

Rising Sea Level: Flood Management in Coastal Cities

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Abstract— In recent years, numerous scientific studies have generated valuable data on rising sea levels. The primary reason for this is the Antarctic glaciers melting produced by climate change exacerbated by global warming. Consequently, coastal cities are grappling with the critical issue of floods, and how to approach this problem. This paper aims to introduce diverse approaches to managing floods, highlighting the strategies employed by different countries in addressing this pressing concern. It is expected that this paper might help raise awareness of the impact this topic embodies.

Keywords: sea level, floods, coastal cities, infrastructure

Resumen— En los últimos años, estudios han revelado un incremento en el nivel del mar. La razón principal de este fenómeno se debe principalmente al derretimiento de los glaciares en la Antártida, producto del cambio climático y profundizado por el calentamiento global. Las ciudades costeras hoy en día deben afrontar esta problemática. A partir de la idea de que no todos los países poseen los mismos recursos ni tecnologías, en este artículo se abordarán las medidas de defensa que los distintos gobiernos han empleado para manejar las inundaciones. Se espera que este trabajo ayude a crear conciencia sobre el impacto que este tema engloba.

Palabras clave: nivel del mar, inundaciones, ciudades costeras, infraestructura

I. INTRODUCTION

Frequently, news about cities flooding around the world are heard. In order to stop that, affected countries need to search for solutions to reduce the impact of these natural disasters.

Since the Earth started to get warm because of greenhouse gases, the level of the sea has increased. Glaciers have been affected by global warming and the water that was once frozen has started to melt [1, p.2]. Consequently, there are a lot of cities which suffer floods because of their proximity to the coast. A system able to protect these critical areas without damaging water or people is needed.

Cities are growing fast as a result of rising populations and increasing migration. It is important to make sustainable communities to increase urban quality of life. However, problematic issues related to floods increase every day. They affect big cities and especially coastal cities.

The United Nations (UN) addresses this problem in its Sustainable Development Goals (SDGs). SDG N°11, ‘Sustainable Cities and Communities’, in its target 11.5 aims to ‘reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters’ [2, p.5]. To achieve that, improving urban infrastructure resilience is extremely necessary.

In order to build sustainable communities, there are several issues connected with the increased flooding in cities that must be addressed. It is important to manage the problem by providing solutions of different nature. In this paper, this topic will be approached and the techniques used by different countries to manage coastal cities’ floods will be presented.

Therefor achieve the objective stated above, this paper is organized in two parts. First of all, a description of the causes and consequences of coastal floods will be analysed. In the second part, a summary of different approaches used around the world to manage this issue will be carried out. This discussion will take place in terms of solving the problem, improving the problem solution, and coexisting with the problem. It is expected that this paper may help raise awareness of the impact this topic embodies.

II. PROBLEM DESCRIPTION

The alarming issue of floods in coastal cities has become a cause for concern in recent years. During the last few years, data have been unfavourably increasing regarding floods caused by global warming. Recognizing the urgency of the situation, various organizations, such as the United Nations (UN) [2, p.5], have prioritized finding solutions to mitigate the effects of flooding.

The increase in greenhouse gases, including carbon dioxide and other hazardous gases, has led to their atmospheric concentration. As a result, the delicate balance of our planet’s climate has been disrupted, causing a chain of adverse consequences. Notably, the melting of glaciers has been observed, exacerbating the rising sea levels that pose a significant threat to coastal areas. Scientific studies have consistently revealed distressing outcomes, including the gradual disappearance of coasts and beaches, all directly linked to the rise in sea levels.

In the following sections, the causes of the rising sea level will be developed, while examining the intricate factors contributing to this phenomenon. The role of greenhouse gas emissions and their influence on climate change will be

explored, together with the consequences of the rising sea level, including the loss of ecosystems to the displacement of coastal populations.

A. *The end of the ice age*

Global warming is described as the rising temperature phenomenon in our planet. Industrial production has increasingly produced hazardous gases like carbon dioxide, nitrogen and sulphur, among others, and these have started to concentrate below the ozone layer. As a consequence, the heating produced in the Earth, cannot dissipate and these harmful gases condense it. The main reason for this is that detrimental gases are denser than ozone, and they are also in the atmosphere.

This situation brings several meteorological events like extreme rains, droughts, extreme temperature differences and, of course, floods, which are also a consequence of climate change. As it is defined by National Geographic, [3, p.3]. 'Climate change' refers to changes in weather patterns and growing seasons around the world. It also refers to sea level rise caused by the expansion of warmer seas and melting ice sheets and glaciers. These phenomena are also characterized by being unpredictable, intense and disruptive for which it is not easily controlled.

