

*Original Article****A Review of the Effects of Climate Change with an Emphasis on Burden of Waterborne Diseases***Fathollah Gholami-Borujeni^{1*} Mohammad Ali Zazouli² Sahar fallahi³

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(Received: 24 Apr. 2018; Revised: 18 Aug. 2018; Accepted: 2 Nov. 2018)

Abstract

Background and Purpose: Climate change has major impact on water cycle, resulting in effects on water resources, the frequency and severity of droughts, floods due to severe rainfall, natural environments, society, and economics and human health. In this paper, surveys on different models of climate change as well as the effects of climate change on the burden of waterborne diseases and also, the strengths and weaknesses of the study methodology have been reviewed.

Materials and Methods The key words “climate change”, “water borne disease”, “temperature change”, burden of disease” were used in combination with the Boolean operators “OR” and “AND”. The researchers did electronic search on PubMed, Science Direct, Springer Link, and Google Scholar. The search was conducted with publication year limitation between January 2005 to June 2017.

Results: From 152 original articles, 54 papers were about modeling of climate change, 74 papers indicated the effect of climate change on infection disease, and 24 papers surveyed the water quality impact. The reviewed literature showed that, most studies had been conducted in rich countries, and the estimates of the burden of disease due to climate change were uncertain for the following reasons: 1- Uncertainty about the climate changes due to changes in greenhouse gas emissions 2- Uncertainty about the direct and indirect relationship between the climate and human health 3- Uncertainty about the relationship between climate and health as a result of socioeconomic changes in the future.

Conclusions: Uncertainty in these estimates has led to little studies in this regard.

Keywords: Climate Change; Environmental Effects; Health Effects; Burden of Waterborne

Citation: Gholami-Borujeni F*, Zazouli MA, fallahi S. A Review of the Effects of Climate Change with an Emphasis on Burden of Waterborne Diseases. Iran J Health Sci. 2018; 6 (4): 47-56.

1. Introduction

Although the industrial revolution played an important role in improving the human condition, it has had adverse effects in terms of environmental aspects. Human activities have led to an increase in greenhouse gases (carbon dioxide, nitrous oxides, methane and chlorofluorocarbons, etc.) in the atmosphere, which has led to climate change. These gases are transparent to waves of short wavelengths coming from the sun to the earth, and in contrast to high-wavelength infrared waves that are reflected from the earth, they are thereby increasing the temperature of the earth's surface causing climate change. Climate change is generally one of the major global challenges and, in particular, one of the challenges facing sustainable development and development goals of the century (1-3). Climate change has a great impact on the water cycle and, consequently, on water resources, the frequency and severity of droughts, floods due to severe rainfall, natural environments, society, and economics and human health. Irregularities in water resources during a drought cause a lot of social and economic losses, which often compensate for these losses for many years (4-8). Major phenomena associated with large changes in the atmospheric composition of gases, such as greenhouse gases, have a huge impact on regional and global weather (3, 9). In this narrative review article, survey on studies on models of climate change estimation as well as the effects of climate change on the burden of waterborne diseases and also, the strengths and weaknesses of the study methodology have been reviewed.

2. Materials and Methods

In a narrative review study, the key words "climate change", "water borne disease", "temperature change", and "burden of disease" were used in combination with the Boolean operators "OR" and "AND". The researchers did electronic search on PubMed, Science Direct, Springer Link, and Google Scholar. The search was conducted with publication year limitation between January 2005 to June 2017.

The researchers selected all original studies that had developed climate change models or papers indicating the effect of climate change on infection diseases and survey on microbial water quality impacts.

3. Results

3.1. Climate Change Predicting Models

According to the research conducted by the Intergovernmental Panel on Climate Change (IPCC), carbon dioxide has the largest share (55%) in global warming. The concentration of these gases was 285 ppm before the industrial revolution (1800 AD) to 337 ppm in 1980, and according to the latest estimates, it reached 398.5 ppm in 2014 (1, 4, 5, 8, 10, 11).

Several scenarios have been presented on how the greenhouse gases continue to grow (4). Which will be doubled by the different scenarios of carbon dioxide concentration before the end of the 21st century. In scenarios B, C, and D, and based on greenhouse gas emission control programs, carbon dioxide concentrations will double in the 2040s, 2050s, and the end of the 21st century, respectively (12).

General circulation model (GCMs) and weather forecasting models in the 1950s are of the same origin. These models are five main groups (UK weather meteorology model, NCAR National Atomic Resource Center model, GISS Goddard Space Research Institute Model, GFDL Geophysical Fluid Dynamics Laboratory Model, and Oregon State University Model OSU (13-19).

