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Impact of Climate Change on Water Resources and the Actions Considered: Case Study of Kingdom of Bahrain

Dalal Hasan AlAlaiwat
College of Engineering
University of Technology Bahrain
Manama, Kingdom of Bahrain

Abstract:- Climate change is considered as one of the threaten to humanity and other organisms' survival, as well as it considered as threaten to the availability of abiotic resources. Indeed, various research done to study the impact of climate change on the environment across the world, at the same time various research done to come up with plan for adaptation and mitigation with climate change impact. Further, most of the countries across the world either they have their own plan, or they work in collaboration with others to protect their natural resources from climate change impact and find alternative resources to manage the demand increases specifically on water, energy, and land which needed for economy development and human survival.

The major purpose of this paper is to study the climate change impact on water resources of Bahrain and review the actions taken by the government in this regard. The change in the atmospheric temperature, the amount of precipitation, the amount of the ground water, and the raise of sea level were reviewed for a specific period. Simultaneously, the actions taken by the government either by establishing committees or starting projects were traced. The result of this study shows that there is a critical impact of the change in the climate on water resources in Bahrain. Further, reviewing the action taken by the government give an indication that impact is noticed, and such actions will show a result in the future through reduction on the impact of climate change on water resources in Bahrain or through finding alternative water resources.

Keywords:- *Climate Change, Greenhouse Gases, Adaptation, Mitigation, Total Dissolved Salt, Water Resources.*

I. INTRODUCTION

Water is part of the environment that provides the life for all organisms in this earth, whenever there is a water life will be there, water is important for plant to maintain their photosynthesis reaction, as well for human and other organisms to control their body temperature and maintain their survival. Environment is changing due to human activities and that change effect on water resources availability and quality. Further, the change in the environment and its effect on water resources, the freshwater especially, will lead to put all organisms life under risk.

Moreover, the climate change and the increase of the atmospheric temperature has impact on environmental resources in general and water resources in specifical. Limiting amount of rain, draught, storm, and flooding are results that can be observed across the world due to the change in the environment. Protecting water resources availability and quality is the responsibility of the community. United Nation World Water Development Report (2020) highlighted the impact of climate change on water across the world. United nation founds that the world life is on danger due to the climate change and global warming that effect on all the organisms, where some of them are facing the danger of extension. Water resources affected as well by the increase of the global temperature which lead to include protection water resources on the 2030 agenda for sustainable development (The 2030 Agenda for Sustainable Devlopment, 2015)[1] all the countries across the world are responsible to participate to ensure the implementation of the goals of 2030 united nation agenda.

The objective of this research is to study the impact of climate change on water resources in Kingdom of Bahrain and the actions taken by the government to protect water resources.

Ecosystem is affected by the climate behaviour within specific region where the organism's interaction together and with their environment, will be affected. The change of the climate has impact on the organism interaction that could change ecosystem nature as well. Indeed, IPCC has traced the changes in climate across the world and documented the consequences of that change, water resources one of the environments that has huge impact of the climate change which make the quality and availability of water resources under risk (Vijay et al 2014)[2].

IPCC (2012)[3] found that the change in the climate is due to the changes in the concentration of specific gases within the atmospheric layer, above the normal, known as greenhouse gases (GHG), those are Carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), and Chlorofluorocarbon (CFC). Crowley TJ (2000)[4] found that the increase in the emissions of the greenhouse gases over

decay lead to the increase of the atmospheric temperature and warming the global. Indeed, the human activities is the main responsible of the increase in the emission of the greenhouse gases that evolved due to the burning of fossil fuel those used for generating electricity, transportation, refrigerating, and other industrial processing (Solomon et al 2007)[5]. The increase in the atmospheric temperature will reach critical value by the end of the twentieth century that will be considered as threshold for the organisms and other matters in the climate system (Molina et al 2009)[6], Solomon et al (2009)[5] added, the amount of CO_2 in the atmosphere that emissions from human activities is high enough which will be there for the coming 1000 year even if CO_2 emission ends.