One of the most visible consequences of the climate change is coastal city floods, produced by the rising sea level. The rising sea level is mainly caused by the melting glaciers, especially South Polar Glaciers. The main cause of this melting is that the liquid water needs to get frozen at 0°C, which is exactly 273 K or 32°F but due to global warming, it does not reach the accurate temperature. If the Earth's temperature rises, those cold areas that once displayed low temperatures, today are getting hot, which means, high rates of ice melting.

Additionally, ice has less density compared to liquid water. Consequently, the volume taken by ice is far less than the volume taken by liquid water with the same mass. As mass cannot be created, melted ice needs to take more volume because the displaced volume of liquid water is not enough. Because of the huge amounts of melted ice, the new liquid water needs to search for new places, affecting the coasts.

This melting does not only affect the geographical landscape, but also the population that inhabits those places affected by this problem. These inhabitants, including humans and animals, suffer striking changes in their habitat. For instance, polar bears live in ice sheets. As illustrated in [4, Fig. 1] if the blocks melt, they lose their habitat.



Fig 1. Polar bear in the last ice sheets [4]

B. *Urban infrastructure consequences today*

The main consequence of Polar Ice melting is the rising sea levels. As was described before, this situation is a consequence of global warming. Those coastal cities that once were built with a specific sea level, today are affected by this problem.

There are many cities that were designed to enjoy beaches and coasts but today they cannot appreciate that. In addition, not all construction materials have the same reaction to water or flood corrosion. Most of the coastal buildings were not prepared to withstand this problematic issue.

Because of these coastal floods, there are organisations which are searching for solutions to those problems that affect the world. The UN in its SDG N°11, 'is searching to improve the cities' infrastructure quality and avoid climatic disasters' [2, p.5]. Solving the flood issue is urgent. Countries around the world that have designed and shared knowledge and technology to solve the problem described above. The main goal has been to find a way to deal with these possible natural disasters consequences. Some of these mechanisms will be described below.

III. PROBLEM APPROACH: WAYS TO DEAL WITH FLOODS

As it was stated before, there are several countries committed to searching for a solution to the coastal flooding issue. Most of them are in coastal zones or have access to them therefore, it is a problem that affects everyone. There are many different approaches and each one is accurate for each situation.

Governments have been trying to solve this problem sustainably, taking care of the natural resources, making wise financial investments and having the least social impact as they can. The potential solutions can be placed in three different categories, those countries that solve the problem, those that improve their infrastructure to endure flooding periods and those that have learned to coexist with the problem.

A. *Solving the problem*

Solving the coastal cities' flood problem has been the affected countries' main target. However, it is a possibility which needs a huge investment that not all countries can afford. To reach it those countries' governments have to analyse factors such as appropriate budget and finance, an organized work plan and instructed manpower.

One of the most developed countries in this category is Japan. Also, Japan is an island which has suffered several flood issues throughout its history. This country needed a solution as a priority because it is a land crossed by five rowdy river systems and dozens of individual rivers.

To solve this problem, the Japanese capital made an engineering marvel. In Tokyo, Japanese engineers have improved a sewer system that made this city one of the most advanced in the world. The system used consists of a 6.3 km-long network of underground tunnels built below the city presented in [5, Fig. 2]. When one of these rivers overflows, the water falls into one of five enormous 70-meter tall cylindrical tanks spread across the Channel's length. Each of these tanks is big enough to accommodate a space shuttle or

the Statue of Liberty and they are interconnected through these tunnels. As the water approaches the Edo River, the 'floodwater cathedral' Tortajada reduces its flow, so the pumps can push it to the river [5, p.17].



Fig 2. View a stunning of the floodwater cathedral above [5]

In this case, Japan used a tunnel network but this solution is not the only one admitted. Solving this issue deserves several studies to check the infrastructure integrity. Another solution can be the creation of bridges or other concrete structures depending on the condition of each country.

B. Improving infrastructure

Despite the fact that solving the problem is the main target, not all countries can do that. Besides the need for a solid investment, there must be structural integrity in buildings, which means new and modern structures which could support an improvement. Many of the affected countries have old buildings and their governments choose to improve their defence systems, reinforcing those coastal buildings.

In addition, there are also countries that have always had a flooding problem but because of global warming and climate change, this issue increased. These nations have established barriers systems in the 80' to deal with the sea and rain floods because of their quite fragile infrastructure. However, this clever movement helped these countries to afford the floods today caused by the rising sea level.

One of the first cities was London. used the barriers system to protect the city from the floods caused by the rising Thames River level. This structure was built in 1982 on the eastern side of the capital at Woolwich. It was designed to protect 48 sq miles (125 sq km) of the city from flooding caused by tidal surges.

