WATER SUPPLY SYSTEMS FOR POST-DISASTER SITUATION

FELAKET SONRASI KULLANILABİLİR SU TEMİNİ SİSTEMLERİ

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ÖZET

FELAKET SONRASI KULLANILABİLİR SU TEMİNİ SISTEMLERİ

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Doğal afetler, insan yapımı her türlü yapıya şiddetli bir şekilde zarar verme kapasitesine sahiptir. Deprem de bunların en yıkıcı ve en acımasız olanlarından biridir. Depremlerin modern şehirlerde yaratacağı en büyük zararlardan bir tanesi, altyapı sistemlerine zarar vererek deprem sonrası senaryolarda afetzedelerin su kaynaklarına erişimini zorlaştırmak olmaktadır. Bu sebeple afet sonrasında, afetzedeler için kullanılabilir su kaynakları oluşturmak büyük bir önem arz etmektedir. Deniz suyu, İstanbul ili için kolay ulaşılabilir olduğundan, deniz suyunun dezenfeksiyonu ve desalinasyonu (tuzdan arındırma) işlemleri, afetzedelere hızlı bir çözüm sunulması için kullanılabilir. Bu çalışmada UV ışınlarıyla, ozonla ve klorla dezenfeksiyon yöntemleri kullanılarak deniz suyunun dezenfekte edilmesi durumları karşılaştırılarak, maliyet ve uygulanabilirlik açısından değerlendirilmesi amaçlanmaktadır. Sadece suyun dezenfeksiyonu değil, tersine ozmoz yöntemi gibi, deniz suyunun desalinasyonu sağlanarak, dezenfekte edilen suların içilebilir olması sağlanmalıdır. Bu çalışma, belirli kabuller üzerinden ilerleyerek, olası senaryolar üzerinden suyu arıtmanın ve tuzundan arındırmanın maliyetlerini yaklaşık olarak hesaplamak için yapılmıştır. En doğru sonuç, hükümet ve organlarının yapacağı, bölgeye özel deneylerin ve bilimsel verilerin ışığında, profesyonellerce alınacaktır.

Anahtar Kelimeler: Deprem, deniz suyu dezenfeksiyonu, desalinasyon, denizden su tahliyesi, pompa, UV, ozon, klor, ozmoz, tersine ozmoz, enerji tüketimi, dezenfeksiyon maliyeti, desalinasyon maliyeti, enerji maliyeti, solar panel, jeneratör.

ABSTRACT

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Natural disasters have the capacity to severely damage all kinds of man-made structures. An earthquake is also one of the most destructive and cruel of them. One of the biggest damages that earthquakes will cause in modern cities is to damage infrastructure systems and make it difficult for disaster victims to access water resources in post-earthquake scenarios. For this reason, it is of great importance to create usable water resources for disaster victims after the disaster. Since seawater is easily accessible for Istanbul province, disinfection and desalination of seawater can be used to provide a quick solution to disaster victims. In this study, it is aimed to evaluate the cost and applicability by comparing the cases of disinfection of seawater using UV rays, ozone and chlorine disinfection methods. Not only disinfection of water, but also desalination of seawater, such as reverse osmosis method, should be provided to ensure that the disinfected water is potable. This study was conducted to approximate the costs of using and desalinating water through possible scenarios, proceeding from certain admissions. Professionals in the light of regional-specific experiments and scientific data that the government and its bodies will conduct will obtain the most accurate result.

Keywords: Earthquake, seawater disinfection, desalination, drawing water off sea, pump, UV, ozone, chlorine, osmosis, reverse osmosis, energy consumption, disinfection cost, desalination cost, energy cost, solar panels, generator.

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Mehmet Uğur ÇETİNKAYA
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Symbols

%	Percentage
°	Degree
Br^-	Bromine
℃	Degree Celsius
CFU	Colony Forming Unit
Q	Flow Rate

Abbreviations

AC	Alternative Current
AFAD	Ministry of Interior Disaster and Emergency Management Presidency
AOC	Assimilable Organic Carbon
ATS	Automatic Transfer Switch
BOD	Biochemical Oxygen Demand
BWRO	Brackish Water Reverse Osmosis
CT	Contact Time
DC	Direct Current
DNA	Deoxyribonucleic Acid
dsDNA	Double Standard DNA
EAOP	Electrochemical Advanced Oxidation Process
EDI	Electro deionization
FCR	Free Chlorine Residual
GRAS	Generally Recognized as Safe

$HOBr^-$	Hypobromous Acid
$HOCl^-$	Hypochlorous Acid
IMO	International Maritime Organization
LADWP	Los Angeles Department of Water and Power
MNF	Minimum Nighttime Flow
NaOCl	Hypochlorite
NCl_3	Trichloramine
NH_2Cl	Monochloramine
$NHCl_2$	Chloramine
O&M	Operation and Maintenance
OM	Organic Matter
PE	Polyethylene
PE	Polyethylene
PPM	Parts per Million
PVC	Polyvinyl Chlorine
RNA	Ribonucleic Acid
RO	Reverse Osmosis
SEC	Specific Energy Consumption
SWRO	Seawater Reverse Osmosis
TEAŞ	Turkish Electricity Transmission Corporation
TRO	Total Residual Oxidant
TÜİK	Turkish Statistical Institute
WSP	Water Safety Plan

1. INTRODUCTION

Natural disasters always caused troubles to humankind since the very beginning of human era. Volcanic activities, floods, sinkholes, avalanches, wildfires and the last but not least, earthquakes took so many lives and human race started to take precautions in order to save their lives. At first, humans moved away from volcanoes, started to live in higher places that flood cannot reach or built a set to slow the water volume down to decrease destructiveness of it. However, human race is having difficulties while trying to find a solution to avoid earthquakes.

Avoiding the earthquake had been a hard job in all human eras. When earthquake happens, there is nowhere to run or hide on the ground. The best thing to do is to learn living with the earthquake and expect it on the most unexpected times. Humans are trying to build earthquake-resistant buildings or foundations to keep individuals safe but the cost and applicability of this method is quite hard. Even if there is a plan to make every single building earthquake-resistant, it will took a lot of time. Since the earthquake cannot be prevented, the pre and post cautions should be considered in order to terminate the correct behavior to save as many lives as possible.

Earthquake; the Earth, the ground shook and spread the sudden vibrations of breaking waves occurring at an unexpected time they create the individual causing harm or damage to property where one can enjoy nature and social life of the event. The severity of the earthquake hazard is measured by damages such as loss of life and property, injuries and structural damage caused by the natural event in question. In terms of its effects, an earthquake can have profound social consequences, as it disrupts the daily functioning of society and changes the order within society, forcing conflict and change. As a matter of fact, people's lives are turned upside down due to the earthquake, and with the destruction of the existing social order and the spread of social dissolutions, the need for reorganization in society may arise (Özkılıç and İpek, 2021).

There are various concepts used with disaster in disaster studies. A concept that is often used together with the concept of disaster also comes across as a ‘danger’. The concept of danger can be defined as natural events that can have an impact in different places and times, alone or in combination with other disasters. According to another definition, danger is expressed in the form of the potential of nature, technology and events of human origin to harm society, socio-economic status, the natural environment and resources (Uyar, 2021).

Being prepared for a disaster can prevent many life losses during and after the earthquake. Citizens should be educated for pre and post-earthquake situations. Earthquake risk reduction activities and the adoption of mitigation measures are considered the most concrete reflection of risk perception. Some people are aware of the risk and take precautions, while others may choose to ignore it. Considering that the participants of the four surveys conducted were not partners, the change in the perception of earthquakes on the same people could not be observed. However, when looking at the answers given, there is an improvement in the measures taken and risk awareness. In a survey conducted in 2021, the proportion of those who want to study disaster education was found to be 71% (Özkılıç and İpek, 2021).

In many cases, most of the people are not dying during the earthquake. The reason that they are losing their lives is, the undeniable fact, catching flat-footed. People are not taking precautions for the earthquakes due to the idea of its probability of happening. With the current technology level of the humanity, it is not possible to foresee or avoid the upcoming seismic activities long before they occur but there is a way to decrease the level of destruction by taking precautions. There must be earthquake scenarios to create this kind of precautions.

Destructive aspect of the earthquake on the Istanbul region cannot be underestimated due to the history of earthquakes that happened on that region. The destructive impact of the earthquakes happened on Istanbul region between 16th and 20th centuries were listed by the destructiveness (Özata and Limoncu, 2014):

- 10th September 1509 Earthquake
- 25th May 1719 Earthquake
- 22nd May 1766 Earthquake
- 10th July 1984 Earthquake
- 17th August 1999 Earthquake

Besides the destructive aspect of earthquakes happened around Istanbul region, the epicenters of earthquakes could differ entirely according to prior earthquakes listed above (Özata and Limoncu, 2014). Therefore, it had been suggested that not to focus on potential earthquake hit zones solitarily, but to determine the sphere of influence of the earthquake to build post-earthquake sheltering fields.

Turkey is traversed by active faults. Two significant earthquakes struck the Marmara area, where Istanbul is located, on 17 August and 12 November 1999, with magnitudes of 7.4 and 7.2 on the Richter scale, respectively. Nearly 18,000 people were killed or injured as a result of these disasters. Although Istanbul was relatively mildly damaged compared to other cities in the Marmara area, some experts predict that an earthquake of magnitude 7 on the Richter scale will strike the Marmara region 62% of the time in any 30-year period. Istanbul is divided into 32 district municipalities and 1 metropolitan municipality. We chose two of these districts for the study: Bakırköy, which is located in a first-degree earthquake risk zone and is likely to suffer the most in the upcoming earthquake, and Beykoz, which is located in a second-degree earthquake risk zone and is expected to suffer the least. There are a number of communities (sub districts) of varying socioeconomic level within the districts (Tekeli-Yeşil et al, 2010).

Since Istanbul is a mega-city settled on a relatively small area, it is not a surprise to expect an unplanned urbanization. It cannot be expected from all the foundations that are planned safe and applicable in the light of regulations and law. Therefore, it is obvious to expect a colossal amount of destruction and life losses. Scientists are expecting an earthquake around Istanbul around 7.0 – 7.5 magnitude on Richter scale. The 17th August 1999 earthquake had a 7.4 magnitude on Richter scale. Hence, an earthquake with approximately 7.0-7.5 magnitude can cause as big devastation as before, even bigger when the unplanned urbanization have been taken into consideration.

There are two main points that should be considered while regarding the post-earthquake scenario. First, is to find a shelter for earthquake victims, as mentioned above. As the mass majority can remember it, tent and container camps were built next to earthquake zones right after the earthquake had happened. Charities like Kızılay and AFAD (Ministry of Interior Disaster and Emergency Management Presidency) trying to help as many people as possible to save lives and help the survivors to continue their lives healthy and prosper enough under such circumstances. At the 1999 Istanbul earthquake, the post-earthquake scenarios were not planned formerly and it cost considerable amount of life and money (Özata and Limoncu, 2014). Therefore, it had been stated that, everyone was able to see the importance of taking pre and post cautions for an earthquake.

Second point is, to supply food and water right after earthquake had happened. There might be a shortage on supplying food and water to survivors, right after the earthquake. This shortage will have a direct proportion with the increasing amount of existing survivors. The first priority is to give people food to eat and water to drink. Therefore, a quick and reliable solution, like disinfecting and desalinating seawater, should be terminated by using engineering methods. Since infrastructure of the city will collapse, an external energy source should be mounted to the seawater disinfection and desalination units to supply the needed energy.

One of the most vital lifeline systems is the water supply. It protects practically all structures and facilities from fire, supports most commercial and industrial activities, and underlies fundamental home services and household functions. Water supply damage, on the other hand, may physically weaken and interrupt nearby vital systems. Damage to water supplies has been used to exemplify the notion of cascading damage, in which damage and loss of function spread throughout many lifeline networks. A single water main failure in New York City's Garment District flooded an electric power substation, causing serious fires, cutting off electricity in midtown Manhattan, disrupting telecommunication services, shutting down a large portion of the subway system, and causing millions of dollars in indirect economic losses due to business disruption. In such circumstances, the initial damage spreads through the loss of operability in broad areas of interdependent systems until a widespread loss of essential infrastructure service occurs, resulting in substantial regional economic effects (Bonneau and O’Rourke, 2009).

Every supply creates its own demand. Under normal circumstances, supply must be surplus in order to correspond any kind of need even there is a leakage inside the system. About this supply and demand formula, the water usage relationship under the normal conditions can be explained with the following formulas (Yoo et al, 2019):

$$Supply = Total\ Usage\ (Demand) \tag{1.1}$$

$$Supply = Usage + Leakage\ Quantity \tag{1.2}$$

Under normal conditions, water supply should at least be equal to demand, if there are not any leakage inside the pipeline. However, since the water supply networks are not isolated systems, leakages are inevitable. Therefore, total usage becomes the sum of usage and leakage quantity. Thus, supply should be in adequate amount to provide the need of water in contrary of both demand and leakage. When an earthquake happens, these normal conditions changes into abnormal situations and different equalities should be taken into consideration. The water usage relationship under abnormal conditions can be explained with the following formulas (Yoo et al, 2019):

$$Supply = Usage + Leakage\ Quantity \tag{1.3}$$

$$Supply < Usage \tag{1.4}$$

$$Supply < Usage + Leakage\ Quantity \tag{1.5}$$

Normally, it has been expected to see a formula similar to Formula 1.2 and Formula 1.3 but under abnormal conditions, like post-earthquake conditions, Formula 1.4 and Formula 1.5 are applicable. Water supply networks are quite big, especially for a metropolitan like Istanbul. Therefore, it is not an easy task to designate and repair the faults, which happened on the pipeline due to earthquake. This situation creates a supply loss because as it can be seen on the Formula 1.5, due to the increment on the leakage quantity, supply becomes insufficient. Even though usage decreases slightly due to collapsing of buildings and life losses happen. Since water supply network cannot provide enough water to city’s needs, external water supply methods should become a part of the supply chain. This way, clean water or usable water can be provided to survivors on the worst-case scenario on an earthquake.

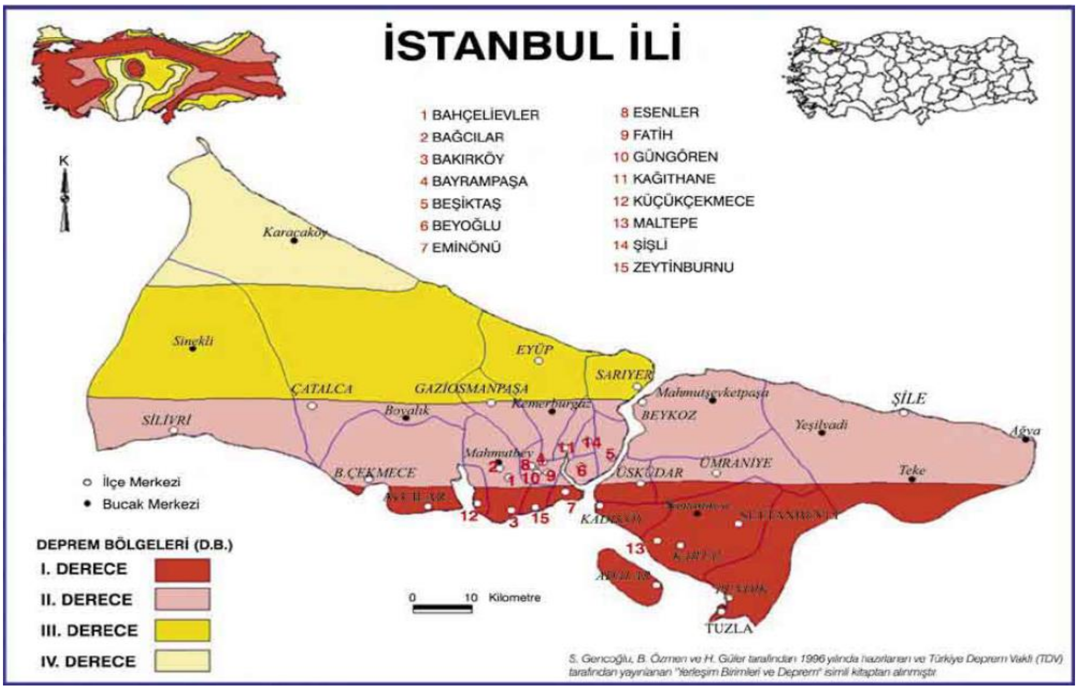

Figure 1.1 Seismic Map of Istanbul (Gencoglu et al, 1996)

Istanbul is standing on Northern Anatolian Fault Line and the areas, which are next to Sea of Marmara, has the highest risk as it may be seen on the figure below. By looking at the seismic map of Istanbul above, degrees of seismic activities as a percentage are as following; 17% is I. Degree Region, 41% is II. Degree Region, 31% is III. Degree Region and 11% is IV. Degree Region. I. Degree Region is the most dangerous region and it means that most of the destruction will occur on the red zones shown in the figure above. However, it does not mean that IV. Degree Region will not have any destructions, it can vary due to the magnitude of the earthquake. The more the magnitude increases, the more destruction will occur, even on the areas that are far away from the fault line. From the seismic map of Istanbul, the areas that will see the destruction at the highest level are Küçükçekmece, Bakırköy, Zeytinburnu, Eminönü and Maltepe. Common ground of these locations is they are facing directly to the Sea of Marmara. Most of the areas were created by filling into the sea. Therefore, shores of Marmara will get devastated if there will be an earthquake as it is expected.