By using various models, researchers predict that with the current greenhouse gas

emissions, the air temperature will increase by about 5.8 to 1.4 degrees Celsius by the end of the 21st century, which will be higher than the temperature changes of the past 10,000 years (14, 16, 18). Some studies show that, the best estimate for the low scenario (B1) is 1.8°C, and the best estimate for the high scenario (A1FI) is 4.0°C. Although these projections are broadly consistent with the span quoted in the TAR (1.4°C to 5.8°C), they are not directly comparable (see Figure 1).

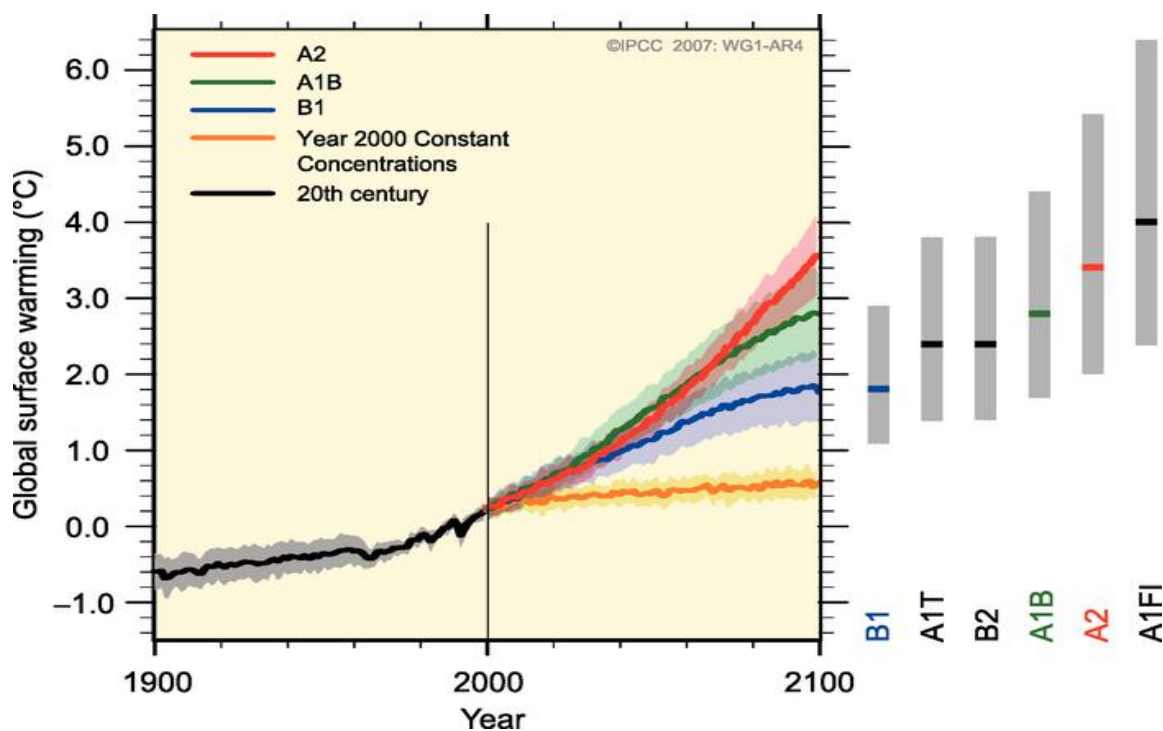


Figure 1. Global averages of surface warming (relative to 1980–1999) with application of multi-model for the scenarios A2, A1B, and B1 (20, 21).

3.2. Environmental Effects of Climate Change

According to studies, increase in temperature has led to an increase in the temperature of the aquatic environment of 0.2 to 2 degrees Celsius in Asia and North America (6, 16, 18).

This increase in temperature in Europe and North America has reduced the laminar thermal layers to 2-3 weeks. The Rhine and Meuse rivers have increased the

temperature of water at 2 °C during the last three decades, which has led to an increase in pH (due to lower carbon dioxide concentrations in water)(1, 8, 11, 22-24).

Climate change has resulted in: rising sea levels, reducing fresh water resources, regional climate change in high latitudes and northern hemisphere, changing rainfall, increasing natural disasters, such as storms, wind, floods due to heavy rainfall, increased drought, the development of

desert areas, the spread of some diseases due to temperature changes, and behavioral patterns of diseases (especially waterborne and foodborne diseases), thermal waves, etc. (5, 10, 11, 15, 25, 26). These effects can be direct (the effects of natural disasters, such as floods or trauma due to extreme temperature rise), and indirect (climate change, environmental conditions, and increased risk of Environmental factors) (20, 27-29).

Climate change has led to an increase in heavy rainfall in the 21st century in many parts of the world, and this has been seen in areas with high tropical altitude and in winter in areas with moderate altitude, which has resulted in an increase in natural disasters, such as floods (30-32). The floods are caused by extreme rainfall, and melting of snow quickly due to the increase in temperature. According to the databases, floods in the Mediterranean countries are more frequent. Thus, floods and the Sea Level Rise (SLRs) have led 1.6 million people in Europe to get into trouble (10, 21, 27, 30).