The barrier developed in the London project is presented in [6, Fig 3]. It was made up of 10 steel gates, reaches 520m (1,700ft) across the river. When open, the gates lie flat on the river floor and close by being rotated upwards until they block the river. The four main gates span 61.5m (200ft) and weigh more than 3,000 tonnes each. The barrier is closed just after low tide to create an empty "reservoir" for the river flow to fill up. It takes 75-90 minutes to close it, starting with the gates on the outside until the middle gates are shut [6, p.5].



Fig 3. London barriers [6]

This project had such good answers that other countries in the same situation decided to use the same solution. Another example is the famous case of the Italian city Venice, worldwide known as a city that must deal with several flood issues. Venice is next to the Adriatic Sea, separated from it by a lake, and the only way to access it, is through three gates or channels: the Treporti channel, the Malamocco channel and the Chioggia channel. Those channels can be seen in [7, Fig 4].



Fig 4. Three Channels gates in Venice's lake [7]

In 1984 the barriers system called the MOSE project was born. Those hydraulic barriers are sensible to the changing sea levels and today Venice uses them to defend the city from the floods. The barriers are 30 meters long, and 20 meters wide and are embedded into cement boxes. Its elements are described in [7, Fig. 5].

This city is one of the first coastal cities which use this kind of system to control hydric levels, allowing more water to get into the lake. It is not only an economical solution but also a tourist place that people and scientists around the world have visited it.

In 2020 the barriers had their inauguration. A tide that was 135 centimeters (53 inches) above normal levels hit Venice. Usually, that would have put around half the city underwater, but this time, the city remained dry. It was the first time the MOSE had been raised in adverse weather conditions [6, p.6].

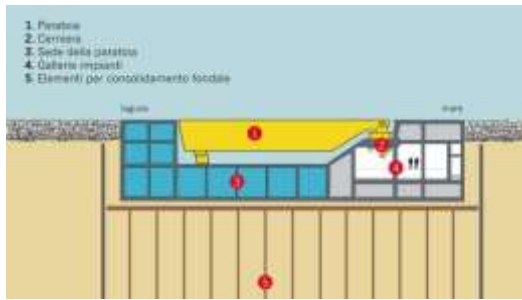


Fig 5. Detail of the MOSE Project

C. Coexisting with the problem

There are some places where the flooding problem cannot be solved because there are countries that have not got time to react or have not got the financial resources to afford it. In both situations, they have to coexist with the problem in the most sustainable way possible.

One of the most resilient cities has been Jakarta, the capital city of Indonesia. Its frequent floods caused by the rising Java sea level have been harmful and the citizens have had to adapt to this new lifestyle as it can be seen in [8, Fig 6] until the problem can be fully addressed. Within the last three years, the flood intensity has gotten worse [8, p.3].

In those cities people have taken decisions to withstand the floods like, moving their furniture to higher floors, saving their home appliances and building vulnerable bridges as people in Manila, Indonesia do. Other useful tools are some underground water tanks which recollect and release water slowly.



Fig 6. People in Jakarta coexist with floods [8]

Another affected country is India, due to subtropical and wet weather this territory receives huge amounts of water every year from the Moonsoon rains and the rising sea level. Coastal zones such as the Chellanam coast in Kerala are the most vulnerable.

These areas suffer the rising sea level empowered by the storm tides. The combined effect of long and short waves over wave setup forms extreme waves rumpus that flood inland areas. At gently sloping beaches, the longwave component dominates and overtops the seawalls and damages households along the shoreline. It can be exposed in [9, Fig 7]. India has a vast coastline covering nine states, and most of these coastal states are densely populated [9, p.1].



Fig 7. People in India coexist with floods [9]

Despite still being insufficient, in order to address this vulnerable situation during flooding periods, native scientists have discovered a temporal solution which does not need an infrastructure improvement but allows a healthy coexistence with the flood waters in Indian cities. The Precise Healthcare Pvt. Ltd. is a professional lab team that created a water purification tablet illustrated in [10, Fig 8]. It is a capsule which contains sodium dichloroisocyanurate (NaDCC) - an organic chlorine donor with a superior disinfection effect, a near-neutral pH and a simple, easy-to-understand system for added safety [10, p.2]. The team assures that these tablets are the fastest to kill different bacteria, viruses, germs, and fungi [10, p.3].

Despite this solution being a clever way to get rid of some problems, searching for non-infrastructure solutions is not enough. It is important to emphasize that living with the problem is not a sustainable way of living and this situation needs to be solved. Meanwhile, these tablets can help as a temporary solution.



Fig 8. Bactafree water purification tablet [10]

IV. THE DIFFERENT FACTORS IMPACTING ON THE SOLUTIONS

There is not a single solution to this problem. However, each country must choose the most accurate option according to their economic resources, the infrastructure possibilities and the level of emergency. Each solution has positive and negative aspects depending on the aforementioned factors.