To protect the environment and resilience climate impact, various regulations, initiatives, and acts established. UNFCC established in 1992 for a purpose of providing a framework for policymaking to mitigate climate change by setting the atmospheric greenhouse gases at low level to reduce and stop the impact on the climate. Kyoto Protocol that formed in 1997 considered as the basis document for international climate change policy, that targets to reduce the emission of CO_2 and other greenhouse gases in the industrialized countries. (Breidenich et al 1998)[7]. The 2030 agenda for sustainable development that plan for action for people, planet, and prosperity where the countries and stakeholders must act in collaboration to implant the plan starting from 1st of January 2016. Hence, two of the 17 sustainable development goals are belonged to protecting water resources those are goal number 6 that stats "Ensure availability and sustainable management of water and sanitation for all" and goal number 13 that stats "Take urgent action to combat climate change and its impacts" (The 2030 Agenda for Sustainable Devlopment, 2015)[1].

The Green Climate Fund (GCF) is a project that set by the United Nations Framework Convention on Climate Change (UNFCCC) in 2010 that aims to provide fund helping the developing countries toward reducing the greenhouse gas emission and enhance the quality of air (https://www.greenclimate.fund/about)[8]. Kingdom of Bahrain is one of the countries participated on GCF with project of "Enhancing climate resilience of the water sector in Bahrain". Kingdom of Bahrain project started in 2018 with a fund of 2.3milion USD while the expected day of completing the project is 13 August 2024. The purpose behind Bahrain participating on this project is the impact of climate change that has effect of shortage water in Bahrain, due to decreasing rainfall and saltwater intrusion into the ground water (https://www.greenclimate.fund/project/sap003)[9].

Impact of climate change on water resources have been studied by various researchers to document evidence of the impact on different location across the world. Steffen et al (2008)[10] studied found that the impact of climate change can be observed on the reduction of the snow layer and increased melting the Greenland and Antarctic ice sheet due to global warming while Solomon et al. (2007)[5] studied the relationship between the rise of temperature and the amount of water evaporation, it found that as the atmospheric temperature increase, the evaporation of water will increase and that will lead to form more precipitation while the amount of rain dropped. Hydrological cycle of water in nature is the main water resources that effected by the climate change where the consequences of the disturbance hydrological cycle is observed in the rainfall drop as well as the flow of river (Bates et al. 2008)[11]. Milly et al (2005)[12] studied the relationship between human activities and amount of rainfall in several places. They found that the human activities affected on water cycle in nature where the consequences shown on the changes of the annual runoff that increase in certain places (such as large part of USA) and drop in the amount of runoff in other area (such as West Africa).

The other impact of climate change on water resources is flooding that observed in several places across the world. Indeed, the causes of flooding are due to heavy rainfall, torrential rain in specific time of the year, and melting of snow that cause raise of sea level specifically on the coastal area (Vijay et al 2014)[2]. Kron and Berz (2007)[13] research related to the amount of flooding at several years where it shows that the flooding cases is increased by twice between 1996 and 2005 compare with the period between 1950 and 1980. However, an evidence shown across the world about the impact of climate change and global warming, that will increase the possibility of flooding risk (Kundzewicz ZW et al 2007)[14].

Le Comte (1995)[15] found that the other impact of climate change and raise of temperature is the drought that have been observed across the world in large areas in Europe, Asia, Africa, Australia, Central America, South America, and North America. While Demuth and Stahl (2001)[16] stated on their report that the drought situation in European regions has reached severe level.

Huss et al (2017)[17] found that the climate change impact of snow and ice are where the global reduction on their layers observed, at the same time according to the IPCC (2019)[18] report the reduction on the snow and ice area will be continuous during the 21st century. The melting of snow and ice are expected to effect negatively on the water resources especially the coastal (Buytaert et al 2017)[19]. World Bank report (2016)[20] that related to climate change, water, and the economy has emphasize the impact of climate change on water cycle will have consequences on other areas such as food, energy, urban, and environmental system where the population growth will raise the demand of water which will have an impact on the economy.

Waleed et al. (2018)[21] in their research related to the "impact of climate change on the municipal water management system in the Kingdom of Bahrain" were focusing on one sector which was municipal water during the period 2000 – 2012. Further, in their research (Waleed et al 2018)[21] found that the amount of municipal water using the available management system is inefficient due to several factors such as the increase in temperature and its impact on the treatment cost, the research raise recommendation that Bahrain should review the current water resources management approaches. Waleed et al (2018)[21] period of the

study was before the implementation of 2030 Agenda for sustainable Development that issued by United Nations in 2015.