Using asbestos based pipes on city's infrastructure, makes the city vulnerable for earthquakes even more than on normal conditions. Asbestos-based pipes are very brittle so this situation causes them to break easier than a PVC (polyvinyl chloride) pipe. When the main pipeline breaks, there will not be any water supplied to people. This situation creates the question; how can everyone can access to usable water after a natural disaster or after a big earthquake? Changing every piece of asbestos and steel-based pipeline in a short time is an impossible duty to apply. The brittle structure of asbestos-based pipes are easy to break and it makes them the first victim of the earthquake. However, asbestos-based pipelines are not just victims; they are suspects in one way. Due to their breakable structure, water supply networks will fail after a big earthquake and people will experience big difficulties, even though they come out one piece under a collapsed building.

Seawater contains all the elements that are normally present in nature. These components found organically and inorganically in the seas, cause many problems in systems that desalinate seawater. In addition to the algae layers that form over time in these systems, the crusting in the form of sediment that occurs on the inner walls of these systems are the main problems. The increased temperature inside the system reduces the ability of the salt to dissolve, which leads to precipitation. Because precipitation formation occurs at high temperatures, it is useful to keep the operating temperature at a maximum of 120°C to prevent precipitation formation. In order to prevent the formation of fungi, bacteria or algae, it is necessary to use copper salt or, in other words, hypochlorite (NaOCl). A regular exchange of salts is very important in distillation systems with simple evaporators. In order to eliminate the problems that may occur in the plant, especially in reverse osmosis systems, a preliminary treatment is absolutely necessary. If chemical preliminary preparation of untreated water is abandoned, a sand-quartz and activated charcoal filter should be used for filtration of undesirable formations (Can et al, 2002).

Water quality is an important aspect, regardless of the post-disaster scenario or not. However, on a post-earthquake scenario, the drinkable water does not mean the highest quality of water. Water must be cleansed from the microorganisms and salt ions, as well as muddiness of the water mass. When people are relocated due to conflict or natural disasters, they may relocate to an area with contaminated unprotected water sources. Unprotected water sources in and around the temporary community are extremely prone to be polluted when population density is high and sanitation is weak. A displaced population with reduced immunity because of hunger caused by food shortages or the burden of other illnesses is more vulnerable to a waterborne disease epidemic. Three steps should be included in emergency planning initiatives:

- Vulnerability assessments (which should be included in any significant supply's WSP) to identify important aspects of current systems that, if attacked, would cause substantial disruptions in fundamental services,
- Mitigation plans to identify possible ways to mitigate or lessen the disruptive impacts of the loss of susceptible elements or facilities,
- Emergency readiness plans to aid in crisis management and service restoration should disruptions occur (WHO, 2014).

Therefore, the main problem here is not to provide the best quality of water to earthquake survivors. The main problem is to achieve a water that can be drinkable without having pathogens or salt ions inside. For some occasions, there might be a small amount of pathogens or salt ions, however, this scenario will not be considered during this research.

There are many methods for disinfection as physical, chemical and biological. Every method has its own advantages and disadvantages. Water can be treated using physical agents such as light, heat, pressure, and radiation to generate beneficial changes in water quality, such as pathogen disinfection or pollutant destruction. While these physical processes do not involve the addition of chemicals directly, they frequently act by generating reactive chemical species, which then cause reactions that transform various constituents in water or break down essential physical properties of microorganisms, resulting in inactivation. Physical agents, on the other hand, can directly alter the chemistry of water by transferring heat, pressure, or light energy to a receptive molecule in water, resulting in transformation and deterioration. Microorganisms can be directly damaged by these physical agents through mechanisms such as DNA or RNA damage, cellular membrane degradation, and protein or enzyme denaturation (Naughton and Mihelic, 2019). Reverse osmosis desalination method will be a good example for physical disinfection methods. In addition to physical methods, chemical disinfectants do not always kill all germs they come into contact with, nor do they disinfect all microorganisms equally well; for example, most disinfectants do not destroy bacterial spores. The disinfectant used will be determined by the microorganism, the application technique, and the nature of the material to be disinfected. To control and prevent infection, chemical disinfectants are administered to non-living objects and materials such as surfaces and tools, whereas antiseptics are applied to live tissues (HSA, 2022). Chlorine disinfection method is an example for the chemical methods. Lastly, there are biological disinfection methods. On biological disinfection methods, the main disinfectant is bacteria. These methods are using “good” bacteria to destroy “bad” ones. An antibacterial treatment is fantastic for a rapid, short-term wipeout, but the surface can be polluted again in a matter of minutes. Biological cleaning, on the other hand, leaves just traces of friendly microorganisms on a surface, hours after usage. This important distinction is that biological cleaning agents not only keep surfaces cleaner for longer, but they also clean long after they've been applied (residual cleaning), making them significantly more cost-effective in the long term (Chant, 2022).

This research focuses on a small-scaled settlement named Avcılar with 457,981 population, which is located on the European side of Istanbul to create an idea of how to bring clean water to earthquake survivors, considering their decreased daily water usage levels, and extrapolate the results based on Avcılar to whole Istanbul region, on a hypothetical post-earthquake situation.

1.1 Infrastructure Damage on Past Earthquakes

Infrastructural damage is a phenomenon that will happen during earthquakes, which has big magnitudes. There are many examples of infrastructural damage happened due to earthquakes from all over the world. Sikkim earthquake, which lies between Nepal and Bhutan region. That earthquake happened on 18 September 2011 with a shallow depth of 19.7 km. Duration of this earthquake was 30-40 seconds with a magnitude of 6.9 on Richter scale. This earthquake was followed by three more aftershocks that are 5.7, 5.1 and 4.6 respectively after 30 minutes (Tambe et al, 2012). Due to the terrain and climate of the region, there were many structural and infrastructural damage happened around the earthquake area. Ninety thousand houses was damaged and water management infrastructures were not able to feed the main city line. More than 50% of the population got affected from the infrastructural damage.

Other example of this infrastructural damage due to earthquake is the 1994 Los Angeles earthquake. The magnitude of this earthquake was 6.7 on Richter scale with a depth of 17 km. 14% of the population got affected from infrastructural damage caused by the earthquake and it makes approximately 500,000 people affected. An earthquake, which is over 6.5 magnitude can devastate infrastructure network easily. This case can be a great example to the expected network failure when the expected earthquake hits Istanbul in the near future. Only 25% of water network can be re-established in one day, 65% after 3 days, 94% after 5 days and full re-establishment completed after 7 days (Tabucchi et al, 2008). 25% of re-establishment will not be enough and/or may not be possible to re-establish on the post-earthquake situation for 25% of the population, which is 3,865,613 individual when 2020 population numbers from TÜIK (Turkish Statistical Institute, 2020). The water distribution pipelines in this zone are 70–90 years old, generally made of cast iron with lead-caulked joints and nominal sizes ranging from 150 to 300 mm, with 150 mm being the most common. According to LADWP (Los Angeles Department of Water and Power) records, pipeline repairs in this zone have been 2–3 times greater than in other portions of the system since the Northridge earthquake. Following prior earthquakes, substantial levels of ongoing pipeline maintenance have been recorded in seismically active zones. The high post-earthquake repair rates not only reveal that the pipelines are fragile owing to their condition of repair, but they may also give indirect evidence of high seismic danger in the area (Romero et al, 2010).

Great Japan earthquake was a great example for the infrastructural damage. That earthquake happened on 11 March 2011 and the magnitude of it was 9.0 magnitude on Richter scale. Due to the earthquake and tsunamis happened after, 18,000 people were found dead. 2.3 million Houses encountered water cut off after the earthquake happened, due to the massive and serious infrastructural damage (Kobayashi, 2014). Japan is one of the most earthquake ready countries among the world. 9.0 magnitude of an earthquake is not an unexpected one, when the geological and seismological conditions were taken into consideration. When Turkey compared to Japan, Turkey is not an earthquake ready country at all. Therefore, an earthquake with 7-7.5 magnitude will cause serious infrastructural damage around Istanbul region.

Another example for the earthquake that created infrastructural damage is 1993 Marathwada earthquake. The magnitude of the earthquake was 6.4 on Richter scale.

Official reports mentioned that, over 8,000 people was dead and over 14,000 people got injured. Before the earthquake, more than 70% of settlements with a population of more than 500 families had overhead tank-based water supply systems. They were designed to supply water to residential faucets, but most were broken for a variety of reasons, including unrepaired pumps, dry bore wells, and pumps installed at too shallow a depth. All big villages (more than 60 households) have a water shortage, with half of them having a shortage of more than 100 liters per family. Small villages (fewer than 400 households) account for 56 percent of all villages. Water scarcity affects about 62 percent of the communities studied (Bhat and Revi, 1995).

Christchurch, New Zealand encountered some earthquakes around 2010 and 2011. The magnitude of the 4 September 2010 earthquake was 7.1 on Richter scale. Following earthquake occurred on 22 February 2011 that had the magnitude of 6.3 on Richter scale. Last earthquake happened on 13 June 2011 and the magnitude of the earthquake was 6.3 on Richter scale. Those earthquakes caused a wide ranged liquefaction, lateral spreading and ground deformation. Due to the earthquakes in Christchurch, water leakage (minimum nighttime flow) has risen. The water delivery network's earthquake damage was examined by comparing pre-earthquake leakage data with post-earthquake leakage data. Water leakage was projected to be 260 L/connection/day in the pre-earthquake network, but 366 L/connection/day in the post-earthquake 2011 network. Based on comparisons of the minimum overnight flow data, leakage levels have increased by roughly 40% across the city. Just after the earthquake on June 13, 2011, the minimum overnight flow increased dramatically. The MNF (minimum nighttime flow) data then stabilized, and there was a 40% rise in leakage flow. Water leakage rates increased as a result of earthquake damage such as pipe breakage and fissures. Millions of dollars have been invested in various sections of Christchurch's water supply recovery effort to repair and restore the network. Around 400 kilometers of pipelines were restored or repaired, a number of new pump stations were created in the city's eastern reaches, and all of the city's important reservoirs and wells were fixed or rebuilt. To conclude, the loss of wells and pump stations, as well as a considerable increase in leakage (about 40%) owing to pipe breakage and fractures, were all part of the total impact of the earthquakes on Christchurch's water supply network. Flexible pipe materials, such as PVC and PE (polyethylene), fared well in the face of ground movement, but asbestos cement pipes were the most vulnerable. The post-earthquake water network functioned with reduced pumping capacity, and the level of service (low pressure, dependability, etc.) worsened in different portions of the network, according to hydraulic modeling studies. A multimillion-dollar repair and rebuild project is assisting in restoring the network's level of service to pre-earthquake levels (Biswas, 2019).

The San Fernando earthquake struck in 1971, measuring 6.6 on the Richter scale. It claimed 65 lives, wounded 2,000 others, and inflicted an estimated $505 million in damage, all while bringing the fragility of California's infrastructure to mild seismic occurrences into sharp view (defined by magnitudes of 6.5 to 7.0). Local water distribution networks in California are complicated. They were built during the previous century with a variety of materials and building processes, and many of them are nearing the end of their design life. Seismically-induced ground movement adds axial and compressional pressures to a pipeline, causing enormous stresses that can cause pipe splitting, bursting, or collapse (material failure), or initiating soil/pipe movement that causes pipe joint pullout. Pipe damage caused by seismically induced ground movement can be classified into three categories (Stanley, 2017):

- Lateral Offset
    - Transverse offset (shearing or connection failure) caused by vertical or horizontal fault rupture.
    - Distance between stiff permanent connections (connection to bridge abutments or other structures)
- Lengthening and Rotation
    - The pipe is elongated (pulled) due to an oblique fault offset.
    - Pipe sag due to settlement
    - Heave/floatation
    - Lateral earth movement (lateral spreading or slope failure)
- Compression
    - Pipe displacement into a fixed position (pipe bend or structure penetration)

The following structural variables may have an influence on pipeline performance during seismic events:

- Materials' age (fatigue and corrosion)
- Type of material (strength)

- Type and spacing of pipe joints (mechanical connection or welded)
- Method of trench construction (configuration and backfill)
- Installation depth (applied loading)
- Creating favorable soil conditions (applied loading)

The following seismic ground characteristics might have a substantial impact on pipeline integrity:

- Offset the fault.
- Natural and man-made slopes with dynamic slope instability (landslides).
- Settlement caused by dynamic densification and/or liquefaction
- Lurching of the earth and concomitant ground cracking
- Liquefaction causes lateral slope displacement (lateral spreading).
- Interaction between soil and structure.

1.2 Power Plant Installation after a Natural Disaster

Cost of the disinfection and desalination processes are very important to supply clean and drinkable water to the survivors after the earthquake. However, the disinfection plant's installation time has great importance, due to the quick response need after the earthquake. The quicker the response is; the more life can be saved with the water disinfection and desalination methods. Therefore, a quick installation process is needed to provide this quick response. Mobile power plants are power plants that can be of the mobile and floating type and belong to the class of thermal power plants. The only difference from normal stationary power plants is that they can be easily transported and put into operation in a short time. Mobile power plants consist of diesel-generator sets or small gas turbines mounted on one or several trailers. As the name implies, they produce electrical energy by being transported by trailer to the places where they are needed. Since they are installed on trailers, the capacity of these power plants is limited by the carrying capacity of the trailers. The fuel and water needs of the power plants are again transported to the storage tanks located on the trailer by means of land tankers. The maximum capacity of mobile type power plants is 15-30 MW. Floating type mobile power plants on the other hand, are power plants installed on large-sized rafts or ships of generator or combined cycle groups. Therefore, they are transported to the places where they are needed by sea, and the need for fuel and water is again provided by Jul by sea or by land. The capacity of floating mobile power plants is in a protected place of the sea, such as a shelter or a port since they are on board, they can be around 150-200 MW. The purpose of using mobile power plants is to provide electrical energy to the relevant region in cases of vital importance such as a natural disaster, beyond the continuous production of electricity. Alternatively, they are power plants that are put on hold in such a way that they can be put into operation immediately in case of any power outage at the Olympics and similar large organizations that will be held in our country. The production of electrical energy is very close to its consumption due to the production plants that have already been disabled for various reasons despite our installed capacity. Again, power transmission lines could not be installed to meet the increasing electrical energy in the Southeastern Anatolia region. In order to meet the increase in demand for electrical energy in such an environment, mobile power plants of mobile type have been put on the agenda. In 1998, four mobile power plants were deployed in Van, Hakkari, Silopi and Idil in a period of 3 months and an international tender was opened by TEAŞ to operate them through leasing and service purchase for a period of 3 years (EMO, 2022). Therefore, with 1998 technology, mobile power plants can be installed in 3 years period and after 24 years, in 2022; mobile power plants are expected to be built in shorter amount of times.

In the countryside outside of Budapest, a team in Veresegház, Hungary, recently demonstrated that it is possible to dismantle, transport, rebuild, and power up a power plant capable of supplying 9,000 European homes in less than 48 hours — an incredible feat in an industry where time is measured in months. The TM2500 gas turbine kit is not a scientific experiment. Since 2000, the first version has been in commercial usage, and more than 300 have been installed across the world. However, calling the TM2500 a mobile power plant is an understatement. The present model is just a GE CF6 jet engine housed in a box. It hums with power, allowing it to swiftly supply grid-level electricity, similar to how a Boeing 747 with four CF6 engines is pushed to the limit at takeoff. The TM2500 also powers down quickly, much like a jet plane that has just landed. The TM2500 is an aero derivative — technology developed from aeronautics — that mirrors the small, modular design of jet turbines, allowing it to be disassembled and put onto a pair of tractor-trailers or transported by cargo plane. The TM2500 was disassembled and stored at Veresegház in about 8 hours by 10 employees. They unloaded, rebuilt, and prepared the unit for safety inspections in another 19 hours. Before the unit could be turned on, such rechecks required around 3 hours. 30 hours and 39 minutes from start to finish (not including an overnight sleep break). While the Hungary endeavor took place under perfect circumstances, it represents the relative speed with which the power plant may be erected in real-world settings. Its small, portable size allows it to be delivered on a single cargo plane or by vehicle, and it has shown to be a vital workhorse in a variety of settings. After a hurricane hit the Mexican state of Baja California in 2014, officials used the TM2500 to rebuild portions of the grid that were too damaged to be fixed rapidly. The units were sent to Mexico and the grid was turned on in under two weeks (GE News, 2022). Therefore, after a disaster as if earthquake occurs, it will take approximately 2 days for a mobile power plant, as mentioned above, to be installed.