Drought periods also affect the quality of water resources, which is due to increased organic matter and mineral erosion. Drought reduces nutrition, groundwater levels, and access to water, but it increases water consumption, pollutants in water resources, as well as the excessive withdrawal of groundwater resources, and the progression of seawater to fresh water sources. Underground and rising salinity will limit water resources. Reports show that only 5% of the pollution of freshwater by seawater is enough to lead to irreparable effects in a variety of uses (drinking, farming)(7, 27) .

3.3. Climate change and burden of waterborne diseases

Investigating the role of climate change on the behavior of water-borne disease due to various factors, such as population behavioral changes, migration, drug resistance, resistance to depletion, urbanization, increasing population density, improving health status and Health services, various behaviors of pathogens in different climates, and so on is very complicated and difficult. Water-borne pathogens that originate from human and animal excrements include a large number of viruses, bacteria, protozoa, and parasites (5,6,23,33-35). Also, many microorganisms in nature can be pathogens for humans, such as various types of vibrio (gastroenteritis, diarrhea and septicemia), *Pseudomonas Aerogenesis* (skin and ear infection), *legionella pneumophila* (*Legionella* disease), and amoebae (*Encephalitis*)(8, 25, 33, 36). Waterborne pathogens that are problematic to humans have the following conditions. They are extensively discharged into the environment, and in humans and animals, they have a low dose of low-infectivity (MID), such as pathogens, which can survive in the environment for a long time, and are resistant to purification systems. Some pathogenic hair types can grow and multiply outside the host body under environmental conditions. Some pathogens, such as vibrio cholera, hepatitis A virus, and *Schistosoma*, are also resistant to tropical areas (6, 24, 34, 37).

Increasing the number of severe precipitation and flooding leads to an increase in the number of pathogens in natural waters.

This is due to an increase in the hydraulic load of the refineries, the spread of human and animal waste, and the transfer and release of pollutants. Transition, survival, and release of pathogens are also dependent on surface hydrodynamics, and it can be said that increasing the discharge of surface water prevents pathogens from being depleted by the sun's UV and temperature (36, 38, 39). Studies on cryptosporidiosis showed that with increasing rainfall, the number of oocytes increased which also increased the pathogenicity risk of this pathogen (40, 41).

The World Health Organization (WHO) has published Disability Adjusted Life Year (DALYs) calculating guidelines for the Disability Adjusted Life Year in the wake of the Global Burden of Disease (GBD). This scale provides the ability to compute the effects that cause disability (42, 43). To do this study, climate change scenarios are derived from global climate change models that are derived from greenhouse gas emission scenarios in the future (44). In this way, the burden of climate change can be estimated with regard to three different scenarios from 1960 to 1991, where the artificial effects of climate change are negligible. Epidemiological models are used to estimate the degree of these changes that are likely to affect various diseases (malaria, diarrhea, malnutrition, flood mortality, drought, and direct effects of cold and heat). And with these scales, we can estimate the burden of climate-related diseases in the future (5, 11, 44).

In order to make a realistic estimate, other future changes in the world should also be sought and considered in such factors as increasing the number of diseases due to technological changes, or improving the socioeconomic status, as well as changes in

population, age structure and population aging, and cardiovascular diseases due to increased Global warming (3, 40). These changes in the future can be estimated through comparing relative risk under different scenarios of climate change on burden of disease (GBD), actual population size, and age structure, which has been attempted in these scenarios. The effect of changes in gross domestic product (GDP), human capital (Human Capital) based on the average years of women's education and the time (technological development) can be used to estimate mortality from climate change (3, 40, 43).

The analysis showed that climate change also has human health benefits, such as reducing mortality from cold in some areas, increasing the yields of agricultural products in warmer areas, but its positive effect on other diseases (infectious diseases, malnutrition) in developing countries is negligible. At the same time, there is the possibility of a slight increase in mortality from cardiovascular disease at high temperatures in tropical areas. Since there is evidence that some of the deaths associated with the temperature cause a slight change in mortality, there is no accurate assessment of the burden of disease-related temperatures (12, 40, 43, 45). It has been estimated that climate change will increase the burden of diarrhea in developing countries by as much as 2.5%. But in rich countries with more than 6000 US\$ GDP / year, the risk of diarrhea is low or insignificant. The effects of climate change are expected to increase more due to the mortality of individuals from coastal floods (about 2 times more in former economies of the socialist economy) and domestic floods (5 times in developed countries) (27, 43).