This research will spotlight the factors where the climate change impact on specific area of the world, which is Kingdom of Bahrain, the actions done by Bahrain to reduce the impact of climate change on water resources will be reviewed and the consequences will be evaluated,

II. RESEARCH METHODS

A. Data Gathering

The data of the research was obtained from collecting the required information from various resources because of inability to conduct experiments for obtaining data. The data were the values of temperature, amount of rain, amount of ground water, level of sea water, and the regulation issued related to water resources.

The value of temperature at various time of year and month obtained from Ministry of Transportation and Telecommunications (http://www.bahrainweather.gov.bh/web/guest/home)[22], Ministry of Transportation and Telecommunications have their own station to measure temperature which is well equipped. Indeed, the obtained data for temperature was helpfully for analysis purpose specially tracing the impact of climate change. The amount of rain at various time of the years was difficult to obtained. Further, record of the year 2020 obtained from (http://www.bahrainweather.gov.bh/web/guest/home)[22].

The report of the government that issued as funding proposal for the United Nations related to enhancing climate resilience of water sector in Bahrain (supreme council of environment, 2018)[23] is considered as one of the more reliable sources for the research data. Further, the regulations issued by the government related to water resources were available on the official website for (https://www.sce.gov.bh/) Supreme council of environment.

The amount of total dissolved salt (TDS) that can be used as an indicator to the quality of the available ground water, the data obtained from Bahrain report related to the goal number 6 of the United Nations Sustainable Goals for the period 2006 – 2016 (Information EGovernment Authority, 2018)[24].

The rise of sea level data were difficult to obtain, a Figure that showing the rise on the seal level and its impact on the ground water obtained from the report provided by the team working on the Bahrain project " Enhancing climate resilience of the water sector in Bahrain" (https://www.greenclimate.fund/project/sap003)[9].

Some of the actions taken by the Kingdom of Bahrain found within the issued report by the information and eGovernment Authority (Information EGovernment Authority, 2018)[24]. The report shows the achievement of Bahrain toward goal 6 of the United Nations 17 goals of sustainable Development 2030 as well as the challenges behind the weakness in the achievement in some areas (Information EGovernment Authority, 2018)[24].

B. Data Interpretation

The The tracing of climate change impact focus on various variable those are values of temperature, amount of rain, raise of sea level, and the amount of ground water. The selected year for interpretation temperature are used to study the monthly average temperature for the year 1990, 2013, 2014, 2015, 2016, 2017, and 2020, and the annual average temperature of several year between 1991 – 2020

The amount of rain was difficult to obtain, where the data where only the monthly amount of rain for the year 2020, and the annual amount of rain for various year between 1976 – 2020.

The data indicate the quality of ground water where the amount of the total dissolved salt for the two locations those are upper area (Alala) and the lower area (Kuber) both located in the Dammam Aquifer System, the data were for the year 2006 up to 2016.

The data related to the rise of the sea level is obtained from the Figure of Bahrain obtained from software modelling for the year 2050 and 2100.

III. RESULTS AND DISCUSSION

A. Change in the Atmospheric Temperture

The monthly average values of atmospheric temperature for the years 1990, 2013, 2014, 2015, 2016, 2017, and 2020 drawn on Figure 1, where the average temperature located in y-axis and the name of the months located on the x-axis. Indeed, the figure shows that the monthly average temperature increases to reach the highest value during months of July and August for each year. Further, year 1990 shows the minimum monthly average amount of temperature compare with other years. The increase in the average temperature is observed clearly on the Figure 1 where it reaches 36^{o}C on August 2020 compare with 34^{o}C on 1990 for the same month, which give an indication that the temperature value increase by 1 – 1.5 ^{o}C and this is reflected on Bahrain report as well " Enhancing climate resilience of the water sector in Bahrain" (https://www.greenclimate.fund/project/sap003)[9]. However, while comparing the increase of the average temperature across the months of specific year with other years, the figure shows that there is an increase in the temperature values, for example, in 1990 average temperature was 18 ^{o}C in February, 21^{o}C in March, and 25^{o}C in April, in 2020 average temperatures were 19 ^{o}C, 22 ^{o}C, and 27 ^{o}C for the same months respectively. The raise on the number of average temperatures is a consequence of the increase on the greenhouse gases emission and their impact on changing climate.