2. METHODOLOGY

Devastating effect of an earthquake is an undeniable truth for every individual. It effects not the buildings, bridges or other superstructure elements solitarily; it effects infrastructure elements as well. Therefore, earthquake affected areas had hard times to rebound back from the devastation in the past. Survivors' and governments' first thought is to use the existing pipelines to reach water as soon as possible in order to clean goods and drink, even everyone knows that water is not healthy to drink. Unfortunately, as mentioned above, earthquakes have a devastating impact to both super and infrastructures and it causes survivors to suffer since there are not enough water sources. On 17 August 1999 Istanbul earthquake 80-85% of the infrastructure units got damaged (Özata and Limoncu, 2014). Water supply networks have the function to transport, distribute and supply clean water and they are such complex connected systems and they are very vulnerable to earthquake hazards since most of the network was buried underground and not all situations can be identified, such as leakages (Yoo et al, 2019). Istanbul still has the same kind of infrastructural elements like steel and asbestos based pipelines, hence it can be expected them to act the same as 1999 earthquake and were damaged around 80-85%. Consequently, this disability will cause hundreds of thousands of people to suffer from draught after the first shock. There should be a way to supply water to survivors right after the earthquake.

Providing clean water to survivors can be made by two ways, with either prior stocked supplies or disinfecting existing dirty water by certain methods. Since the earthquake cannot be foreseen long before it happens, there might not be enough supplies ready to serve survivors. However, clean water does not mean only drinkable water. Survivors need clean water to clean their hands and body or some goods after the incident. After the first impact devastated the asbestos and steel pipelines, as the members of city infrastructure, there might not be any access to main city lines. Therefore clean water sources should be created externally. Disinfection of seawater can be used as a solution to provide for the increasing demand on clean water after an earthquake catastrophe.

However, Marmara Sea region coasts of Istanbul are under a great risk of collapse and gotten swallow by the sea itself, because of their backfill foundation structure. Based on this risk factor of collation, it might be inconsequential to build those facilities on those risky coasts. Williams mentioned that, a number of brick buildings erected on landfilled areas in San Francisco's commercial center were badly damaged or wrecked completely and caused thirty people to die (Williams, 1995). Therefore, it should be well analyzed where to mount those facilities to get the maximum efficiency from them and to save as much life as possible after the earthquake.

2.1 Drawing Water off Marmara Sea

Two seas: Black Sea and Marmara Sea surround Istanbul. Marmara Sea is an inland sea that Avcılar is facing. Therefore using Marmara Sea water to disinfection will be faster to achieve this project's aim. Since Avcılar coasts directly facing to Marmara Sea, facilities should be located on the coast as well to draw water off.

As mentioned before, Avcılar has 457,981 population and since daily water usage will decrease on a huge amount, there should be enough water disinfected, hence enough water should be drew off the sea. Under normal conditions in Istanbul, 190-liter water was drew for every individual daily (TÜİK, 2016). This amount may be approximately applicable today but when an earthquake happens, daily water usage for every individual will decrease on a large scale. For general population, daily water need after a natural disaster will be around 15-20 liters (Dündar et. al, 2018). Under the light of this information, approximate amount of water needed to draw off sea can be calculated.

Calculations will be done assuming 20 liter per person daily will be enough on a post-earthquake situation. Therefore, following equations can be executed:

$$457{,}981\ person\ x\ 20\ Liter/(Person - Day) = 9{,}159{,}620\ Liter/Day \quad (2.1)$$

$$9{,}159{,}620\ Liter/Day = 9{,}159.62\ m^3/Day \quad (2.2)$$

According to the calculations 2.1 and 2.2, 9,159.62 m³ water should be disinfected daily only for Avcılar population, approximately. Thus, equal amount of water should be drew out of sea. To provide this daily water mass, one or more water pumps should be used. Industrial pumps can provide 200-900 m³/h water to the system but energy consumption and price are important while selecting an optimal pump.

Since the increment of flow rate (Q) will also increase the price of the system, an optimal pump should be selected. A pump that has a 480 m³/h flow rate should work approximately 20 hours to feed the system to supply enough water for 457,981 individual. Shangai Shuangbao Machinery brand DCZ200-315C type centrifugal stainless steel pump with 480 m³/h can be selected due to its 37 kW/h energy rate and capacity. Maximum head of the pump is 18 meters, and design pressure and hydro test pressures are 1.6 MPa and 2.4 MPa, respectively.

Figure 2.1.1 Shangai Shungbao Machinery IH50-32-125 Centrifugal Pump

To achieve 9,159.62 m³/day water supply, this pump should work 20 hours a day.

$$480\ m^3/h\ x\ 20\ hours = 9{,}600\ m^3 \quad (2.3)$$

Since the daily water supply should be more than 9,159.62 m³, 20 hours of active time will be enough for needed supply to the system. Moreover, there must be a power supply to keep the 20 hours working pump, to be working non-stop.

$$37\ kW/h\ x\ 20\ hours = 740\ kW/day \quad (2.4)$$

The pump alone will be in need of 740 kW of energy on a daily basis. Doubling the amount of pump may provide water swiftly to survivors however; the cost will be doubled as expected. Therefore, pumping time will be reduced to 10 hours a day to provide enough water and energy need for the system will be 1,480 kW/day. The cost of this pump is 10,150.00 USD per pump.

Apart from that, there should be pipes that can provide enough water inlet to the system to achieve desirable amount of water that will disinfected. Therefore, approximately 10-15 meters of pipes will be in need in order to satisfy the length demand. The pump's technical datasheet is showing us that, this product can be used for the purpose of this project.

Performance	
Flow（m3/h)	480
Total Head （m）	18
Minimum continuous stable flow（m^3/h）	144
NPSHr（m）	3.5
Efficiency（%）	80
Shaft Power（Medium） （KW）	
Shaft Power（water） （KW）	29.41
Speed（r/min）	1450
Design Pressure（MPa）	1.6
Hydrotest Pressure（MPa）	2.4

Figure 2.1.2 Technical Datasheet of the Pump

2.2 Seawater Disinfection

Disinfecting seawater is not an easy and/or the healthiest way to supply clean water to humanity in such short amount of times. However, during a natural disaster situation, this is the best-case scenario to get rid of the first shock; right before supplies from government and other social communities arrives. It is quite essential to maintain human life in such cases. There are many cases that, survivors who stuck under debris of the earthquake with no water and food for days. It may have understood that, human body can survive with lack of food but it cannot survive with lack of water for a long time. The scientists that human body cannot stay in one piece without water for approximately 3 days straight have proved it. Most of the survivors drank their own urines to stay hydrated enough until authorities survived them. There are a couple of disinfection method of water as follows:

1) Disinfecting with UV-C
2) Disinfecting with Ozone
3) Disinfecting with Chlorine

The method of disinfecting water should be rapid, at low cost and healthy for human kind. The disinfection should be fast because of water's importance for human lives after a big and devastating natural disaster scenario. The more speed that the water disinfecting application has, the more it will be useful for thousands of people on the debris areas. Furthermore, the cost of the disinfection method should be as low as possible to keep this project budget-friendly and environmental-friendly at the same time. Certainly, when the topic is saving human lives, cost should be on back plan. However, the amount of money that will be spent to this project should be leveled due to the devastation and re-building the city itself after a big earthquake.

Microorganisms are abundant in saltwater and coastal waters, and they play a vital role in practically every aquatic environment on the planet. In eutrophic environments, there are roughly 10^2 protists (single-celled eukaryotes), 10^6 bacteria, and 10^7-10^9 viruses per milliliter of ocean and freshwater, with somewhat lower levels in oligotrophic locations. Although the majority of these bacteria pose little threat to other creatures or human health, some may be dangerous to people and wildlife, and others may cause ecological dysfunction and services to be lost. Due to their great reproductive capacity and tolerance for unfavorable settings, inactivating microorganisms, particularly bacteria, is difficult. Furthermore, in comparison to other creatures, bacterial diversity in water is relatively unknown (Hess-Erga et al, 2010).

This project is applicable for the first shock of the earthquake and for the first survivors only. Nongovernmental organizations, Disaster and Emergency Management Presidency and government itself will use all of its organs to help the survivors as fast as possible. That is the reason that this project should be budget-friendly in the first place, when the aim is to re-create the city in the first place, after a devastating earthquake.

2.2.1 Disinfecting with UV

Water disinfection with UV-C beams method was used in Marseille-France at the starting periods of 20th century with mercury steamed UV lamps. After 1950, disinfecting water with UV technology became a widespread application with the increasing level of technology and decreasing cost of UV lights. Nowadays, it has been proven that it is a standard and safe application to use. Since UV-C lights are absorbed by the ozone layer, they cannot reach to the surface. It is a lucky fact that UV-C light cannot reach to surface due to its destructive aspect for microorganisms and there will be no living form in the planet Earth (Aydın, 2009). Since the destructive effect of the UV-C lights are massive, it can be used to kill every living and harmful organism inside of the water and it will make it safe to drink or use.

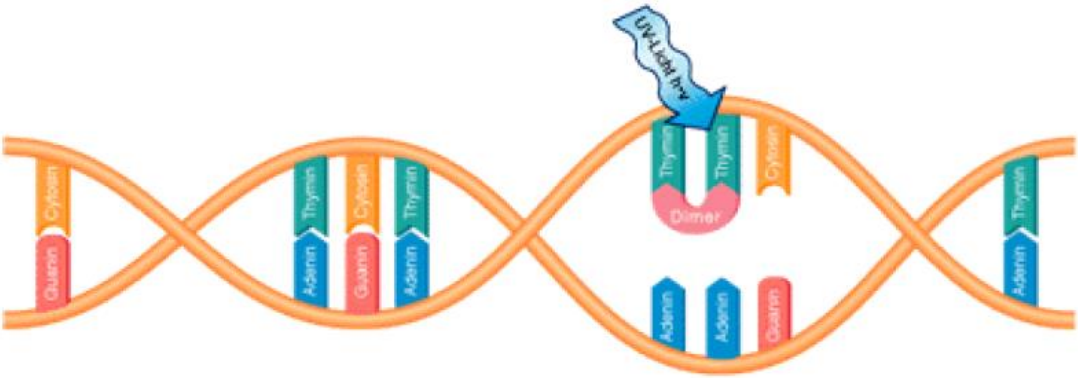

Figure 2.2.1.1 UV-C Beam's Effect on a DNA String (Aydın, 2009)

On the destructive aspect of the disinfection with UV-C beams, the process is important. First, UV-C beams enters through the body and reaches to the DNA of the living organism. After that reach, nucleic acids like thymine absorbs UV-C beams and this causes DNA string to corrupt. Cell cannot execute vital mechanisms anymore and dies (Aydın, 2009). In other words, UV-C beams can be used for water disinfection since it is effective against microorganisms. The method of the UV-C disinfection is that, UV-C beams are changing the biological components of microorganisms, especially destroying the chemical bonds in DNA, RNA and proteins (Ishaq et al, 2019).

A successful UV lamp should create more UV-C light without using much energy and it should serve long. In addition, it should specifically create 254 nm wavelength beams, in order to execute a safe disinfection process. Hence, the system should be well constructed and the capacity should be well defined to satisfy the needs on a post-earthquake situation. The stability of C–C bonds in various compounds, such as pyrimidines, purines, and flavins, is exposed by light with wavelengths between UV_{200} and UV_{280}. After absorbing UV light, the major mechanism of UV disinfection is the synthesis of pyrimidine dimers (thymine and cytosine in DNA, uracil and cytosine in RNA), which affects a number of biochemical activities such as DNA replication, RNA transcription, and protein translation (Kong et al, 2021).

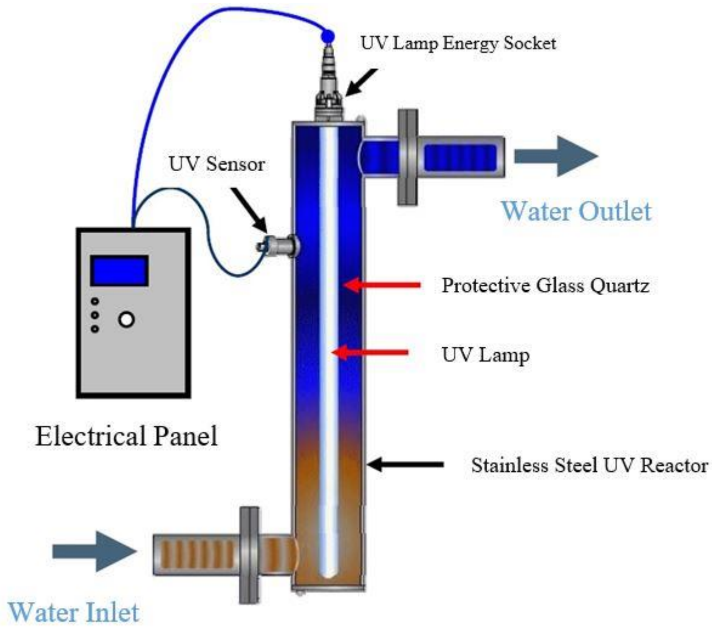

Figure 2.2.1.2 UV Device Simple Cross Section (Aydın, 2009)

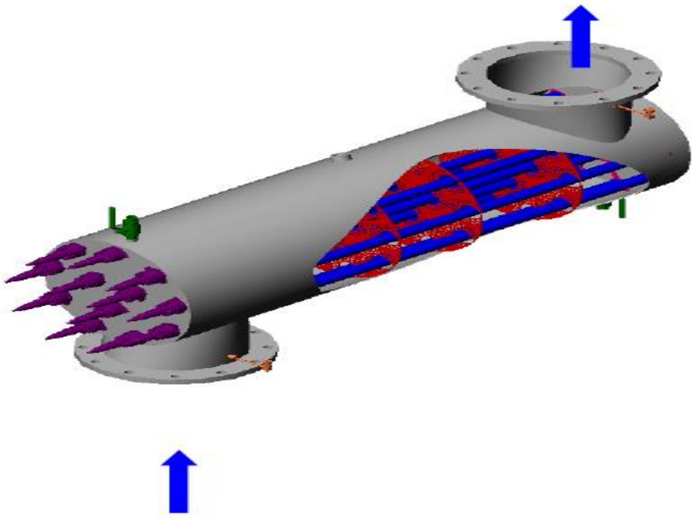

Figure 2.2.1.3 Multiple UV Lamp Device (Aydın, 2009)

Main components of the UV device are:

- UV Reactor
- Electrical Panel
- UV Sensor

In the UV-C water disinfection device, there are numerous amount of UV lamps and their placement is important. The more that they got placed better, the more effective this device will be. In addition, the design of the reactor has an importance due to the water flow inside should be faced by all the UV lamps covered with quartz tubes. Furthermore, the sensor has an important role of getting the data of the wavelength of UV light. It has to be 254 nm to get the best results out of this disinfection process.

Many academics have concentrated on the development of disinfection technologies for use in seawater for a variety of reasons throughout the last decade. Indeed, the International Maritime Organization (IMO) convention for the management of ships' ballast water and sediments has required all ships to install a ballast water treatment system since 2004 in order to avoid the potentially devastating effects of invasive harmful aquatic organisms released in ships' ballast water from one region to another. Ozone and UV-C (254 nm) irradiation have been examined as suitable disinfection treatments for this purpose, both in the lab and on a wider scale, including on board. Other seawater-based activity sectors pique curiosity (Ywann et al, 2013).

UV light of the suitable wavelength is created by electrical discharge through low-pressure mercury vapor, which is encased in a UV-transmitting glass tube in current commercial usage. The germicidal lamp that results emit UV light with a primary wavelength of 253.7 nm. This wavelength belongs to the UV light's short wave, or "C" band. It is also known as germicidal UV or ultraviolet germicidal irradiation and is occasionally abbreviated as UVC (both abbreviated as UVGI). Viruses, mycoplasma, bacteria, and fungus have all been proven to be deactivated by UVGI (VanOsdell and Foarde, 2002).

Some microorganisms that UV light can remove under certain UV doses is shown on the table below. UV dose is a value that represents disinfecting power according to the water flow rate in order to get proper percentage of removal of microorganisms and the unit of UV dose is J/m².

Table 2.2.1.1 Minimum UV Doses for Pathogen Removal (Aydın, 2009)

Patogen Microorganism	Minimum UV Doses for Removal (J/m²)			
	90%	99%	99,90%	99,99%
Cryptosporidium oocysts	-	100	190	350
Vibrio cholerae	65	110	180	300
Escherichia coli O157:H7	15	28	41	56
Salmonella typhimurium	80	118	152	195
Hepatitis A virus	55	140	220	300
Poliovirus Type 1	60	140	230	300
Coxsackie B5 virus	69	140	220	300
Rotavirus SA11	71	150	240	365
Corynebacterium Diphtheriae	-	-	65	125
Sarcina Lutea	-	-	265	350

It can be seen on the table that around 400 J/m² UV dose is nearly enough for removing all pathogens completely. UV dose can be changed from one situation to another but seawater can contain some unwanted pathogens and it will be safer to use 400 J/m² UV dose to obtain usable water (Aydın, 2009).

$$UV\ Dose = UV\ Density\ x\ Contact\ Time \tag{2.5}$$

There must be a minimum UV beam density (concentration), which is UV energy that passes from unit cross section with the unit of W/m^2 (Aydın, 2009).

$$UV\ Dose\ (J/m^2) = UV\ Beam\ Density\ (W/m^2)\ x\ Contact\ Time\ (s) \qquad (2.6)$$

If there is not enough UV dose applied to water mass, viruses, bacteria and other organisms can become alive after some times and the name of this phenomenon is photo-reactivation. However, the UV dose over 400 J/m^2 decreases the photo-reactivation chance to zero (Aydın, 2009). Therefore, UV system should be selected and operated accordingly.

