



## The rising sea level in Maldives

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### I. Introduction

Over the past century, the sea level has been rising significantly, and the rate has increased even more over the recent decades. On average, the mean sea level has risen about 8 to 9 inches since 1880, with about 3 inches in just the last 2 decades. In fact, in 2018, the global mean sea level was about 3.2 inches above the average level in 1993, hitting the highest annual average in the satellite record (1993-present) [1]. All figures imply that there is a global change in the amount of water in the oceans. Moreover, any small increase in the sea level can have catastrophic effects on the environment, especially on coastal areas. There are numerous countries around the world that suffer from rising oceans and flooding, such as Dhaka, Hong Kong, Melbourne, Miami, New Orleans, New York, Rotterdam, Tokyo and Venice [2]. The main reason behind this rise is pollution. In fact, pollution can have many serious consequences, such as damage of landscapes and poison of soil, but the main effect is global warming. Basically, as our atmosphere gets more polluted, our environment gets warmer and warmer. This change in temperature is defined as climate change, which is in our case global warming. Further, rising seas triggered by global warming can be linked to several factors. There are three primary factors that are linked to change in sea level: thermal expansion, imbalance between the snow formation and seawater evaporation, and loss of Greenland and Antarctica's ice sheets. All of these factors are induced by the ongoing climate change and will be discussed further in this paper. While almost all coastal cities might be affected by the rising sea level, low lying cities are hit harder. Therefore, in this paper, I will be discussing the rising sea level, its causes and consequences, especially on the Maldives. This paper will also include some possible solutions that cities might apply to solve this problem.

The causes of sea level rise

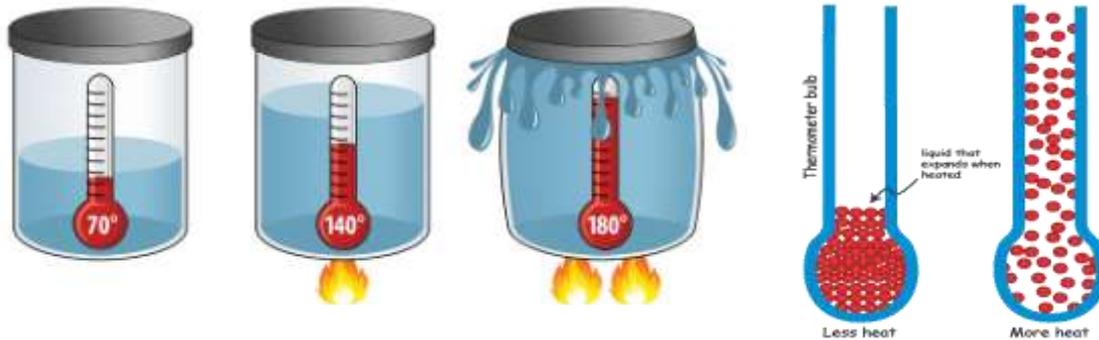
Over the decades, almost all countries around the world strived to provide their citizens with high standards of living and good jobs. While reaching higher efficiencies in different technologies and industries might have led many countries to prosperity and wealth, possibilities of harmful effects on the environment also increase. For example, with the operation of the industries and the evolution new technologies, the demand for non-renewable energy sources, such as fossil fuels, also increased significantly. This increase translated to an additional burden on the environment that can be seen clearly through land degradation, the decreasing water table, and global warming. In fact, the numerous greenhouse gases that emerge from unclean energy combustion end up contributing to the environmental pollution. For example, there are highly-polluting industries, such as thermal power plants, coal mines, cement, sponge iron, and steel producers emit tremendous amounts of toxic gases into the environment [3]. These gases usually include carbon dioxide and methane, in addition to many other hazardous chemicals. These toxic gases are often referred to as greenhouse gases. As a one might expect from the name, greenhouse effect works just as a greenhouse, but in this case for the planet not the plants. Just as those glass walls and roofs keep the plants warm in all seasons and times by trapping the sun's heat, the same effect works on the Earth. During the day, when the sun shines the earth's surface warms up, and at night the heat is released back into the atmosphere. While some of this heat might be released off, due to the human activities a good percentage of the heat is trapped by these greenhouse gases. As a result, the earth gets warmer, causing climate change [4].