Even with increased income in countries and socioeconomic and behavioral changes, the burden of disease caused by climate change is likely to increase over time. In general, these effects are most likely to occur in poor countries of the world that live in low-altitude areas which are sensitive to climate change due to malnutrition, diarrhea and malaria. The burden of these diseases will be greater in lower-age groups and children in developing countries. Moor in a descriptive-analytic study, studied the different models of climate change in the world, and the appropriate model was determined according to the climatic conditions of the Gang basin in northern India and climate change was investigated in a 30-year period (27, 33, 43, 46, 47).

Then, using library studies, the association between diarrhea-mediated diarrhea and climate change (elevated temperature, drought, flood, and relative humidity) was separately determined. The results of this study showed that due to increases of 10.1% in temperature, 1.8% in relative humidity, 0.14% in precipitation, and a decrease of 1.1% in precipitation, an increase equal to 13.1% has occurred in diarrheal diseases in the Gang basin in northern India due to climate change over a 30 years' period (3, 34).

In Delpha et al., the effects of climate change on the quality of aqueous environments (initial parameters, such as temperature, pH, DO, soluble organic matter, nitrite, inorganic minor pollutants, such as metals, organic pollutants, such as pesticides, pathogens, Cyanobacteria and cyano-toxins, water quality indicators, detergent side products) were investigated. According to the results presented in this paper, drought and temperature rise could lead to an increase in pH and a decrease in

DO. DOC increases due to increased temperature and drought, as well as seasonal floods. Reductions in water resources due to drought and seasonal floods will increase dramatically due to increased release from sediments, increased temperature, and increased mineralization and release from the soil, and increased seasonal floods (1).

Increased snow melting could then lead to an increase in metals in water sources, and the concentration of pesticides and drug substances (minor organic matter) will also increase. Floods will lead to an increase equal to 70% in waterborne pathogens. As the temperature increases, the algae grows and flourishes in surface water and the concentration of cyanobacteria, and hence the cyano-toxins increases. An increase in organic matter contributes to an increased risk of the production of disinfectant products in the process of water purification. More studies of this kind showed that there is a high correlation between waterborne diseases and climate change, but few studies have been carried out in countries with high temperature increases (11, 20, 48).

According to the study of Park, any increase in the number of extreme rainfall and floods leads to an increase in the number of pathogens in natural waters. This is due to an increase in the hydraulic load of the refineries, the spread of human and animal waste and waste, as well as the transfer and release of pollutants. Transition, survival, and release of pathogens are also dependent on surface hydrodynamics, and it can be said that increasing the discharge of surface water prevents pathogens from being depleted by the sun's UV and temperature. Studies on cryptosporidiosis showed that with increasing rainfall, the number of oocysts

leads to an increased pathogenicity risk (48). Eissa and Zaki in their study investigated the effects of climate change are illustrated below. Climate change has resulted in: rising sea levels, reducing fresh water resources, regional climate change in high latitudes and northern hemisphere, changing rainfall, increasing natural disasters, such as storms, wind, floods due to heavy rainfall, increased drought, the development of desert areas, the spread of some diseases as a result of temperature changes, and behavioral patterns of diseases (especially waterborne and foodborne diseases), thermal waves, etc. Climate change can lead to many effects on human health. These effects can be direct (the effects of natural disasters, such as floods or trauma on the increase in temperature), or indirect (climate change and environmental conditions which increase the risk of environmental factors) (6).

4. Discussion

Investigating the role of climate change on water-borne diseases due to various factors, such as population behavioral changes, migration, drug resistance, degradation resistance, urbanization, population density, improvement of health status, and health services, various behaviors of types pathogens under various climatic conditions and ..., are very complicated and difficult. By estimating the burden and behavior of diseases attributable to climate change, a comprehensive program on appropriate control measures and mitigation of impacts can be developed. Studies show that plenty of research has been carried out in rich countries, and estimates of the burden of diseases due to climate change are uncertain for the following reasons:

- Uncertain climate changes due to changes in greenhouse gas emissions
 - Uncertainty about the direct and indirect relationship between the climate and human health
 - The uncertainty about the relationship between climate and health that will arise from socioeconomic changes in the future
- This uncertainty should also be seen in the future studies:
- Studying the use of a wide variety of models of climate change or the possible distribution of these models
 - Studying a wide range of data on diseases associated with climate change in different environments

More accurate validation of past, present, and future patterns and models, broader studies of the interaction of climate change and non-climatic changes on the health of uncertainty in these estimates has led to quantitative studies in this regard. In existing studies, other parameters related to diarrhea have been considered, and there has so far been found no accurate assessment of the increased risk associated with climate change on waterborne diarrhea diseases.

Acknowledgement

This research was supported by Student Research Committee of Mazandaran University of Medical Sciences, School of Health (IR.MAZUMS.REC. 96. 243). The authors express their thanks for collaboration in doing this research.

Conflict of Interests

Authors have no conflict of interests.

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