UV beam density is related with water's UV-Transmission value apart from UV richness of a lamp. This UV-Transmission parameter shows how much UV light on 254 nm from 1 cm thick of water can get through. Therefore, to apply UV disinfecting method, water must be filtered before it goes into the UV system. Contact time is about UV reactor's inner volume and design. Design should be perfect for each spot inside of this reactor to provide same opening and same determined water flow rate inside. According to design, some UV systems cannot work properly due to water's flow rate is increasing and decreasing while running in the system.

Some of the advantages of UV-C disinfection will be as following (Office of Water, 1999):

- Effectivity at inactivating most viruses, spores and cysts.
- Being a physical process instead of a chemical one, therefore not using any toxic products.
- No residual effect to humans or aquatic life.
- Shorter contact time with water.
- Requires less space.

In addition to these advantages of the UV disinfection method, no chemicals are needed to be added and due to that, there will not be any chemical residue inside the water mass. Likewise, it can kill all kinds of organisms, including drug resistant bacteria (Advanced Biotechnologies Inc., 2022). Furthermore, there will not be any by-products formed during the disinfection process. Moreover, UV-C beam will do a better job while eliminating Giardia and Cryptosporidium from ozone and chlorine disinfection methods, on the cost aspect. UV-C beams limits the regrowth of potential biodegradable or assimilable organic carbon (AOC) occurring's (Ishaq et al, 2019).

On the other hand, disadvantages of UV disinfection method are (Office of Water, 1999):

- Low UV dosage may be ineffective to inactivate viruses, spores and cysts.
- With the help of photo reactivation (dark repair), viruses and other organisms may repair themselves after the destructive effects of UV light.
- Not as cost effective as other disinfection method such as chlorination.
- Turbidity and total suspended solids may make the UV disinfection process ineffective.

Moreover, to the disadvantages of the UV disinfection method mentioned above, UV-C beams are extremely dangerous to human life. Therefore, this system should only be used with protective shields around the system to provide human life. Especially eyes and skin should be blocked from UV-C beams in the first place. In addition to that, the water mass to be disinfected should not be blocked by any other object to achieve a 100% of contact with UV beams. This issue can be solved by increasing the amount of the UV lamps used in the system (Advanced Biotechnologies Inc., 2022).

Apart from the advantages and disadvantages of UV disinfecting, applicability of this system has an importance. There are three critical factors while choosing UV system. First of all, the hydraulic properties of the reactor. System should have a uniform flow with enough axial motion to maximize exposure to UV radiation. Second one is the intensity of the UV radiation. The factors effecting the intensity are age of lamps, lamp fouling, configuration and placement of lamps inside of the reactor. The final factor is wastewater characteristics. This portion includes flow rate, suspended and colloidal solids, initial bacterial density and other physical and chemical parameters (Office of Water, 1999).

The design of the UV disinfection method is relatively easy. UV light sources should be encased in a transparent protective sleeve. Water mass, which goes into the UV system, will encounter UV-C beams from different angles, thanks to the transparent sleeves. Contact time is very short when compared to other disinfection methods and there will not be any change in color, taste or odor of the water mass (Ishaq et al, 2019).

UV radiation inactivates viruses and spores the least, followed by bacteria, and protozoa like Cryptosporidium and Giardia the most. However, some microorganisms (such as Deinococcus radiodurans) are resistant to low-dose irradiation, necessitating high-dose irradiation for successful inactivation. Although UV disinfection inactivates germs by damaging their DNA, some microbes may repair this damage by photo reactivation, allowing inactivated microbes to recontamination of water. Furthermore, certain viruses, such as human adenoviruses and polyomaviruses, have a dsDNA genome type, which allows for its repair by host cell machinery during viral replication, allowing them to withstand UV-induced DNA damage (Gomes et al, 2019).

An UV-C device with approximately 460 m^3/h disinfection capacity will be enough to supply enough cleaned water to survivors. The contact time should be 3 seconds for water mass to be disinfected as a whole. Capacity should be minimum of 460 m^3/h, hence ZSE Water brand two sets of “Medium Pressure Ultraviolet Sterilizer” product (250 m^3/h each) will correspond the demand. Properties of the product are as following:

- Flow rate: 250 m^3/h,
- Inlet & outlet: DN 250 (10’’ or 273,05 mm),
- 316 L stainless steel vessel, mirror polished,
- Size: 1100 x 600 x 600 mm,
- U.S.A UV lamp, service life of 6000 hours, 3 lamps each,
- Inductive ballast,
- Voltage coefficient: 0,98, single phase 220 V / 50 Hz,
- Power: 6 kW,
- PLC + touch screen,
- Carbon steel with powder spraying control cabinet, 1000 x 700 x 300 mm,

- Functions: lamp working time accumulation, UV intensity monitoring, fault alarm, automatic cleaning (motor drive), overheat protection.

This product comes with every single piping and spare parts within the package. Installation part and fitting list is as following:

- DN 250 flange (6 pcs)
- DN 250 butterfly valve (3 pcs)
- DN 250 elbow (2 pcs)
- DN 250 straight tee (2 pcs)
- DN 250 pipe (6 meter)
- 316 L stainless steel bolt set M20 x 190 (60 set)
- 2 kW UV lamp (4 pcs, spare part)

Since 20 hours of worktime estimated for the disinfection devices, power consumption for two products will be as following:

$$6\ kW\ x\ 20\ hours\ x\ 2 = 240\ kW/day \tag{2.7}$$

Both of these devices will consume 240 kW/day and solar panels and generators should provide this energy.

Figure 2.2.1.4 ZSE Medium Pressure UV Sterilizer

By using the equipment with the technical datasheet above, UV disinfection method can be executed. It should be remembered that, cost is an important aspect for selecting the best disinfection method to use after a natural disaster, earthquake in this case. Therefore, disinfection potential, applicability, operation and maintenance and cost will be the main aspect when choosing the best method.

2.2.2 Disinfecting with Ozone

Ozone oxidation has a very high power and is the most powerful disinfectant known. Its high oxidation power is very effective in destroying bacteria. Applying ozone to water for 4 to 10 minutes is enough to decontaminate the water. Since viruses are very small, they form parasitic biological clusters. Therefore, it is not possible to keep viruses with bacterial filters (Polat, 2009). Since the late 1800s, ozone has been used to disinfect drinking water. Ozone is a good biocide that is water insoluble. It is commonly used in Europe and to a lesser extent in the United States for drinking water purification. Recent reviews look at the chemistry of ozone in drinking water and the impact of bromide ions in source waters on reaction products. Ozone is also used as an oxidant and disinfectant in wastewater treatment, and its use is growing (Perrins et al, 2006).

Ozone is used in many countries of the world, in the sterilization of drinking water and in all companies engaged in the production of bottled water. The most important reason for using ozone in the sterilization of drinking water is that it turns into oxygen in a short time and after providing effective disinfection; it leaves the environment and leaves no residue (Polat, 2009).

The management of wastewater is still a major concern. Traditional treatments are not always effective when wastewater is polluted with hazardous anthropogenic pollutants. Electrochemical advanced oxidation processes (EAOPs), which are based on the formation and use of hydroxyl radicals, have shown their suitability and, surprisingly, their remarkable success in dealing with such serious environmental challenges. Focusing on ozonization and electrolysis among the EAOPs is demanding. The former relies on the production and activation of ozone, whereas the latter relies on the oxidation and/or reduction of wastewater components to create and activate a combination of oxidants. As a result, with electrochemically based approaches, various other species, such as cathodically created hydrogen peroxide or anodically made chlorine, peroxocarbonates, peroxosulfates, and so on, might be generated in addition to ozone. This demonstrates the improved efficacy of such a strategy in dealing with a variety of pollutants ranging from dyes to insecticides, as well as various other anthropogenic contaminants (Ghernaut and Elboughdiri, 2020).

The presence of bromide ion (Br^-) in saltwater is the most significant variation in ozone chemistry between freshwater and seawater, and it has a significant impact on disinfection. Even though saltwater ozonization is dominated by the effects of bromide and pH, resulting in the creation of hypobromous acid, HOBr, as the primary disinfectant, ozone may have promise for recirculating aquaculture systems and ballast water treatment (Gonçalves and Gagnon, 2018).

Ozone gas; in nature, it is formed because of the fact that ultraviolet rays from the sun, break down oxygen in the atmosphere and convert it into ozone molecules (Office of Water, 2003). Technologically, it is obtained from the air we breathe with the help of electron discharge or from pure oxygen. Ozone is a gas with a high oxidation power, so it has been widely used, especially in recent years, for disinfection purposes. Ozone gas, the raw material of which is oxygen, is the only natural disinfectant. The fact that it is a natural disinfectant has led to the rapid spread and safe use of its areas of use. Interest in the use of ozone for disinfection purposes in the field of aquaculture has been growing rapidly in recent years (Polat, 2009).

Due to the threat of chlorine-resistant bacteria, research into other disinfection methods such as ozone, UV, chlorine dioxide, or a combination of these methods has become a public concern. Among them, ozonization is often effective, quick, and regarded as a promising disinfection technology for drinking water treatment, particularly for microbe inactivation. Because of its lack of continuous disinfection capabilities, ozone is frequently used in drinking water with chlorine or UV inactivation. (Ding et al, 2019).

Ozone, another substance used for disinfection purposes and included in the GRAS (generally recognized as safe) list, is a powerful antimicrobial agent that has many applications in the food industry. Y. enterocolitica, Salmonella typhimurium, s. aureus, monocytogenes and E. ozone, which is known to inactivate coli O157:H7, is also used to reduce shelf life in fruits and vegetables due to its effect on reducing microbial load. In a study using ozone disinfection, chopped and 104 cfu (colony forming unit)/g mesophilic bacteria inoculated lettuce leaves were washed with a flow rate of 0.5 L/min by applying 1.3 mM ozone to the water and it was found that there was a 2 log cfu/g decrease in the total number of mesophilic aerobic bacteria by washing with ozone water for 3 minutes. In another study in which chopped green peppers were disinfected with ozonized water, it was noted that there was no reduction in microbial load and that ozonized water could give better results in unpeeled products. As a result of the use of high doses of ozone used to disinfect vegetables and fruits, it has been shown that it negatively affects the sensory properties of vegetables and fruits, such as color, taste (Ayhan and Bilici, 2015). The chemistry of ozone in seawater differs significantly from that of freshwater. This chemical variation has a significant impact on disinfection. The presence of bromide, Br, in saltwater causes the most significant change in ozone chemistry when compared to freshwater. Ozone oxidizes bromine to HOBr and OBr, hypobromous acid and hypobromite ion, respectively. The chemistry of the water has a significant impact on the chemistry and toxicity of ozonization of seawater. TRO (total residual oxidant) is used as an indirect indicator of ozone toxicity. The concentration of TRO in seawater drops with time, which might be a concern or an appealing characteristic of ozone treatment of ballast water. Toxicity linked with treated water is eliminated when it falls below a particular threshold (Perrins et al, 2006).

Additionally, ozone can enhance water quality by lowering biochemical oxygen demand (BOD), ammonia, and nitrite levels, as well as disinfecting entering hatchery water, hatchery wastes, and fish eggs. Although ozone and the oxidants generated in ozonized saltwater can be fatal to aquatic creatures, fertilized fish eggs can survive varied quantities of dissolved ozone. To guarantee that fatal limits are not exceeded, specific exposure thresholds for each species must be identified, and accurate methods to test ozone in sea water are required. This review, according to this material, aims to give information on the usage of ozone in aquaculture systems as well as its safety to cultured organisms (Gonçalves and Gagnon, 2011). Furthermore, at every dosages given, the dissolved ozone concentration remains zero less than 15 seconds after addition of dissolved ozone solution, confirming the extraordinarily quick ozone reactions in seawater (Ywann et al, 2013).

Ozone is still a potent oxidant that is used to disinfect water, and it has been used in the treatment of wastewater in conventional treatment facilities. Nonetheless, one of the most difficult challenges in ozonization is mass transfer between the gaseous and liquid phases. For this reason, many configurations and types of reactors have been designed to increase the amount of ozone in solution. Another obstacle is the low percentages of organic matter (OM) mineralization due to its low selectivity. For wastewater treatment, electrochemically producing ozone in situ can improve mass transfer and mineralization performance (Ghernaut and Elboughdiri, 2020).

One of the areas where ozone is most widely used is the disinfection of second-degree or biologically treated wastewater. Ozone is widely used for cleaning wastewater that flows into large reservoirs or places where living organisms can be found in them. Advantages of ozone disinfection compared to chlorine atoms in such waters; ozone eliminates all viruses more effectively than chlorine, as well as causing great damage to aquatic creatures from chlorine on the contrary, it is the preservation of the natural balance of waters, since water is enriched with oxygen on the one hand by ozonization. Ozone provides effective disinfection for this type of water on the one hand, and on the other hand, it removes color and turbidity, reduces the need for chemical oxygen (Polat, 2009).

The administration of 0.1 to 0.5 mg/L of ozone, depending on the state of the water, is sufficient to kill bacteria by 99.99%. Ozone has a biocidal effect, especially when there is water in the environment. This biocidal effect of ozone is widely used in the disinfection of drinking water. If there is 2 mg/L of ozone in the water, the number of living microorganisms decreases by 99% in a few minutes. On the other hand, ozone also has a lethal effect on pathogenic viruses. Although ozone application in drinking and use waters has been a method used for a long time in our country, it was approved by TSE and published in TS EN 1278 standard (Airozon, 2020). Because of its oxidizing impact on microbes, ozone has disinfectant characteristics. It oxidizes organic molecules in microorganism cell membranes, causing membrane rupture and decreasing cell viability, resulting in disinfection. When a certain volume of water is treated with a known amount of ozone, the number of microorganisms destroyed rises, as the period of treatment is increased (Jyoti and Pandit, 2004).

Bacteria and viruses are far more vulnerable to ozone oxidation than protozoa, since bacteria and viruses require lower ozone dosages to be removed. As a result, ozone is a promising disinfectant for the inactivation of bacteria and viruses. This means that ozone-based disinfection systems must be built with protozoa removal in mind, as protozoa will be the process' limiting pathogen (Gomes et al, 2019). Ozone gas is applied in the reaction tank to maximize the mixing of ozone with water using a venture system, and the time required to contact ozone is completed to obtain quality and safe drinking water.

Advantages of ozone usage while disinfecting water will be as following (Uzun, 2011):

- Low energy consumption.
- Increases the water filters effectiveness and lifetime.
- Involves no consumables.
- It destroys pathogenic (harmful to human health) microorganisms in water.
- It is 3125 times more effective than chlorine.
- Due to its very strong oxidation structure, it also destroys substances that are extremely dangerous to human health, such as iron, manganese, arsenic, in water.
- Increases the oxygen concentration of water.
- Reduces the degree of rigidity.
- Removes heavy metals.
- It makes the water clearer.
- It maximizes the quality of water.
- Since ozone is produced and used as much as needed, there are no storage problems.
- It destroys bad smells and tastes.
- It prevents flowering.
- It is economical to use, does not require extra time and personnel.
- It provides a faster and more continuous sterilization.
- It prevents the transmission and spread of diseases spread through water.
- It ensures that every point of the system is disinfected.
- Ozonized water can be used as a disinfectant, so it has great results in both the kitchen and in general cleaning points.

- Ozone does not change the pH value of water.
- It destroys 99.9% of E.coli and legionella, especially those that nest in water tanks.
- It is not carcinogenic.
- It is environmentally friendly.
- It is easy to maintain and assemble.

Disadvantages and restrains of ozone usage while disinfecting water will be as following (Uzun, 2011):

- Can cause a toxic effect (toxic effect of ozone depends on concentration and duration of exposure).
- The ozonization system is relatively difficult to install.
- Undesirable aldehydes and ketones can be formed because of the reaction of ozone with some organic substances.
- Since its solubility is less than chlorine, special mixers are required.
- It may not have any oxidizing effect on some organic species at all, or it may be negligible.
- Biodegradable organic substances released because of the use of ozone can cause the development of the organism. This causes the corrosion rate in the distribution system to increase if the biologically active filtration process is not applied. When ozonization is used before filtering, biological development affects the filters, resulting in an increased frequency of backwash.
- The ozone used can react with other oxidants such as chlorine, monochloramine, chlorine dioxide.
- Because of ozone oxidation, iron and manganese turn into insoluble compounds in water, sedimentation or filtration is required. These insoluble solid species can clog filters and thus increase the frequency of backwashing.

