preventing the initiation of disease occuring as a consequence of certain environmental conditions among the exposed population;
- **secondary adaptation measures:** preventive measures aimed at providing a response to the early evidence of impacts on health (e.g. strengthening disease control and providing an adequate response to the disease); and
- **tertiary adaptation measures:** health care measures aimed at reducing the mortality or morbidity caused by disease (e.g. improved diagnostics and treatment of certain infectious diseases).

Adaptation to potential consequences of climate change on communicable diseases at local and regional levels encompasses public health measures in the following fields:

- establishing early warning systems;
- systematic control and surveillance of foodborne, waterborne and vector-borne diseases;
- upgrading existing facilities for laboratory diagnosis and expertise;
- promoting and improving the health education of the general population, promoting hygiene measures among the population and enforcing environmental protection measures.

Adaptation measures form part of the National Climate Change Health Adaptation Strategy. As regards the surveillance of communicable diseases, the Republic of Macedonia has in place a syndrome-based early warning system (EWARN system that includes reporting upon eight syndromic diseases, such as diarrhoea, outbreaks, acute haemorrhagic fevers, etc.) and a system for mandatory reporting of diseases under the Infectious Diseases Protection Law. In addition, it is necessary to provide adequate laboratory confirmation capacity as well as capacity for continuous education of medical staff regarding the health risks associated with climate change. In this regard, the key activity for the health sector must be health promotion and improvement of health education for the general population, as well as the promotion of good hygiene practices, HACCP system in whole food chain. Health education campaigns should promote good hygiene, and include guidance on the safe preparation of food, education about avoiding certain foods in specific climate conditions, and sanitary-hygienic knowledge for individuals with their own water supply and food production facilities. Education and information of the public should especially be targeted to those parts of the country that are at higher risk due to shortage or lack of water. Key activities for health sector institutions should include health education and information for the public; preparation of health advocacy materials, such as posters and leaflets providing information about infectious diseases, and distribution thereof; and media campaigns for health promotion [16] On the basis of analysis of the Vulnerability Assessment Report in the Republic of Macedonia, the Climate Change Adaptation Strategy [29] was endorsed in 2011 by the government with the following priority domains of action:

- raising awareness of climate change and the effect on health in the former Yugoslav Republic of Macedonia;
- identifying, registering and monitoring risks connected with climate change and their influence on people's health; and
- improving the health system in its promotion, prevention and timely response to climate change risks for people's health.

The following specific goals are envisaged as part of the implementation of the Climate Change Adaptation Strategy in relation with food:

- Provide a coordinated approach and functional cooperation between the sectors and the relevant institutions in terms of effective and efficient use of the available resources.
- Raise public awareness about climate change and its effect on health
- Establish an integrated, efficient and effective approach for prevention, early warning, management and overcoming of the effects of climate change due to heat-waves including food safety advices .
- Establish an integrated, efficient and effective approach for prevention, early warning, management and overcoming of the effects of floods and fires.
- Protect people from climate-change-related communicable diseases.

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9. References

[1] Hall GV, D'Souza RM, Kirk MD (2002) Foodborne disease in the new millennium: out of the frying pan and into the fire? Med. J. Aust. 177:614-618.

[2] Rose JB, Epstein PR, Lipp EK, Sherman BH, Bernard SM, Patz JA (2001) Climate variability and change in the United States: potential impacts on water- and foodborne diseases caused by microbiologic agent. Environ. Health Perspectives 109:211-221.

[3] Food and Agriculture Organization (2008) Climate Change: Implications for Food Safety. Food and Agriculture Organization, Rome

[4] Tirado C, Schmidt K (2001). WHO surveillance programme for control of foodborne infections and intoxications: preliminary results and trends across greater Europe. J Infect. 43(1):80-4.

[5] World Health Organization (2002). World Health Report. Geneva

[6] Patz, JA et al. (2000), Effects of environmental change on emerging parasitic diseases. Int J Parasitol, .30 p 12-13

[7] Wilson ML (2001) Ecology and infectious disease, in Ecosystem Change and Public Health: A Global Perspective, Aron JL, Patz JA Editors. Johns Hopkins University Press: Baltimore. p. 283-324.