On the other hand, Figure 2 shows the yearly average temperature for the period 1991 up to 2020 where the average temperature values located on the y-axis and the years

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number located on the x-axis. Hence, Figure 2 shows a similar finding to Figure 1, the yearly average temperature increases from 25.5ºC in 1991 to reach 27.5ºC in 2012 and 28.4ºC in 2018 the percentage of the increase from 1991 to 2018 is 11.4%. Indeed, such rise on the temperature reflects to the rise on the emission of greenhouse gases due to the development of technologies and establishing various industries as well as the growth in the human population. In addition, Figure 2 shows that the average temperature for the year 2020 drop up to 28.1ºC compare with year 2018 where the average temperature was 28.4ºC, such drop by 1.06% could be attributed to COVID-19 where a less number of cars were used at that time, also the closing action of various places, and limiting in the process of industries, also, it could be due to the regulations related to environment that started to show effect on the air quality. The real cause behind the drop of temperature in 2020 will be clarified more on the coming years.

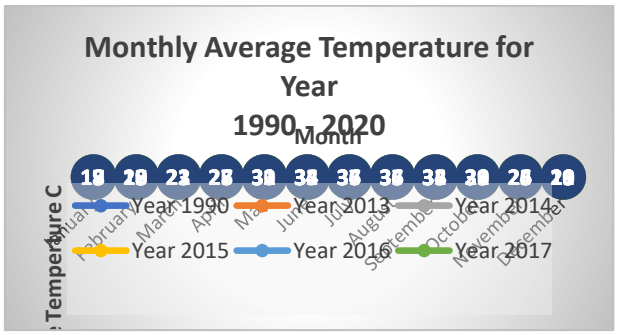

Figure 1 Monthly Average Temperature for the year 1990 - 2020

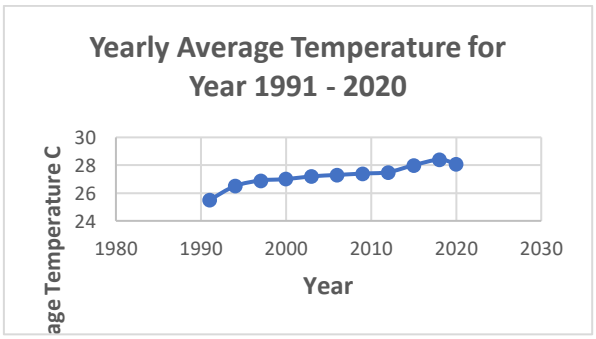

Figure 2 Yearly Average Temperature for the year 1991 - 2020

B. Change in the Amount of Rain

The monthly amount of rain for the year 2020 is drawn in the Figure 3, where the monthly amount of rain in mm is located in y-axis and the name of the months located in the x-axis. Indeed, Figure 3 shows that the total amount of rain is low across the months where it reached 23.9mm as the highest value during November, at the same time the figure shows no rain at all (0mm) during month of May, June, July, and August. Further, such findings reflect the observed in Figure 1, where the temperature reach the maximum during these months. Thus, there is a big impact of the raise of atmospheric temperature on the amount of rain which mean climate change has an impact on this natural phenomenon as well.

Figure 4 shows the annual total amount of rain for the period 1976 up to 2020 where the annual amount of rain in mm located in the y-axis and the years located in the x-axis. Indeed, the Figure shows that the annual amount of rain dropped from 233mm in 1976 to reach 82.6mm on year 2020, such drop on the amount of rain attributed to the impact of climate change due to the increase on the emission of the greenhouse gases across the years and their impact on raising the temperature of the atmosphere. As a result of such scenario the reduction in the amount of rain will have a direct impact on the water resources specifically here in Bahrain where no natural resources of fresh water are available. At the same time Figure 4 shows that the annual amount of rain dropped in a certain year and raise again on the year after, but that phenomenon become limited where the dropped in the amount of rain more than the raise. Hence, reduction on the amount of rain will effect on the availability of water resources, as the human population growth the demand on water increases for domestic, industrial, and agriculture which make search for alternative resources and review the current water management system is important to maintain the increase on the demand of water. At the same time, regulation to reduce the emission of greenhouse gases is required.