Figure 2.2.2.1 Ozone Disinfection System

Ozone is produced from oxygen in the air or from pure oxygen. There are two most widely known production methods. The first of these is achieved by exposing the oxygen in the air to an electric current at a very high voltage (7,000 – 15,000 volts). Flowing inside of corona sparks of the system that created with high voltage can be a good explanation for that method. It is the most valid method to produce high levels of ozone. Lightning arcs are also one of the most important sources of ozone formation in the atmosphere. The second method is the production of ozone by UV rays. Ozone is produced by passing air or oxygen through an ultraviolet lamp. The beam emitted by the UV lamp separates some of the oxygen molecules in the air stream, which ensures the formation of ozone (Manoukian et al., 2016).

When ozone is applied to water containing organic matter, ozone reacts primarily with inanimate organic substances in the water. Only a little portion of the bacteria can be killed meanwhile. When the reaction of ozone with organic material ends, the bacteria execution rate increases rapidly. For this reason, the amount of ozone required for disinfection in filtered and granular activated carbon waters is less than in untreated waters (Polat, 2009).

Since there should be very high voltage to create ozone to disinfect 9,600-m³ water per day, energy consumption will be high. Therefore, the capacity should be well designed and proper products should be selected. According to the information above, 0.1 – 0.5 mg/L of ozone can kill 99.99% of the harmful entities inside of the water mass. Since the daily demand of water will be approximately 9,600,000 L, approximate ozone mass can be found by this calculation:

$$0.3\ mg/L\ \ x\ 9{,}600{,}000\ L = 2{,}880{,}000\ mg \tag{2.8}$$

$$2{,}880{,}000\ mg = 2{,}880\ g = 2.88\ kg \tag{2.9}$$

Daily needed ozone mass is 2.88 kg approximately due to the mean value of the ozone that can clean the water is selected as 0.3 mg/L. Thus, an ozone product should supply approximately 150 g of ozone per hour. That will create an enough supply for the daily need of Avcılar.

2.2.3 Disinfection with Chlorine

Disinfection with chlorine is perceived as a very simple process in many enterprises in our country, and it is believed that all viruses die when chlorine is added into water. However, in order to succeed in disinfection with chlorine, it is necessary to apply it correctly. Of course, the element itself and the chloride ion, which are found in large quantities in seawater and table salt in natural waters, do not have a disinfection property. Chlorine Compounds, which are substances produced by Chemical Science and humans used for disinfection purposes, are not found in nature under normal conditions.

Chlorine is still used around the world, as it kills many microorganisms harmful to humans and food products, and is available at a cheap price. There are also many microorganisms that chlorine cannot kill and are harmful to human life, although chlorine is still considered a successful disinfectant, because chlorine has more of what it can kill than what it cannot kill.

The inhibitory or antimicrobial activity of chlorine may vary depending on the amount of hypochlorous acid in the water in contact with microorganisms (favorable chlorine). Hypochlorous acid is a free form of chlorine with the highest level of bactericidal activity against pathogenic microorganisms that are commonly found in fresh fruits and vegetables (Ayhan and Bilici, 2015).

Chlorine has a high disinfection efficacy and is inexpensive; hence, it has been widely utilized for microbial control in saltwater and surface sanitation in several intensive aquaculture operations in various forms. Chlorine's great biocidal efficacy against viruses and bacterial pathogens has been established in laboratory and field research. Chlorine has no effect on flora or animals at permissible levels. If too much chlorine is accidentally discharged into aquatic ecosystems, it can damage aquatic plants and animals until it is diluted to a safe level. According to certain research, interactions between chlorine and organic nitrogen in water can generate harmful residues for marine species (Jorquera et al, 2002).

Elemental chlorine is one of the most widely used forms of chlorine and is also the cheapest among chlorine forms. It is transported and stored in the form of liquefied gas in pressurized tanks. There is no shelf life specified so far for this form. In a study investigating the disinfectant effects of chlorine gas, it was found that there was a 2.4 log cfu/g decrease in the total mesophilic bacterial load, which was initially 6.8 log cfu/g, at the end of the five-minute disinfection process in artichoke samples treated with 200 mg/L chlorine gas. Despite the studies showing its effectiveness, chlorine gas is a dangerous gas, and therefore it should be remembered that caution should be exercised during its use and that experienced people/people should use it (Ayhan and Bilici, 2015).

Chloramines are obtained by combining certain amounts of chlorine and ammonia in an aqueous medium. Chloramines are generally not used as primary disinfectants because they are more powerless than chlorine. One of the most important properties of chloramines is that they can remain undisturbed in the environment for a long time. For this reason, chloramines are often used as a secondary (residual) disinfectant to meet the need of free chlorine in long distribution networks. Another preferred reason for chloramines is that the by-products formed after disinfection are less than chlorination. Again, they are also preferred due to their taste and deodorizing properties (Ünver and Aksu, 2011).

Chloramines are obtained by combining certain amounts of chlorine and ammonia in an aqueous medium. Since they are weaker disinfectants compared to chlorine, their use alone is usually not preferred. Chloramines do not lose their effectiveness in the environment for a long time, and their chemical structure can remain intact. In addition, the formation of by-products such as trihalomethane and halo acetic acid is less common during their use, and because they do not oxidize bromide to bromine, they do not ultimately produce by-products with brominate. In a study in which chloramines, which also have a taste and deodorizing property, were used as disinfectants, which was originally 108 cfu/ml, was used as a disinfectant. After 20 minutes of disinfection of the colonies of coli with 2 mg/L of monochloramine, it was found that they were not present in the environment at all at the end of 20 minutes (Ayhan and Bilici, 2015).

Chlorine interacts irreversibly with different elements that exert chlorine demand, such as natural organic matter, ammonia, nitrogen, hydrogen sulfide, and metals such as iron and manganese, when added to water for disinfection. The reacted chlorine is no longer accessible for disinfection. Total chlorine residual (TCR) is what's left after chlorine demand is met, and it's made up of combined chlorine (NH_2Cl), which is chlorine combined with ammonia to form chloramines (monochloramine: NH_2Cl, chloramine: $NHCl_2$, and trichloramine: NCl_3); and free chlorine residual (FCR), which is mostly hypochlorous acid and hypochlorite. Free chlorine is a more effective disinfectant than combined chlorine; to attain the same inactivation of diverse bacteria as free chlorine, the combined chlorine concentration must be raised 25-fold or the contact duration must be extended 100-fold (Murray and Lantagne, 2014).

Ozonization and UV irradiation have both been characterized as effective wastewater disinfection treatments. The efficiency of these disinfection techniques, however, is strongly reliant on the quality of the water. Due to the strong demand for this oxidant caused by wastewater organic matter, ozone dosages as high as 15 mg have been reported in the literature for successful disinfection of specific wastewater effluents. Because of its absorption under UV radiation and scattering effects caused by the presence of suspended particles, wastewater organic matter might reduce the effectiveness of UV disinfection (Sgroi et al, 2021).

In both freshwater and marine systems, ozone has been proved an efficient disinfectant, although its effectiveness is dependent on system design and specifications. A venture injector system utilizing a commercially available source of ozone did not significantly lower bacterial levels when compared to an air-stone system employing onsite ozone generation in an investigation of several disinfection systems for a freshwater hatchery. Additional filtering followed by UV treatment resulted in the greatest decrease in bacterial counts. Preliminary investigations comparing ozone disinfection to UV disinfection at the Marine Resources Center have yielded comparable results (Hsieh et al, 2002).

Chlorine, being a powerful oxidant, reacts with a wide range of other compounds in water, including ferrous iron, manganese, ammonia, and other inorganic and organic materials. HOCl interacts quickly with ammonia in aqueous solutions of pH 7.0 to 8.5 to generate inorganic chloramines (also known as mixed chlorine) in a series of competing reactions. These reactions happen instantly, with no significant disinfection-taking place until the initial "chlorine requirement" is fulfilled. Following the addition of chlorine, a free accessible chlorine will be established. Chlorine is efficient in killing bacteria and viruses, as well as Giardia under specific conditions. At common water treatment doses (up to 5 mg/L), however, chlorine has minimal effect on Cryptosporidium oocysts. Because HOCl has a far higher germicidal efficacy than OCl^-, the CT (contact time) need for a given log-reduction increases as pH rises. Chlorine is more biocidal at low pH than at high pH, according to most studies, and the pH impact is stronger for chlorine than for other disinfectants like chlorine dioxide, ozone, and even mixed chlorine (chloramines). Inactivation tests have revealed that at pH 7.0, 50 percent more contact time is required for equivalent viral inactivation than at pH 6.0, and that increasing the pH from 7.0 to 9.0 needs a six-fold increase in contact time for comparable viral inactivation. Some viruses, on the other hand, have been demonstrated to be more susceptible to chlorine at high pH than at low pH. Increased disinfection effectiveness might be attributed to OCl^- creating neutral ion pairs with sodium, potassium, and lithium in these circumstances (Pickard et al, 2006).

There are three chlorine materials that are being used in Turkey, which are (Recai et al, 2004):

- Liquid Chlorine (Sodium Hypochlorite)

- Gas Chlorine (Pure Chlorine)
- Chlorine Dust (Calcium Hypochlorite)

The disinfection effect of chlorine in water depends on four elements (Recai et al, 2004):

- The amount of active chlorine contained in the water (in mg/L),
- The pH level of the water,
- The time of contact of free chlorine with microbes,
- Temperature of water.

In a good disinfection environment, these four elements are very intertwined with each other and the importance of each is very high. Because of this, the effects of these four elements on disinfection should be considered together. The chlorine compound, which is placed in water and turns into active chlorine, reacts with some substances contained in water. Microorganisms, organics, oxidizable metals such as iron and manganese dissolved in water are substances that consume active chlorine. Advantages and disadvantages of the chlorine materials are as following (Recai et al, 2004):

- Chlorine-containing disinfectants are effective against many known pathogenic microorganisms, and they completely destroy them or prevent their reproduction.
- It is the only method that provides continuous disinfection from the facility where the water is processed to the source, where it reaches the user.
- Other alternative disinfection methods, such as ozone and ultraviolet, are called primary disinfectants and do not provide residual disinfection (residual disinfection is the presence of a disinfectant substance in the water to prevent the reproduction of microorganisms that can pass into the water as a result of microbiological contamination after the water is supplied to the system.).
- All chemical disinfectants form by-products; one of the advantages of chlorine is that its by-products are the most studied disinfectant.
- Chlorine provides taste and odor control, oxidizes a large number of natural organic substances (especially those caused by algae), which can cause a bad smell and taste in drinking water.
- It eliminates sulfides and odors that occur because of vegetation.
- Chlorine controls biological growth, prevents the formation of living things that can clog pipes and devices and cause malfunctions or develop in warehouses.

- Chlorine provides chemical control, breaks down hydrogen sulfide, ammonia and other nitrogenous compounds that can be found in water.

On the other hand, there are some criteria to consider while disinfecting with chlorine (Recai et al, 2004):

- Free chlorine must at least have 30 minutes of contact time with water.
- The best time for chlorine disinfection is right before storing or distribution phase of the water mass.
- Under normal circumstances, the rate of residual chlorine must be a maximum of 0.50 ppm.
- Under abnormal circumstances, this value must go up to a minimum of 1.0 ppm.
- Before disinfection process, muddiness of water should be removed.
- To avoid inflectional diseases, which are sourced by water itself, due to wrong storage or insufficient amount of cleaning source, some protective measurements should be applied.

Since the most used application of disinfection with chlorine is pure chlorine, it will be easier to find tools and other necessary items for chlorine disinfection unit. Chlorine gas has a 1-16 mg/L rate depending on the quality of chlorine gas used (Recai et al, 2004). On the other hand, to disinfect 1 liters of water, there should be 0.5 mg free chlorine inside of that water mass. In addition to that, for drinking water, it will be sufficient to add 1.5 mg of chlorine or equivalent chlorine-containing solution to 1 liter of water. That is, it is enough to put about 1.5 grams of chlorine into a 1-ton water tank. In order for chlorine to have an effect, it must be in contact with water for 30 minutes. Therefore, after carrying out the chlorination process, it should be waited for at least half an hour. The amount of chlorine that should be present in the water should be no more than 0.5 mg/lt. That is, it is necessary to have no more than 0.5 mg of free chlorine per liter of water (The Regulation on Waters Intended for Human Consumption, 2015). However, in the chlorination process, 1.5 mg/L of chlorine is used. The regulation determines the amount of free chlorine in the water, that is, the amount of chlorine remaining after the elimination of microorganisms. During the chlorination process, chlorine molecules bind to the cells of microorganisms and neutralize them, while it itself collapses along with these bacteria and living things and exits the free chlorine state. Therefore, in a water chlorinated with

1.5 mg/L of chlorine, there will be free chlorine well below the value of 0.5 mg/L specified in the regulation after the disinfection process. Furthermore, chlorine levels up to 4 milligrams per liter (mg/L or four parts per million (ppm)) are considered safe in drinking water external icon. At this level, harmful health effects are unlikely to occur (CDC, 2020).

2.3 Reverse Osmosis Desalination Method

Reverse osmosis process is a water desalination process that mainly focuses on using a membrane to separate the ions, undesirable compounds and other harmful particles as well as the salt inside the related water mass to create a disinfected one. Since this method focuses on mainly larger particles than viruses, bacteria and other small particles inside of the water might not be disinfected completely, however it will eliminate the salt ions inside the water mass. Therefore, this method's applicability, effectuality and cost efficiency should be taken into consideration more seriously, because this execution will desalinate the water to make it drinkable.

The term osmosis describes the phenomenon of spontaneous passage of a liquid in solution through a semipermeable membrane. In this way, two solutions with different concentrations are separated from the liquid in which they are dissolved. These semi-permeable membranes consist of a very thin material. Under ideal conditions, this membrane separates the solution from inorganic and organic substances, colloids, bacteria, unwanted molecules, and its ions, turning it into a pure solution. The solution flow always occurs towards the diluted pure solution. This flow lasts until the moment when the osmotic pressure stabilizes. This moment is the time during which the solution flow occurs in both directions of the membrane. In this case, there is a dynamic balance between the desire to achieve dilution and the hydrostatic high pressure caused by the increase in volume occurring in the concentrated solution. This hydrostatic high pressure is equal to the osmotic pressure difference between solutions with various concentrations. In reverse osmosis, a semi-permeable membrane separates two solutions with different concentrations, just like in the osmosis event. If a higher pressure is applied to the concentrated solution side than the osmotic pressure from the outside, the event reverses, and this condition is called reverse osmosis. In this case, the liquid flows through the membrane from the side where the solution concentration is high to the side where it is low. This solution, passing through the membrane, is called permeate. Dissolved substances on the pressurized side rise to a certain maximum value. This solution with a high concentration that occurs is called a concentrate (Can et al, 2002).

First of all, osmosis is a passive process that can be happen without any need of energy. Osmosis is the phenomenon of equalizing the ion concentration of two solutions with the help of osmotic pressure, which have different ion concentrations and have a semi-permeable membrane between them. Molecules inside of the water travels from lower concentration area to higher concentration area by itself until the system comes to an equilibrium and there is a membrane in between to separate high and low concentration areas. In osmosis method, mentioned membrane is a semi-permeable membrane, which will let water particles to flow through while holding any small and unwanted particles inside of it (PURETEC, 2012).

In order to reverse the osmosis phenomenon in the system, a pressure greater than the osmotic pressure is applied with the help of a pump. By applying intense pressure to the system, water passes from a very dense volume to a less dense volume. Membrane pore size of 5 Angstroms that can migrate only pure water, bacteria, organic matter, suspended solids, molten salts, positively and negatively charged ions and molecules is greater than 5 angstroms. Reverse osmosis units are usually used after the pre-filtration or pre-disinfection stages. The water must first be passed through the particulate filter and then through the activated carbon filter in order to prevent clogging of the filtration membranes (Ünver and Aksu, 2011). However, all the disinfection and desalination systems are thought as they are working under optimized scenarios. If every aspect and every scenario will be taken into consideration, government and community organizations should make a comprehensive research. Mentioned optimized scenarios will be mentioned on future segments.