As humans continued to pour more and more greenhouse gases into the atmosphere, the tempering effect is transferred to the oceans. On average, the world's seas are absorbing more than 90 percent of the heat from the greenhouse gases [5]. As a result, the sea level continues to rise at rate of 0.13 inches every year. To elaborate, the change in sea level is mainly caused by three factors, all induced by global warming:

#### a. Thermal expansion

As the seas warm up due to heat-trapping greenhouse gases, the kinetic energy of the water molecules rises. When the kinetic energy of these molecules increases, particles start moving faster, thus, maintaining a greater separation. As the separation between the water molecules increases, the volume of the oceans also increases. This process is called thermal expansion. Therefore, when the temperature of the ocean

increases so will the total oceanic volume. This increase of volume causes the level of water in the oceans to rise [6].



**b. Melting glaciers and snow-formation imbalance**

In general, during summers some of ice formations such as mountain glaciers melt. However, when winter arrives, snow forms again from the evaporated seawater, which was sufficient to compensate for the summer loss. However, recently, higher temperatures caused by global warming led to a greater-than average melting in summer. In addition to the greater amounts of melted snow, climate change also led to latter winters and earlier springs. This trend created an imbalance between the snow formation and seawater evaporation, meaning that, more is being melted into the seas than what is evaporating out of them. Thus, leading to sea level rise [5].

**c. Loss of Greenland and Antarctica’s ice sheets**

Similar to mountain glaciers, the increase in global temperature is causing the massive ice sheets that cover Greenland and Antarctica to melt at a faster rate. Greenland and Antarctic ice sheets are the largest ice bodies in the world; thus, they can play an important role when it comes to the global climate system. Both ice sheets have been losing a lot of mass since the 1990s. In fact, this loss contributed to one third of the global sea level rise. In the past two decades alone, Greenland lost more than 3,900 billion tones of its mass, which contributed to approximately 11mm of the global sea level rise. On the other hand, Antarctica also lost 2,600 billion tones, equivalent to a 7 mm contribution [7].



Melting ice sheets of Greenland  
Consequences of sea level rise (especially on Maldives)

The warning signs of sea level rise became extremely hard to ignore. The issue is real, it started displacing millions of people, destroying thousands of acres of land, and generating billion-dollar losses. Few millimeters rise of sea level can cause severe costal erosion, soil contamination with salt, and lost habitat for fish, birds, and plants [5]. Higher sea levels also coincide with extremely hazardous natural disasters such as hurricanes and typhoons. Due to the fact that when the sea level rises, so does the height of the waves; therefore,

washing away a greater area of land. Furthermore, those consequences tend to be more severe in low-lying countries such as the Maldives. The republic of Maldives is made up of 26 atoll islands, which are basically risen coral reefs. Atoll islands are only a few meters high (2-3 meters above mean sea level), for this reason, the Maldives sits very close to the sea level. It is considered as the flattest country on earth, with 80 percent of the land area lying below 1 meter above average sea level [8]. In addition to the global rise, the Maldives is also suffering from regional sea level rise because the winds are pushing more water towards the shores, which is worsening the situation even more as the land is already lacking topography. With that being said, the republic is extremely vulnerable to rising sea levels.

Maldives is facing a possibility that by the end of this century, the majority of its land area will be completely underwater. It is expected to experience half a meter of sea water rise and lose 77% of its land area by 2100. The rising sea level in the republic is increasing the existing environmental stress, such as frequent flooding and freshwater scarcity. Furthermore, rising seas in Maldives are creating a huge threat to homes and industries near the coast since huge waves could be generated from storms that are far away, leading to flooding. In fact, more than 90% of the Maldivian islands experience annual floods. In 2007, more than 1,600 people evacuated their homes and 500 housing units were destroyed due to severe flooding [8]. In addition to the severe floods, sea level rise is also placing a bigger stress on the Maldives' scarce freshwater. According to hydrologists, as salty water (sea water) moves inland, it penetrates underground as far as it does above the ground. In Maldives, groundwater aquifers on the islands are very shallow, which makes them even more vulnerable to inundation by saltwater [8,9]. Consequently, the Maldives is considered to be in a huge danger due to the rising sea level.