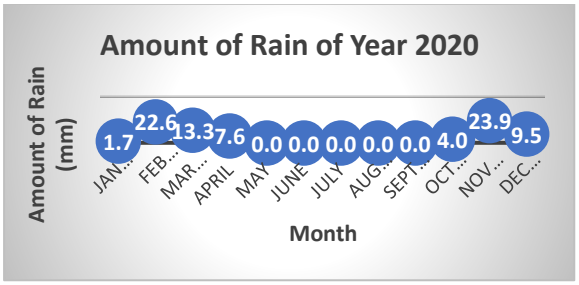

Figure 3 Monthly Amount of Rain of Year 2020

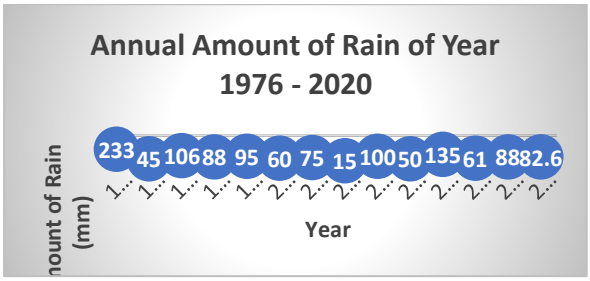

Figure 4 Annual Amount of Rain of Year 1976 - 2020

C. Impact on the Amount of Ground Water

The amount of ground water was difficult to estimate for studying the impact of climate change on such important source of water. Indeed, ground water is considered as the only fresh water source in Kingdom of Bahrain where it depends mainly on the infiltration of rain to reach ground water area. There are two main area for ground water those are ALLAT and KUBER.

Figure 5 shows the changes on the amount of total dissolved salt (TDS) for the period 2006 up to 2016 where the amount of TDS is located in the y-axis and the years is located in the x-axis. The figure shows the amount of TDS on the ground water areas are too high, although the amount

dropped from 7590 mg/L on year 2006 to 5813 mg/L in 2016 on KUBER area, the dropped in the TDS in the ALLAT area from 4772mg/L on 2006 to 4429mg/L in 2016. Hence, the amount of TDS in the ground water is too high even with the reduction across the year, such amount of TDS is limiting the benefit of the ground water directly without treatment which mean more consumption of energy and more emission of greenhouse gases accordingly due to the treatment process. Such high amount of TSD could be attributed to highly consumption of ground water, limited amount of rain, and the raise of sea level which may lead to reach the storage area of ground water. The reduction in the amount of TDS in the ground water give an indication that Bahrain is doing lots of effort to safe such water source.

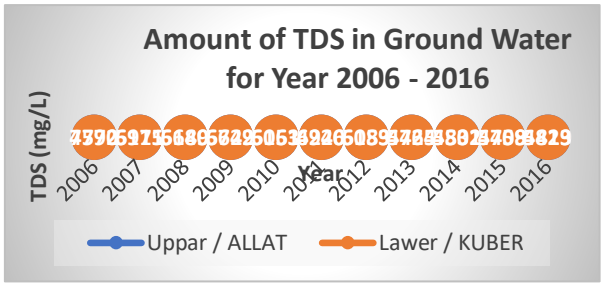

Figure 5 Total Amount of Dissolved Salt in the Ground Water for the Year 1976 - 2020

D. Raise of Sea Level

Study the impact of climate change on the sea level was using the figure provided by the Kingdom of Bahrain on the report of "Enhancing climate resilience of the water sector in Bahrain" (https://www.greenclimate.fund/project/sap003)[9]. Figure 6 shows the land area of the Kingdom of Bahrain which will be expected to be affected by the raise of sea level due to the impact of climate change, loosing such area will have an effect on the economy, and people survival specifically with increase in the human population. On the other side, Figure 7 shows the impact of raising sea level on the freshwater resources which is specifically ground water by 2050 due to the impact of climate change, loosing such source will have a critical impact of the satisfying the demand on water specifically with increase on water demand from different sectors.