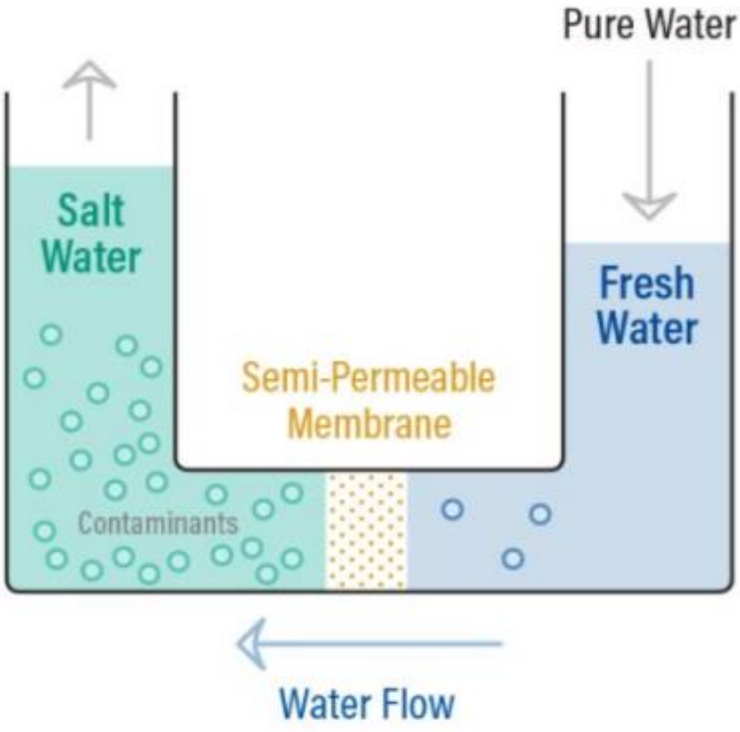

Figure 2.3.1 Representation of Osmosis Process (PURETEC, 2012)

The osmotic pressure is the pressure that would inhibit net movement of pure water through a semi-permeable membrane if applied as a hydraulic pressure to a highly concentrated solution. The difference in the water chemical potential allows pure water to be transported from the lower salt concentration solution (higher water concentration) to the higher salt concentration solution (lower water concentration). The flow work required to stop water movement is the difference (Sharqawy et al, 2011).

Since osmosis requires no energy and can happen by itself inside of the system, reverse osmosis process will be the opposite of osmosis. Therefore, to create a system and successfully operate it, an energy source should be integrated inside of the system. Moreover, reverse osmosis process is not cheap either, when it comes to maintenance (Melin and Rautenbach, 2007). As it can be seen on the figure above, osmosis process happens from the low concentration area to high concentration area. Fresh water flows through the semi-permeable membrane to the salt-water area, full of contaminants. Since the aim of this project is to disinfect water, opposite version of this process should be applied, which is called reverse osmosis.

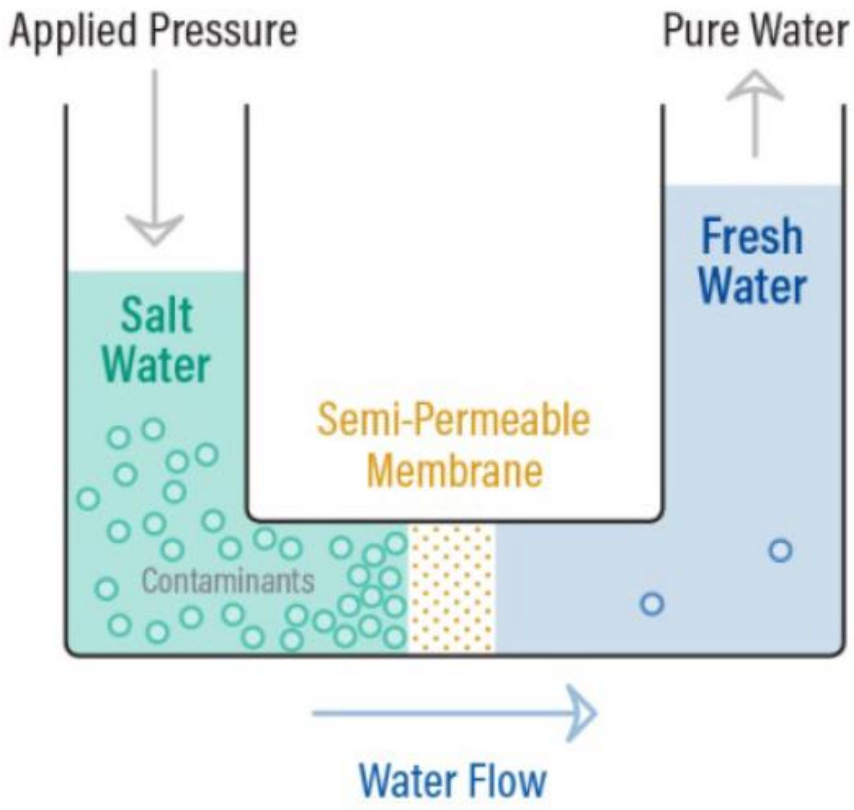

Figure 2.3.2 Representation of Reverse Osmosis Process (PURETEC, 2012)

As it can be seen on the figure above, different from the osmosis process, there should be a pressure on the salty water part of the system, which has a higher concentration rate, to force water to go inside through the semi-permeable membrane. The applied pressure means an extra energy that should be added to the system. Energy consumption level of the reverse osmosis process varies on things like water salinity, reverse osmosis plant's size and reverse osmosis process method. However, as it was mentioned before, this kind of factors will be thought as they are on optimal state. Since the daily-required water amount is 9,159.62 m^3 for 457,981 people, which is the population of Avcılar, Istanbul, at least 460 m^3 of water should be desalinated on an hourly basis. The membrane, as mentioned earlier, has a pore size of 5 Angstrom, which is equal to 5×10^{-10} meters. The length of the pores seems so small, hence this length is enough to hold any unwanted particles but it is big enough to let unsalted water particles inside of it. Membrane can hold 95-99% of the salt particles out of water. The material of the semi-permeable membrane is a polymer material that forms a layered, web-like structure and water must follow a tortuous pathway through the membrane to reach the permeate side (Greenlee L.F. et al, 2009). On the figure below, it can be seen the range of pore diameters needed to use to avoid from different kind of particles.

In other words, reverse osmosis technology is an improved version of the osmosis event that occurs naturally in the nature. In osmosis, there is a transition of water from a less dense medium separated from each other by a semi-permeable membrane to a very dense medium. In order to reverse the osmosis phenomenon in the system, a pressure greater than the osmotic pressure is applied with the help of a pump. By applying intense pressure to the medium, water passes from a very dense medium to a less dense medium. Spirally wound and semi-permeable, which is at the same time, membrane pore size of 5 Angstroms when you migrate only pure water, bacteria, organic matter, suspended solids, molten salts, positively and negatively charged ions and molecules is greater than 5 angstroms is kept and drainage are given. Reverse osmosis units are usually used after the pre-filtration stages. The water is first passed through the particulate filter and then through the activated carbon filter in order to prevent clogging of the filtration membranes (Ünver and Aksu, 2011).

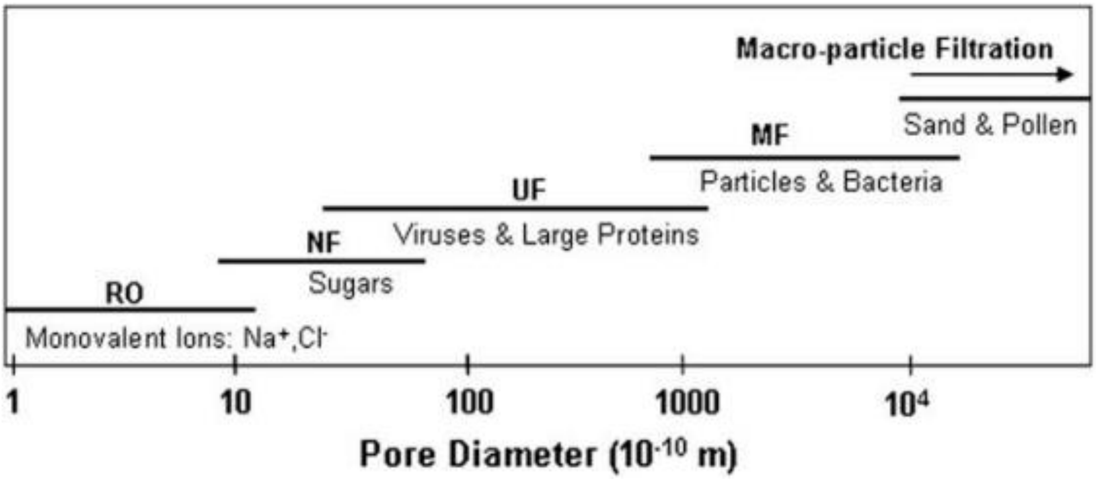

Figure 2.3.3 Pore Diameters for Different Types of Particles (Greenlee L.F et al., 2009)

The mentioned pore diameter, which is 5 Angstrom, will be enough to hold most of the ions and harmful particles like viruses and bacteria. Since the aim is to produce unsalted and drinkable water to earthquake survivors, this disinfection method will do enough work to supply. Apart from the other water disinfection methods mentioned before, reverse osmosis method will have two types of water outcomes. First one is “good water” or the wanted product which is the water that goes through the membrane itself and get cleaned from the leftover harmful particles and salty ions. The second one is called the “bad water” and this water type contains every unwanted materials inside of the water. The reason that the bad water still has the unwanted materials after the disinfection process is, not every water particle can get through the membrane. Therefore, some part of the water volume should be extracted from the system. The water that is still dirty and is extracted from the system is called “brine”. On the figure below, the representation of the reverse osmosis method is shown.

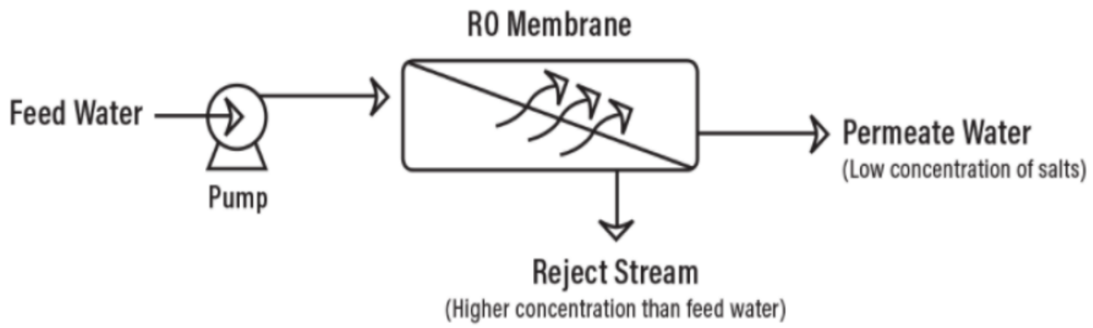

Figure 2.3.4 Reverse Osmosis System Representation (PURETEC, 2012)

As it can be seen from the figure, the membrane is located crosswise inside of the system. One of the reason for this kind of membrane placement is to help water to find its way to collide with the membrane and leave the system as brine easily. The second reason is to get the maximum efficiency from the membrane, as the water will collide with the membrane with a certain angle; there is a high possibility to sweep bacteria, viruses and other unwanted particles from the membrane itself. This passive cleaning will increase the product life and will decrease the maintenance costs. Moreover, this passive cleaning will delay the filling of the pores, therefore provides a better disinfection process of water at the end of the day. In addition to that, the water particles that cannot pass through the membrane leaves the system from the rejected stream way as shown on the figure above. Water particles that goes through the membrane are counted as “good water” due to their desalination process (PURETEC, 2012). After this desalination process, good water will be stored for some brief time in containers and they will be ready to transport on the pre-determined emergency assembly points all around Istanbul.

As it was mentioned before, reverse osmosis process can eliminate 95-99% of unwanted particles inside of drinking water, which are particles, colloids, organics, bacteria and pyrogens (PURETEC, 2012). Moreover, reverse osmosis system can reject 99.9+% of viruses, bacteria and pyrogens and around 50 to 1000 psig (3.4 to 69 bar) pressure will be the interval of needed pressure for this disinfection process (Osmonics, 1991). Furthermore, since reverse osmosis process can be effective to disinfect the unwanted contaminants and salt ions inside of the water with a rate of 99.9+ percentage, it is a great method to use as a desalination method. Moreover, fouling, scaling, and expensive premature RO (reverse osmosis) membrane failure and frequent cleaning are all preventable with proper pretreatment employing both mechanical and chemical treatments (PURETEC, 2012).

The most energy-efficient procedure for practical operation following the improvement method of decreasing irreversibility in high performance pumps would be two-stage reverse osmosis process. Even though perfect batch reverse osmosis is the most energy-efficient, two-stage reverse osmosis is the most realistic method for reducing high performance pumps irreversibility. If the two-stage reverse osmosis configuration was successfully implemented instead of the single-stage RO, energy consumption would be reduced to the greatest extent: approximately 0.34 kWh/m^3 compared to the single-stage reverse osmosis, while the semi-batch reverse osmosis and modified batch reverse osmosis showed energy reductions of 0.29 kWh/m^3 and 0.13 kWh/m^3, respectively, with a moderate circulation pressure loss of 0.1 bar (Kiho et al, 2020).

More than half of the feed is discharged as concentrate in typical SWRO operations (recovery less than 50%). As a result, efforts to boost SWRO (seawater reverse osmosis) recovery have been examined. Some facilities began using a two-stage SWRO process in the early 2000s, feeding the concentrate from a single-stage SWRO into the second stage. Increased recovery allows the plant to be smaller and the volume of concentrate to be lowered. Due to its high-pressure operation, which uses over 100 bars of pressure in the second stage, a two-stage SWRO requires a higher SEC (specific energy consumption). Furthermore, because the second stage of the SWRO process is carried out under high pressure, various operational challenges develop. Because modern SWRO plants demand low SEC rather than high recovery, a two-stage RO configuration has been infrequently used in recent years, whereas BWRO (brackish water reverse osmosis) is commonly constructed with two or more stages (Kim et al, 2019).

Project capital, operation and maintenance (O&M), and overall desalinated water production costs are influenced by a variety of factors, the majority of which are location-specific, such as feed water quality, target product water quality, environmental impacts and regulations, and energy consumption (Water Global Practice Technical Paper, 2019). Reverse osmosis is a tried-and-true method of removing pollutants from water. After the reverse osmosis system, further post-treatments such as mixed bed deionization can improve the reverse osmosis permeates quality and make it appropriate for the most demanding applications. To avoid costly repairs and unscheduled maintenance, a reverse osmosis system requires proper pretreatment and monitoring. Reverse osmosis system should deliver many years of high purity water with the right system design, maintenance schedule, and expert service assistance (PURETEC, 2012).

Furthermore, due to its cheaper capital cost and high dependability, the seawater reverse osmosis process is quickly substituting distillation techniques on offshore oilrigs and oil production platforms. More than a quarter of offshore oil rigs (130 out of 500) have converted to the seawater reverse osmosis technology for potable water supply in the last 18 months. Key West, Florida has chosen seawater reverse osmosis to produce three million gallons per day of drinkable water. In just seven months, this entire facility, including sea wells, was manufactured, installed, and became operational. The ability to deliver rapidly is a fundamental benefit of modular RO systems (Sackinger, 1982).

As all methods mentioned before, reverse osmosis desalination method has advantages and disadvantages on application. By looking at advantages and disadvantages of the reverse osmosis process, it can be seen that if it is makes sense to use this method or not. Reverse osmosis membrane technology is the most advanced and most energy-saving separation technology. It is a physical method (Jiang et al, 2018). Advantages of reverse osmosis method can be seen below:

- The only driving factor in reverse osmosis is pressure. It uses the least amount of energy and saves energy when compared to other traditional physical processing methods.
- Without phase change, reverse osmosis may be performed at ambient temperature.

- Chemical treatment chemicals are not used in reverse osmosis, and chemical waste liquid is not discharged. As a result, it does not contaminate the environment.
- The operating equipment takes up little space and is straightforward to use.
- Water quality of the product of reverse osmosis is excellent and efficiency is high.
- Low energy consumption, anti-pollution, high temperature resistance, high pressure, and particular separation are all features of reverse osmosis membranes.
- Small and chlorinated organic compounds can be removed by using a polymer film.
- Reverse osmosis membrane made of inorganic materials that can separate hydrocarbon mixtures.
- New membrane materials with good water permeability, acid alkali resistance, and oxidation resistance.
- Reverse osmosis membrane components combined with ultrafiltration, microfiltration, Nano-filtration and EDI components (Jiang et al, 2018).

Apart from the advantages, disadvantages of the reverse osmosis desalination method can be seen below:

- The management and operation are not stringent. When the system is operational, the pressure must be within the membrane's operating range.
- The water quality of the actual water cannot be selected for the film materials and models.
- The quality of filtered water and the recommendations established by health organizations are in serious contrast. Because the reverse osmosis equipment simultaneously eliminates important trace elements from the human body (Jiang et al, 2018).

The use of reverse osmosis membrane technology in the improvement of drinking water quality is critical in addressing issues such as a flawed water resources management system, poor drinking water quality, ecological environment investigation, ecological environment change, detailed management of water resources science, and ecological environment improvement. The reverse osmosis membrane separation technique points in the right path for bettering drinking water quality. The water quality enhancement project for drinking water has been taken to a new level thanks to a number of successful applications in the water source. In recent years, the technology has been regularly applied and used. As a result, it is currently rather mature (Jiang et al, 2018).