[8] McMichael JA, Woodruff ER, Hales S (2006) Climate change and human health: present and future risks. Lancet 367: 859–69

[9] Kendrovski V (2006). Vulnerability and Adaptation of Climate Change in Health Sector, under the Second National Communication to UNFCCC. UNDP, MoEPP. Skopje

[10] Food and Agriculture Organization (2002) The State of Food Insecurity in the World 2001.Food and Agriculture Organization, Rome

[11] Schmidhuber J, Tubiello NF (2007) Global food security under climate change. PNAS; Vol 104: 50: 19703-19708

[12] Intergovernmental Panel on Climate Change. Climate Change (2007) Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge Univ Press, Cambridge, UK

[13] Rosenzweig C, Tubiello FN, Goldberg RA, Mills E, Bloomfield J (2002) Global Environ Change 12: 197–202.

[14] World Health Organization (2004). World Health Report. Geneva

[15] Altizer S, Dobson A, Hosseini P, Hudson P, Pascual M, Rohani P (2006). Seasonality and the dynamics of infectious diseases. Ecol Lett 9:467–484.

[16] Kendrovski V, Milenkovik Z, Karadzovski Z, Spasenovska M, Kostovska J, Kisman M (2011) Guidelines for prevention of communicable diseases related to climate change in the former Yugoslav Republic of Macedonia. World Health Organization, Copenhagen

[17] European Food Safety Authority (2009). The Community Summary Report on Trends and Sources of Zoonoses and Zoonotic Agents in the European Union in 2007. The EFSA Journal 223:1–215.

[18] Kovats RS, Edwards SJ, Hajat S, Armstrong BG, Ebi KL, Menne B (2004). The effect of temperature on food poisoning: a time-series analysis of salmonellosis in ten European countries. Epidemiol Infect 132(3):443–453.

[19] Kendrovski V, Karadzovski Z, Spasenovska M (2011). Ambient maximum temperature as a function of Salmonella food poisoning cases in the Republic of Macedonia North Am J Med Sci 3: 264-267

[20] Ministry of Environment and Physical Planning of the Republic of Macedonia (2008). Second national communication under the United Nations Framework convention on climate change. Skopje

[21] State Statistical Office (2010). Macedonia in figures, 2010. State Statistical Office, Skopje

[22] Alcinova SM, Ristevski P, Pavlovska V, Todorovska S (2010) Projection of Temperature and Precipitation Changes in the XXI Century on the Territory of Republic of Macedonia, Fourth International Scientific Conference BALWOIS 2010, Ohrid, Republic of Macedonia.

[23] Fleury M, Charron DF, Holt JD, Allen OB, Maarouf AR (2006) A time series analysis of the relationship of ambient temperature and common bacterial enteric infections in two Canadian provinces. Int J Biometeorol. 50(6): 385-391.

[24] D'Souza RM, Becker NG, Hall G, Moodie KBA (2004) Does Ambient Temperature Affect Foodborne Disease? Epidemiology 15(1): 86-92.

[25] Bentham G, Langford IH (2001) Environmental temperatures and the incidence of food poisoning in England and Wales. Int J Biometeorol 45: 22–26.

[26] Kovats RS, Campbell-Lendrum D, McMichael AJ, Woodward A, Cox J (2001) Early effects of climate change: do they include changes in vector-borne disease? Philos Trans R Soc Lond B Biol Sci 356: 1057–1068.

[27] Lake IR, Gillespie IA, Bentham G, Nichols GL, Lane C, Adak GK, Threlfall EJ (2009) A Re-evaluation of the Impact of Temperature and Climate Change upon Foodborne Illness. Epidemiol Infect 137(11): 1538-1547.

[28] Semenza JC, Menne B (2009) Climate Change and Infectious Diseases in Europe. Lancet Infec Dis 9: 365-75.

[29] Ministry of Health of the Republic of Macedonia (2011) Adaptation Strategy in Health Sector from Climate Change of the Republic of Macedonia. Skopje