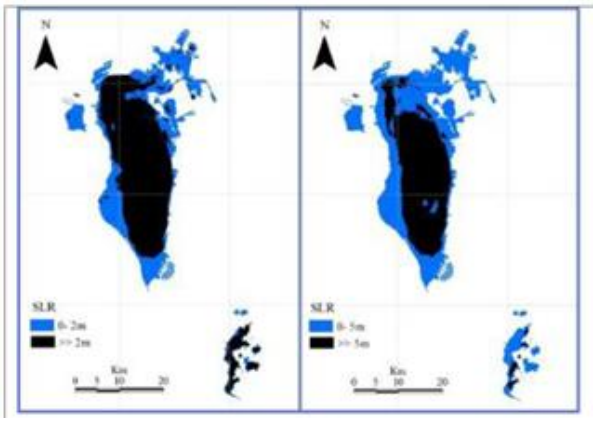

Figure 6 Predict Sea Level Rise in Bahrain for 2050 and 2100 (https://www.greenclimate.fund/project/sap003)[9]

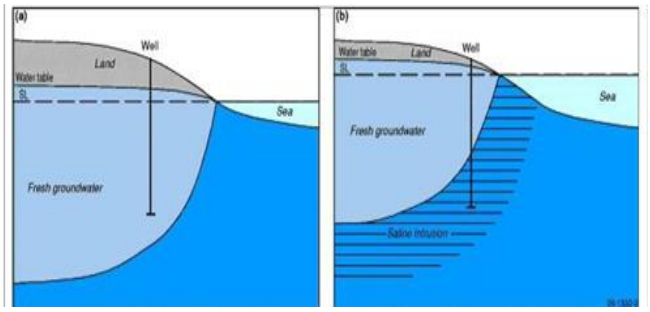

Figure 7 Effect of Sea Level Rise on the Fresh Water Resources in Bahrain by Year 2050 (https://www.greenclimate.fund/project/sap003)[9]

E. Actions Taken by the Government

The issues highlighted in the subsections *A*, *B*, *C*, and *D* give an indication about the level of climate change impact on the water resources, as the demand on water from different sector increases the issue will be more critical. Indeed, government aware about such issue where the Kingdom of Bahrain taken several actions to reduce the impact of climate change on the water resources from one side and ensure that enough alternative water resources are available to satisfy the current demand from other side. Kingdom of Bahrain started project and established committees to come up with a solution that will be implemented on reality soon such as, established National Water Strategy, issued National Renewable Energy Action Plan, established Bahrain Water Resources Database, started Project for Enhancing Climate Resilience of Water Sector in Bahrain. Such actions will show a result on reality in the coming years, alternative water resources will be found and the impact of climate change on water resources will be reduced and controlled. Hence, the expected on the coming years with such actions, the available water resources will satisfy the increase on the water demand.

IV. CONCLUSION

This research aims to trace the impact of climate change on water resources on the Kingdom of Bahrain. Further, around 4 areas were selected for this study those are the change on the atmospheric temperature, the change on the amount of rain, the amount of ground water, the raise in sea level. Accordingly, the conclusion obtained from this study are as the below points:

- The research shows that climate change has an impact on water resources in Bahrain, based on the selected areas for study.
- The raise of the atmospheric temperature need to be controlled otherwise, the survival of the organisms will be under risk such as the agriculture area, also the demand on the electricity will increase.
- Depending on utilization of fossil fuel, the emission of greenhouse gases will increase which will lead to raise the atmospheric temperature further. Indeed, finding alternative energy sources to generate electricity is needed to limit the raise on the atmospheric temperature.
- Limited annual amount of rain required to go further on finding alternative water resources to satisfy the increase on water demand.

- More restriction on water utilization by industries and individual is required to ensure that enough water is available for human needs.
- Bahrain is doing lots of action to save the available resources, to find alternative water resources, and to limit the impact of climate change on water resources. Indeed, such actions result will be observed on the coming year.

The research output shows the impact of climate change on water resources in the Kingdom of Bahrain and the actions taken by the government to protect such resources. Further, review the latest water management system procedures and compare it with the Kingdom of Bahrain practice can be studied in future research.

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