On the one hand, as the pace of modernization accelerates, water resources become scarcer, and lower-quality water sources are increasingly utilized. On the other hand, the government's environmental protection department's pressure and the public's demand for high-quality drinking water require the process to be updated and improved, which has created a large market potential and space for membrane separation technology, particularly reverse osmosis membrane technology. Simultaneously, the advancement of membrane processing technology has a wide range of potential applications in environmental engineering, particularly in the fields of wastewater treatment and water reuse (Jiang et al, 2018).

2.4 Optimal Scenarios for Disinfection and Desalination Methods

For every disinfection method, there are optimal working conditions in order to have the optimal results with lesser problems. Since there are many unknown variables that can change the process itself and application, there should be optimized scenarios for every disinfection process in order to make a comparison between the disinfection methods. As it was mentioned before, since the disinfection processes have large amounts of variables, government organs and non-governmental organizations should make serious tests, investigations and researches to fully understand every negative scenario that can happen before, during and after the disinfection process, as well as the quality of water, technical problems that may occur during the disinfection process and potential energy need for the selected disinfection method. Therefore, best-case scenarios should be mentioned to narrow down the scope of the project and create an advantageous environment for each disinfection process.

2.4.1 Optimal Scenario for UV Disinfection Method

UV disinfection method is one the best disinfection methods that had mentioned due to its non-chemical disinfection process. It is not only using UV light to kill every single microorganisms that are harmful to human life, but also it can do it very fast and on a straight line. Meaning of straight line is, the water goes into the system and goes out as a disinfected water. There are not any other path that water can or will go, as it can be seen on Figure 2.2.1.2.

Optimized scenario for UV disinfection method can be narrowed down as following:

- The plant itself and systems like pump, piping and disinfection system will not get any damage by the earthquake.
- Energy sources like generators and solar panels will not get any damage by the earthquake as well.
- There will be enough fuel or other combustible materials to keep the plant working during the one-month period after the earthquake.
- System will work 20 hours a day, every day for one month without stopping on that 20 hours periods. Repair and maintenance processes will be done on the 4-hour non-working period, when it is necessary.
- Seawater will not be drifted away from the shoreline and the length of the piping will be enough to draw seawater off.
- Selected pump will be able to draw the required amount of water every hour from the sea.
- The seawater should not have any solid particles that will cause a problem in the system. Seawater should only contain microorganisms like bacteria, viruses and other harmful organisms.
- UV lights that located in the system will have the perfect angle to hit every water particle that is flowing through the system. Therefore, providing a 100% clean water that will not harm survivors that drink or use the disinfected water.
- UV lights will always work on 254 nm, therefore providing the best-case scenario for this disinfection process.
- Water flow rate will be constant to provide the same amount of UV light, which will contact the water particles. Hence, having an equal disinfection on every cm^3 volume of seawater.
- The microorganisms inside of the water will be exterminable with the 254 nm UV light with 400 J/m^2 UV dosage.

To achieve a clean disinfection process, scenarios mentioned above are important. This project is thought to run under these optimal circumstances. Authorized organs should provide further investigation and research in order to achieve the correct values, due to the numbers of changing variables of the conditions in real case scenario.

2.4.2 Optimal Scenario for Ozone Disinfection

Ozone disinfection method is using ozone to eliminate the unwanted organisms that are present on seawater as mentioned earlier. While selecting the best scenario for ozone disinfection method, some of the assumptions will be applicable for ozone and other disinfection systems either. The first seven assumptions will stay the same for ozone and following disinfection systems. By not repeating the same assumptions repeatedly, it should have been known that first seven assumptions would be applicable for every disinfection system. Therefore, best-case scenario for ozone disinfection method will be as following:

- There will not be any toxic effect by the dosage of the ozone given to the system.
- Ozone will be applied to the system on right duration to avoid poisoning.
- There will not be any aldehydes or ketones from the reaction of ozone and organic substances.
- Ozone will be able to mix equally and enough with the water volume to make a homogenous disinfected water.
- Ozone will be thought to eliminate every kind of harmful substances inside of the seawater mass.
- There will not be any materials like chlorine, monochloramine and chlorine dioxide in the seawater, which can react to ozone and can create unwanted substances.
- There will not be iron or manganese present inside the water, which ozone can corrode and create insoluble materials.
- Disinfected water will not be stored for a long time. After disinfection, clean water will be distributed to avoid toxicity inside of the water tanks.
- There will not be any need for another disinfection process after the ozonization; ozone will disinfect the seawater solely.

Ozone disinfection process will be optimized with the assumptions above. As mentioned before, since there are many variables that can and will change constantly, creating optimized scenarios is crucial.

2.4.3 Optimal Scenario for Chlorine Disinfection

Chlorine disinfection will be executed with pure chlorine, which is on a gas form. The optimal scenario also contains first seven assumptions on the UV disinfection optimal scenario section mentioned above. The best-case scenario for chlorine disinfection will be as following:

- Chlorine will be able to disinfect every single microorganism that present in the seawater.
- The pH level of the water is optimal for chlorine disinfection.
- The time of contact will be just enough to clean the water, not as much to poison the water with excessive chemicals.
- Water temperature will be on an optimal level for chlorine to work properly.
- The dosage of chlorine will not excess 1 ppm, under abnormal situation. Under normal circumstances, it will not exceed 0.5 ppm.
- There will be no reproduction after the disinfection process with the help of residual disinfection.
- There will not be algae presence in the water that can give bad taste and odor to disinfected water.
- There will not any microorganisms that can grow inside of the pipes and storage units.
- Chlorine will be able to eliminate hydrogen sulfide, ammonia and other nitrogenous compounds.
- Water will not be stored for too long. It should be sent to the emergency assembly point for survivors to prevent occurring unwanted organisms inside the containers.
- There will not be any infected particles inside of the water after the disinfection process.

The optimized case for chlorine disinfection method mentioned above. There are many variables changing as mentioned before, however, creating an equal environment for each disinfection method will make the methods easier to compare.

2.4.4 Optimal Scenario for Reverse Osmosis Desalination

Reverse osmosis system relies on a powerful pump and a semi-permeable membrane to execute the disinfection process. To make this desalination after the other systems disinfection process, various assumptions should be made like others. Likewise, the first seven assumptions that stated on UV disinfection scenario section are applicable to reverse osmosis desalination process too. The best-case scenario for reverse osmosis desalination will be as following:

- The membrane is thought to have a long product life. That means it will not be deformed very easily throughout the desalination process.
- The microorganisms that are still present inside the seawater mass, after the first disinfection process, will have enough size to be blocked by the membrane.
- There will not be any obstruction inside of the system, especially on the reject stream. Therefore, pressure of the system will be steady throughout the desalination process.
- Membrane is thought to be fixed on the sides inside of the system to provide any seawater particles to mix with clean water on the outlet section of the system.
- The membrane will catch all the salt ions and there will not be any salty taste on the clean water.

3. RESULTS AND DISCUSSION

After disasters like earthquakes, it is a crucial job to bring medical supplies and provisions to survivor, right after the earthquake incident happens. Due to the magnitude of the earthquake, there is a big chance for main city pipelines to break and become unavailable to use. Therefore, having an alternative water supply system will be a lifesaver in post-earthquake situations. Every water disinfection method has its own pros and cons at the end of the day but one of them must be chosen. Among four disinfection methods mentioned above, selection of the most efficient method with relative cost efficiency will be useful, as well as short installation time. The cost is an important aspect for the selection of the optimal method, however the price will not be the final decider while selecting. Other aspects, as mentioned above, will be important as well to select the optimal method with the optimal installation time and optimal costs.

3.1 UV Disinfection System Cost Calculations

UV system is an electrical system that requires UV lamps to execute the disinfection process. This process does not need serious equipment. However, a proper UV system should include sufficient amount of high quality UV lamps and piping as well as other electrical and structural equipment that the system needs. On the other hand, operation and maintenance issues should be taken into consideration to find the closest amount to the real values. It should be remembered that, since there are many numbers of assumptions for every disinfection scenario, achieving the correct value is not easy. Therefore, some additional unseen costs should be added to calculations to stay on the safe side.

3.1.1 UV System Cost Calculations

Starting with UV disinfection method, total price breakdown will include all the structural, operation and maintenance, miscellaneous and other unseen costs. It can be seen that, UV disinfection method is one of the cheapest method among the others. For this disinfection method main costs of an UV-C disinfection facility calculated as following:

Table 3.1.1.1 Calculated Costs of UV System (Office of Water, 1999)

Cost Item	**UV System Cost ($)**
Capital Costs	
Equipment	120,000
Structural modifications	64,000
Miscellaneous	40,000
Total:	**224,000**
Annual operating and maintenance costs	
Energy	3,300.00
Lamps and chemicals	2,840.00
Cleaning	1,180.00
Maintenance	1,440.00
Process control	6,240.00
Testing	4,160.00
Total:	**19,190**

Capital costs will be applicable for the UV disinfection method. However, it will be safer to take the annual operating and maintenance costs as monthly to stay on the safe side as well, due to the changing economic conditions and market prices. Furthermore, a system with peak flow of 98 m^3/d will cost 4,700.00 USD (Office of Water, 2003).

The cost per m^3 of water volume will be:

$$4{,}700.00\ USD/98\ m^3 = 47.96\ USD/m^3 \tag{3.1}$$

Since daily water need is 9,159.62 m^3/day, total cost will be (Office of Water, 2003):

$$47.96\ USD/m^3\ \ x\ 9{,}159.62\ m^3 = 439{,}295.38\ USD \tag{3.2}$$

This amount is for an annual usage of UV disinfection method and all other calculations will be made for monthly costs, monthly costs of this system for disinfection costs will be:

$$439{,}295.38\ USD/12\ month = 36{,}607.95\ USD/month \tag{3.3}$$

Since EPA has two research about UV disinfection process, using the updated costs in 2003 will result better on the comparison with other disinfection methods. However, only the disinfection costs were given on the 2003 research. Operation and maintenance, miscellaneous and energy costs should be taken from 1999 research of EPA. In addition, lamp costs for UV disinfection systems were calculated as following:

Table 3.1.1.2 Lamp Costs for UV Disinfection Systems (Office of Water, 1999)

Item	Range*	Typical*
UV lamps	*($/lamp)*	*($/lamp)*
1-5 mgd	397-1.365	575
5-10 mgd	343-594	475
19-100 mgd	274-588	400
Construction cost for physical facilities	(%of UV lamps cost) 75-200	(% of UV lamp cost) 150

By their calculations, EPA found a sum of both operation and maintenance costs as 263,190.00 $ in the year 1999. By 1999, getting into the technology was quite hard; hence, the prices are expected to be higher when compared today. As known by now, price is an important impact for a disinfection method to be selected. Therefore, price breakdown of the UV sterilizer is as following:

Table 3.1.1.3 Price Breakdown of UV Sterilizer

Item Name	Unit Price ($)	Quantity (pcs)	Total Price ($)
Medium Pressure UV Sterilizer	8,900.00	2	17,800.00
Installation Pipes & Fittings	1,260.00	2	2,520.00
Spare Parts	630.00	4	2,520.00
Total Price			**22,840.00**

Total price of UV unit with all spare parts and installation materials is 22,840.00 USD. In this pricing, maintenance, chemicals, cleaning, maintenance, process control and testing is not included. Therefore, by looking at the inflation rate and buying power in 1993, prices can be converted to at least have a convergent price aspect for the items above. The entire price calculations can be converted to today's worth, except the energy item. Moreover, this calculation should be done for structural modifications and miscellaneous items.

1.00 USD worth of a product in 1993 increases its price by 1.95 in 2022. Therefore, in 2022, that product's worth should be 1.95 USD.

Table 3.1.1.4 Price Conversion Table (1993-2022)

Item Name	Price in 1993 ($)	Price Coefficient	Price in 2022 ($)
Structural Modifications	64,000.00	1.95	124,800.00
Miscellaneous	40,000.00	1.95	78,000.00
Lamps and Chemicals	2,840.00	1.95	5,538.00
Cleaning	1,180.00	1.95	2,301.00
Maintenance	1,440.00	1.95	2,808.00
Process Control	6,240.00	1.95	12,168.00
Testing	4,160.00	1.95	8,112.00
Total	**119,860.00**		**233,727.00**

Total costs for the UV disinfection method as a whole will be as following:

Table 3.1.1.5 Total Costs of UV Disinfection Method

Cost Type	Total Price (USD)
UV Disinfection Costs (30 Days)	36,607.95
Operation & Maintenance Costs (30 Days)	30,927.00
Capital Costs	124,800.00
Generator Costs	10,150.00
Equipment Costs	22,840.00
Miscellaneous Costs	78,000.00
Total	**303,324.95**

Total price of the UV disinfection method is 303,924.95 USD, with all the other unseen costs included. In addition to the costs above, energy consumption costs should be calculated. Needed energy for all the disinfection methods will be provided with solar panels and generators. Optimal amount of solar panels and generators will be combined to decrease the total costs of energy as much as possible. Therefore, knowing the total energy consumption of each system is vital to calculate the total energy cost of the system.

3.1.2 UV Disinfection System Energy Calculations and Costs

Selected UV system's energy consumption rate is 6 kW/h and to supply as much as water as demand, two of the UV disinfection systems should be used. It makes a total of 12 kWh energy consumption rate, just for the UV system itself. Daily consumption of UV disinfection system is:

$$12\ kWh\ \ x\ 20\ hours = 240\ kW \tag{3.4}$$

There might be some other unseen energy consumptions inside of the system. To avoid a miscalculation, energy consumption rates should be increased by 20%, as the disinfection method costs. In addition to the system's energy consumption, the pump that will feed the system by drawing water off the sea should be taken into consideration, since the energy rate of the pump is high. Selected pump has an energy consumption rate of 37 kW per hour and for 20 hours of work time daily, total need of energy for the pump only is 740 kW per day. This energy consumption rate should be increased by 20% as well to stay on the safe side. Total daily energy consumption will be:

$$740\ kW + 240\ kW\ = 980\ kW \tag{3.5}$$

There might be additions to 980 kW daily power usage; therefore, 20% increment should be applied to stay on the safe side.

$$980\ kW\ x\ 1.20 = 1{,}176\ kW \tag{3.6}$$

Total of 1,176 kW daily energy consumption should be considered for UV disinfection system. As mentioned before, to supply the energy need of the system, solar panels and generators will be used. Solar energy is a clean energy when contrary to diesel fuel generators. Total cost of the solar panels might seem a little bit more than generator and fuel costs. However, solar energy is a clean energy and does not harm environment. That is the reason why solar energy should be used as an energy source for the system.

Under every circumstance, there must be a generator to feed the system with enough power, when solar energy panels cannot receive sunlight, in the nighttime for example. Therefore, selected generator should have enough hourly energy output to provide this much of energy by itself. Total hourly energy consumption of the pump and the UV system is:

$$1{,}176\ kW\ /\ 20\ hours = 58.8\ kW \tag{3.7}$$

58.8 kW is a 20% increased value due to staying on the safe side. Therefore, a generator with an hourly capacity of 60 kW will be enough for the system to work with no issues. On the figure below, it can be seen the generator kVA rating to amperage conversion values:

		Single Phase		
kW	kVA	220V	230V	240V
6	7.5	34.1	32.6	31.3
9	10.0	45.5	43.5	41.7
12	15.0	68.2	65.2	62.5
16	20.0	90.9	87.0	83.3
20	25.0	114.0	109.0	104.0
24	30.0	136.0	130.0	125.0
32	40.0	182.0	174.0	167.0
40	50.0	227.0	217.0	208.0
48	60.0	273.0	261.0	250.0
60	75.0	341.0	326.0	313.0
80	100.0	455.0	435.0	417.0
100	125.0	568.0	543.0	521.0

Figure 3.1.2.1 Generator kVA to kW Conversion Table (TGC, 2021)

The graph depicts an expected output amps of a generator based on operational power and voltage with a power factor of 0.8. Please keep in mind that this chart is simply for reference and is not an accurate representation of every generator because specific installation variables will change outputs and voltages. A generator with 60 kW hourly energy output should be selected from the chart and it corresponds to 75-kVA power. To stay on the safe side, generator capacity should be increased from 60 kW to 75 kW. Any extra currents or systematic errors that can cause to consume more power than calculated will not threat the system by increasing the generator capacity. Therefore, Weichai brand WP41D80E200 model, 75 kW output power capacity generator was selected. In addition for the generator, there must be an Automatic Transfer Switch added to the system to make the system autonomous. This ATS device will automatically start the generator one second after the power went down, after the earthquake happens. Properties of the diesel engine and generator will be as following:

Diesel Engine Parameters			
Model	WP41D80E200	Output power（KW）	75kw
Engine structure form	In-line, 4-cylinder, four stroke, turbocharged cooling		
Cylinder bore×stroke（mm）	115/118	Rotating speed(Rpm/min)	1500
Exhaust (L)	4.1	Speed adjusting mode	Mechanical speed adjustment
Starting mode：	24V DC	Cooling mode	Closed water circulation air cooling
Fuel consumption（100%） g/kw.h	≤197	Compression ratio	16.5：1
Filter system	Using an integral replacement oil, diesel filter and air filter		
Exhaust system	Industrial high drop noise effect muffler		