The monetary resource is a big decisive factor. There are some countries with budget enough to spend the necessary to build new floods proof structures. On the other hand, there are countries whose only solution is to coexist with floods. For instance, the solution used in Tokyo is highly successful but extremely expensive. For the time being, the conditions in Indonesia or India do not allow for the building of new structures and their

solutions are limited to moving the population to another place or investing in water purification.

Another main factor is taking care of the cultural heritage. The oldest cities such as Venice and London are historical places where preserving old buildings is also a priority. It would be easier to demolish and rebuild the Thames walls or move the Venice citizens to higher lands. However, these cities have a cultural background that cannot be just forgotten. This is the reason why they use some technologies to protect the cities from floods without disturbing the views.

V. CONCLUSION

Deciding the coastal cities flood management is extremely urgent whether the method used, solving the problem, improving structure or living with it until infrastructure development is possible. It is necessary to search for an accurate solution to each country, always aiming at dealing with the problem in the most comprehensive manner.

Every day news about coastal cities' floods caused by global warming and climate change are heard. As stated in SDG N° 11 [2, p.5] humanity must seek a compromise to improve sustainable structures and, in this way, increase urban quality of life. This not only affects our buildings but also our society.

Engineers are an important piece of the puzzle that must work towards developing a sustainable future, taking care of nature, the resources, the money and the people. As Mahmoud Abbas said, 'If you run from a leaking roof, you'll end up with a flood' [11, p.3]. Using his arguments, a water problem must be solved as soon as possible no matter how small it seems to be.

As a conclusion, it is necessary to protect the infrastructure and the world also. Because of the global warming, solving the flood issue has become a priority. That is because it is important to work sustainably, finding ingenious solutions which allow an efficient urban infrastructure quality. The coastal cities floods caused by the rising sea level problem deserve to be solved as soon as possible.

REFERENCES

- [1] T. Brown "Sea Level Rise" National Geographic <https://education.nationalgeographic.org/resource/sea-level-rise/> (accessed May 20, 2022)
- [2] D. Lowthian "The Sustainable Development Goals" United Nations <https://www.undp.org/sustainable-development-goals/sustainable-cities-and-communities> (accessed 2023)
- [3] T. Brown "Global Warming" National Geographic <https://education.nationalgeographic.org/resource/global-warming/> (accessed May 20, 2022)
- [4] T. Brown "Greenhouse Effect" National Geographic <https://education.nationalgeographic.org/resource/greenhouse-effect/> (accessed May 20, 2022)
- [5] D. Arguedas Ortiz "The underground cathedral protecting Tokyo from floods" BBC Future <https://www.bbc.com/future/article/20181129-the-underground-cathedral-protecting-tokyo-from-floods> (accessed November 29, 2018)
- [6] T. de Castella "How does the Thames Barrier stop London flooding?" BBC News <https://www.bbc.co.uk/news/magazine-26133660> (accessed February 11, 2014)
- [7] J. Buckley "The flood barriers that might save Venice" CNN Travel <https://edition.cnn.com/travel/article/mose-venice-flood-barriers/index.html> (accessed February 18, 2022)
- [8] S. Yuniyar "Flooding in Jakarta: A Call to Increase Climate Change Awareness" State of the planet <https://news.climate.columbia.edu/2023/03/03/flooding-in-jakarta-a-call-to-increase-climate-change-awareness/> (accessed March 3, 2023)
- [9] R. Ramakrishnan "Wave induced coastal flooding along the southwest coast of India during tropical cyclone Tauktae" Scientific reports <https://www.nature.com/articles/s41598-022-24557-z> (accessed November 19, 2022)
- [10] A. Ahmedabad "Flood & Emergency" Bactafree <https://www.bactafree.com/flood-emergency/> (accessed 2021)
- [11] N. Juma "Flood Quotes That Are Flooded With Emotions" Everyday power <https://everydaypower.com/flood-quotes/> (accessed April 20, 2023)

María del Rosario Schmidt Caballero is a Civil Engineering student at UTN FRP: mariaschmidtcaballero@alu.frp.utn.edu.ar The present manuscript is part of the research activities in the Inglés II lesson at Universidad Tecnológica Nacional, Facultad Regional Paraná. Students are asked to research a topic so as to shed light on a topic of their interest within the National Academy of Engineering's Grand Challenges or the United Nations' Sustainable Development Goals frameworks. If sources have not been well paraphrased or credited, it might be due to students' developing intercultural communicative competence rather than a conscious intention to plagiarize a text. Should the reader have any questions regarding this work, please contact Graciela Yugdar Tófaló, Senior Lecturer, at gyugdar@frp.utn.edu.ar