#### Possible solutions

For some people climate change and rising seas are problems that will affect future generations only. But for many low-lying countries, such as the Maldives, the future is already here. In 2008, Mohamed Nasheed, the previous president of Maldives, was looking for a land elsewhere to buy so the population could relocate. However, recently the mood has changed. The new government decided to stay and resist the rising sea level with geoengineering projects [10]. The key to the new strategy is basically to build high retaining walls that can protect the islands from the rising water level. Indeed, in Male, the capital of Maldives, a seawall was built and it did protect the city during the floods. Therefore, the government is planning to build similar structures along all shores in Maldives. However, this might not be the wisest decision because there are several problems associated with these seawalls. Firstly, instead of absorbing the wave energy, these hard structures reflect the waves to adjacent areas. So, basically it is solving an issue in one coastal property and creating other problems to the neighboring properties. This also means that neighboring properties will experience even greater waves since the waves are reflected by a hard surface. Secondly, even if these seawalls are carefully constructed, they are prone to failure. For example, the wall can easily collapse if the water waves keep on eroding soil or big sediments at the base of the wall. Finally, these constructed barriers can affect the delicate coastal habitats and reduce biodiversity [11]. Building seawalls, also referred to as shoreline hardening, is recognized to reduce ecosystem services that coastal populations rely on [12]. Therefore, building more of hard seawalls, such as the one built in Male, might not be the best solution to the other Maldivian islands.



#### The seawall in Male

A better approach could be living shorelines, also known as natural seawalls. Actually, it was found that seawalls support 23% lower biodiversity and 45% fewer organisms than natural seawalls [12]. Furthermore,

natural shorelines are site-dependent. For example, in the case of the Maldivian atolls, the shores are already very biodiverse since the islands themselves are risen coral reefs. Therefore, water barriers could consist of water-absorbing salt marsh, oyster shell bags, or even coconut fibers. Living shorelines are also more efficient with it comes to absorbing wave energy. Steven Scyphers, a coastal scientist at Northeastern University, says that natural barriers such as coral and oyster reefs tend to absorb the wave energy instead of reflecting it to the neighboring properties. In addition to the wave energy absorption, natural shorelines are considered a better option for the future. Unlike hard seawalls, where future construction is required to elevate the barrier as the sea level rises, natural shorelines are made up of living matter, which allows them to grow in elevation as time passes. Natural reefs can outpace sea level rise and protect shorelines well into the future [11]. Therefore, the Maldives should consider Natural shorelines since their atoll islands are already biodiverse.



Natural/living shorelines

With respect to the mentioned solution, controlling the toxic emissions remains the long-term key to control sea level rise. The human's behavior now and in the next decades will decide how far the oceans rise. It is our option whether to control and reduce those emissions, managing the disruption or just ignore the warning signs, ending up with catastrophic inundation. If an action is taken now, not only the Maldives will be saved, but also millions of people and animals that live in coastal regions.

## **II. Conclusion**

In conclusion, sea level-rise a phenomenon mainly triggered by pollution. As people continued to pollute their environment, tremendous amount of heat was absorbed by the atmosphere. Consequently, the tempering effected was transferred to the oceans and many large ice formations started melting, leading to an increase in the oceanic volume. And with more and more pollution, the pace of the sea rise got doubled. As a result, many costal regions are suffering, but, low-lying regions are affected more. In the case of Maldives for example, being the flattest country in the world, it is threatened of loosing 77% of its land area by 2100. Moreover, there are several solutions that could implemented to reduce and control the consequences of the rising seas, such as building seawalls. Seawalls can protect the land from waves and flooding that became harsher with the rising oceans. However, hydrologist now are preferring living or natural seawalls over constructed seawalls since they are more efficient technically and environmentally. Moreover, seawall building is just one project out of many geoengineering projects that could be implemented, but, the long-term solution is to reduce the toxic emissions. Finally, sea level rise is inevitable due to the massive emissions that were produces in the past; but the aim now is to slow down its pace by controlling the pollution. So be responsible, have a positive impact on your environment, and save the world.

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