Figure 3.1.2.2 Diesel Engine Parameters

Generator Parameters			
Model	Wuxi Fuli Motor YHB-75		
Structure, excitation mode	Self-excitation, self-refining, pure copper wire		
Output capacity（KVA）	93.75KVA	Output power（KW）	75kw
Protective level	IP21	Insulation level	H
Pole number	4 poles	Efficiency	98.3%
Voltage unload adjustment range	≥±5%	Voltage control method	AVR Automatic pressure regulation
Voltage recovery time	＜1s	Frequency fluctuation rate	≤±0.25%
Overload capacity and time	10%， 1 hour is allowed within 12 hours		

Figure 3.1.2.3 Generator Parameters

Fuel consumption of the diesel motor is 197 g/kWh, as it can be seen on the Figure 3.1.2.2. Density of the diesel fuel is approximately 0.85 kg/L (Khan, R. M., 2011). Therefore, hourly consumption value can be found as:

$$197\ g/kWh\ \ x\ 75\ kWh = 14{,}775.00\ g = 14.775\ kg \tag{3.8}$$

$$14.775\ kg/0.85\ kg/L = 17.38\ Liters \tag{3.9}$$

The hourly fuel consumption of the generator with the 100% efficiency rate is 17.38 liters. The cost of one liter of diesel fuel costs as following in Istanbul:

Figure 3.1.2.4 Fuel Costs of 3 March 2022 (Petrol Ofisi, 2022)

It can be seen on the figure above that, on the European side of Istanbul, cost of one liter of diesel fuel is varying from 22.02 to 22.06 Turkish Lira. The optimum price can be taken as 22.04 Turkish Lira per liter. 22.04 Turkish Lira is approximately 1.48 USD, if the exchange rate is taken as 14.89 TL/USD. Therefore, hourly consumption of the generator will be:

$$1.48\ USD/Liter\ \ x\ 17.38\ Liter/hour\ =\ 25.72\ USD/hour \qquad (3.10)$$

Total fuel cost of the generator will be 25.72 USD for one hour. Generator is thought to work for 20 hours a day. However, generator and solar panels should work together under all circumstances as mentioned above. Solar panels and generators will work together even in the daytime. Solar panels will not be storing power that they gain from the daylight. Energy coming from the panels will be used immediately after they were produced. Therefore, generator will not work with full capacity when the sun is shining. Again, some assumptions to be made in order to make clear calculations about the solar energy cost and energy consumption. Assumptions will be as following:

- For solar energy calculations, shortest day in a year, which is 21 December, selected. In addition, daylight time was assumed as 9 hours, since the sunrise and sunset times will be as below:

December 2022		
Date	Sunrise	Sunset
01 Thu	08:10:13	17:37:39
02 Fri	08:11:14	17:37:24
03 Sat	08:12:15	17:37:11
04 Sun	08:13:14	17:37:00
05 Mon	08:14:12	17:36:52
06 Tue	08:15:09	17:36:46
07 Wed	08:16:04	17:36:43
08 Thu	08:16:58	17:36:41
09 Fri	08:17:51	17:36:43
10 Sat	08:18:42	17:36:46
11 Sun	08:19:32	17:36:52
12 Mon	08:20:20	17:37:00
13 Tue	08:21:07	17:37:10
14 Wed	08:21:52	17:37:23
15 Thu	08:22:36	17:37:38
16 Fri	08:23:17	17:37:55
17 Sat	08:23:57	17:38:15
18 Sun	08:24:35	17:38:36
19 Mon	08:25:11	17:39:00
20 Tue	08:25:45	17:39:26
21 Wed	08:26:17	17:39:54

Figure 3.1.2.5 Sunrise and Sunset Times of Avcılar (Sun Earth Tools, 2022)

- Since there should be a proper distance between solar panels for them not to block each other's sunlight, total selected area for solar panels should be reduced by 1/3.
- It is expected to have an energy loss while converting direct current to alternative current by 10%, since the usable current for the electrical equipment is AC and produced electric from solar panels is DC, therefore this conversion is necessary. However, for the sake of the calculations, it will be neglected.
- It was assumed that, the area where the solar panels will be located is available for the solar panels is aligned to the south and there will not be any area loss because of the allocation of the solar panels.
- Area that solar panels will be placed, assumed as 900 m^2 for further calculations.

- It was assumed that, there will not be any energy storage for solar panels. Produced energy will be used after it was converted to alternative current.
- There will not be any losses while transferring the energy from inverter to the cleaning units.
- Sunlight angle, which comes to the solar panels, should be standardized to have an idea how to design the solar panel area. On 21st December at 12 p.m., sunlight comes to Avcılar with a 23.94° as it can be seen on the figure below:

Date:	21/12/2022 | GMT2	
coordinates:	40.972071, 28.726944	
location:	40.97207100,28.72694400	
hour	Elevation	Azimuth
08:26:18	-0.833°	120.94°
9:00:00	4.45°	126.58°
10:00:00	12.85°	137.6°
11:00:00	19.54°	150.12°
12:00:00	23.94°	164.16°
13:00:00	25.59°	179.2°
14:00:00	24.25°	194.3°
15:00:00	20.11°	208.47°
16:00:00	13.64°	221.16°
17:00:00	5.39°	232.33°
17:39:57	-0.833°	239.06°

Figure 3.1.2.6 Sunlight Angles for Avcılar for 21 December 2022 (Sun Earth Tools, 2022)

It can be seen on the Figure 3.1.2.5 that the daylight time on 21st of December 2022 will be approximately 9 hours. To make calculations easier and more understandable, daylight time will be used as 9 hours. Since the daily working period of the system will be 20 hours in total, generator will provide 11 hours of energy supply single-handedly. Solar panels will get sunlight approximately for 9 hours and they will supply energy to the system. Solar panels, as known by now, are environmental friendly as mentioned before. However, solar system requires some space to be effective and not all the energy produced by the solar panels can be used as it is. There will be some reductions due to its yielding value and losses due to transferring the direct current energy to an alternative current one. Most of the solar panels have a yield value approximately 20%.

Solar panels will not produce with the same efficiency during the approximately 9-hour sun-facing period. Hourly UV energy coming from the sun will not be the same at every hour. For instance, at 12 p.m., light beams coming from sun will be on a more perpendicular to earth surface. Therefore, it will not be the same with 9 a.m. or 17 p.m. energy income.

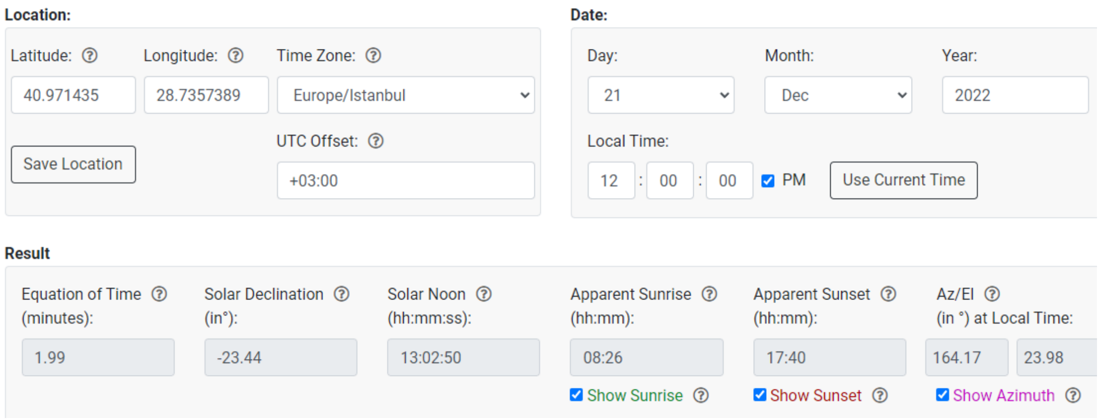

Figure 3.1.2.7 Sunrise and Sunset Times of Avcılar (Global Monitoring Laboratory, 2022)

Solar declination angle calculated as 23.44° by the tool that can be seen on the figure above. It can be seen that, there is a slight difference between the two calculations. The reason is the selected point from the map while using the tool. Even a slight movement of the selected point from the map will cause a difference.

Direct UV beams coming from the sun can be transformed into energy via solar panels. By using the solar radiation calculations, it is possible to find the expected collectable energy from the sun. Moreover, maximum collectable energy can be found and by using solar panels, this energy will be turned into a usable one. The collectable energy amount for Avcılar will be as following:

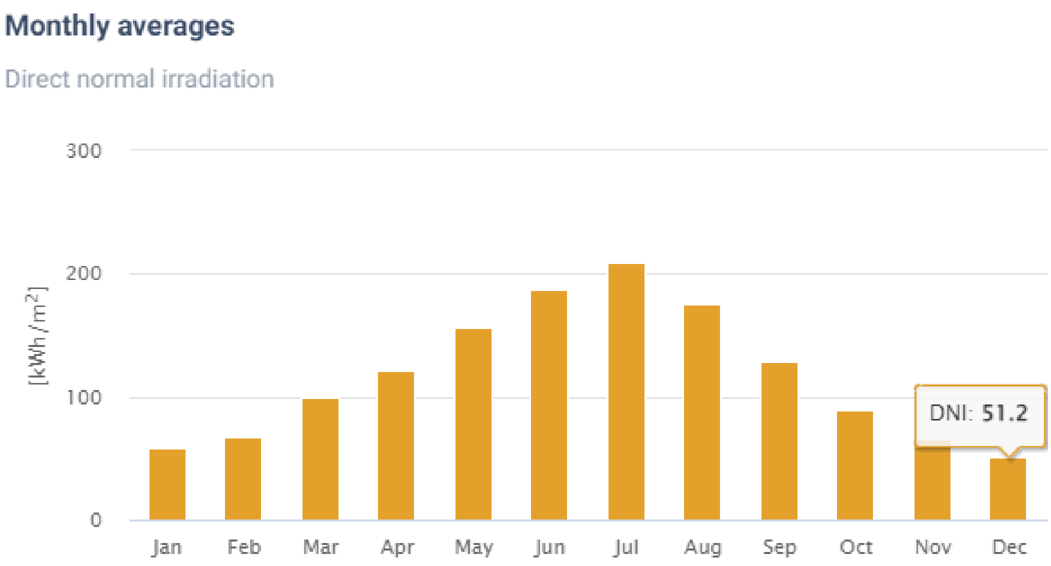

Figure 3.1.2.8 Monthly Direct Normal Irradiation for Avcılar (Global Solar Atlas, 2022)

From the Figure 3.1.2.8, monthly average energy amount coming from the sunlight is shown. It was mentioned before that; based day for the calculations was 21 December 2022. The reason of this date was selected is to have the shortest sunlight time in a year. Total collectable energy for one-month period in December 2022 is 51.2 kWh/m². To be more specific, total energy coming from the sun on an hourly basis can be seen on the figure below:

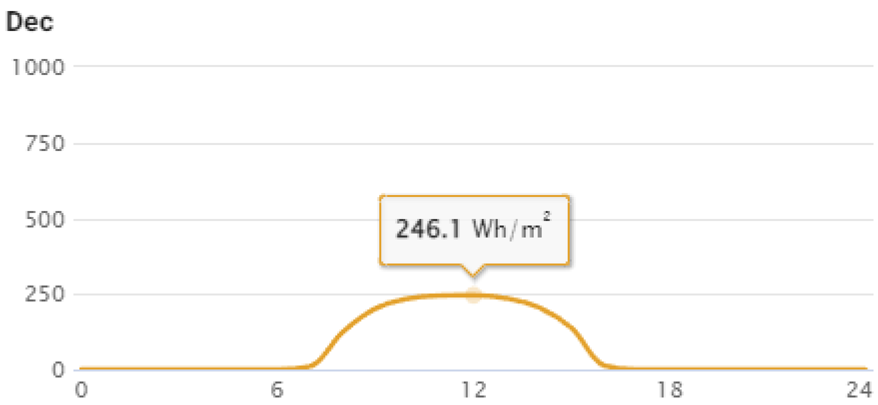

Figure 3.1.2.9 Average Hourly Energy Rates for Avcılar, December 2022 (Global Solar Atlas, 2022)

Throughout December, 246.1 Wh/m² energy will calculated coming from the sun at 12 p.m., which is the hour that sunlight is coming with the most perpendicular angle to the ground surface. More detailed version of this information can be found on the following figure and calculations will be done according to this figure:

Average hourly profiles

Direct normal irradiation [Wh/m²]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6				2	59	113	92	12				
6 - 7			21	108	193	278	292	198	106	16		
7 - 8	11	47	150	223	288	383	409	349	283	165	62	10
8 - 9	135	175	240	310	375	474	506	437	367	270	197	123
9 - 10	217	247	311	382	450	542	576	511	433	323	261	201
10 - 11	257	289	357	427	501	587	615	559	467	349	298	235
11 - 12	275	309	379	451	524	606	640	576	478	351	307	245
12 - 13	271	312	379	457	529	602	637	584	480	349	307	246
13 - 14	266	307	383	448	515	590	640	582	468	350	304	236
14 - 15	242	292	360	418	490	559	621	557	443	327	263	205
15 - 16	188	243	297	364	437	508	579	510	382	254	179	137
16 - 17	48	153	224	290	360	450	507	434	298	109	21	13
17 - 18		14	87	170	268	362	410	308	100	4		
18 - 19				12	82	196	218	62				
19 - 20						6	6					
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	1910	2387	3187	4062	5071	6256	6747	5681	4305	2867	2199	1652

Figure 3.1.2.10 Average Hourly Energy Rates (Detailed) (Global Solar Atlas, 2022)

Total monthly energy coming from the sun in December 2022 will be 1,652 Wh/m². The average of this value will be as following:

$$1{,}652\ Wh/m^2\ /\ 10\ hours = \ 165.2\ Wh/m^2 \ \ = \ 0.1652\ kWh/m^2 \qquad (3.11)$$

Therefore, 0.1652 kWh/m² energy is coming from the sun and as it was mentioned before, 900 m² assumed available for solar panels to be placed. Again, 1/3 of the area should be reduced when total solar panel area is calculating. The reason of this is that, solar panels must not block their path while receiving the sun. Therefore, there must be a proper opening around all solar panels to provide non-blocking placement. The area that solar panels can be placed is:

$$900\ m^2\ x\ (2/3) = \ 600\ m^2 \tag{3.12}$$

According to this solar panel area calculation, total energy coming from the sun that can turn into usable energy will be:

$$0.1652\ kWh\ /\ m^2\ x\ 600\ m^2 = \ 99.12\ kWh \tag{3.13}$$

As it was mentioned before, the yield of solar panels are approximately 20% in general. When the reduction is made, total hourly energy can be calculated as:

$$99.12\ kWh\ x\ 0.20 = 19.82\ kWh \tag{3.14}$$

For 600 m^2 of solar panel area, hourly 19.82 kW energy can be produced according to information above.

Solar panel costs can be calculated according to a sample solar panel. Selected solar panels are JA Solar brand JAM72S39 530-555/MR series solar panels. Further calculations will be done with the model 545. Specifications of the selected solar panels are as following:

SPECIFICATIONS	
Cell	Mono
Weight	28.1kg±3%
Dimensions	2278±2mm×1134±2mm×35±1mm
Cable Cross Section Size	4mm² (IEC) , 12 AWG(UL)
No. of cells	144(6×24)
Junction Box	IP68, 3 diodes
Connector	QC 4.10(1000V) QC 4.10-35(1500V)
Cable Length (Including Connector)	Portrait: 300mm(+)/400mm(-); Landscape: 1300mm(+)/1300mm(-)
Packaging Configuration	31pcs/Pallet 620pcs/40HQ Container

Figure 3.1.2.11 Technical Specifications of Solar Panels

According to the specifications, area of one panel will be:

$$2.278\ m\ \ x\ 1.134\ m\ =\ 2.583\ m^2 \tag{3.15}$$

It was mentioned before, that the sunlight would come to the solar panels with a 23.94°. Therefore, solar panels should be installed with this specific angle to get the maximum efficiency from the sun and solar panels. When the solar panels aligned according to that angle, the area of the solar panels will decrease. For 23.94° angle, area of the panels will decrease 11.2% and area of the panel will be:

$$2.583\ m^2\ x\ 0.888\ =\ 2.29\ m^2 \tag{3.16}$$

For 900 m^2 assumed area for solar panels and knowing only 2/3 of the area can be used by solar panels, due to their positioning, 600 m^2 of area will be used for solar panels only. Therefore, the quantity of the solar panels will be:

$$600\ m^2\ x\ 2.29\ m^2 = 262\ pcs. \tag{3.17}$$

For 600-m² area, 262 solar panels will fit in with an inclined setup. Energy production rate of those solar panels was mentioned on the technical specification sheet. It should be remembered that, for the solar panels, 545W series would be used for calculations.

ELECTRICAL PARAMETERS AT STC

TYPE	JAM72S30 -530/MR	JAM72S30 -535/MR	JAM72S30 -540/MR	JAM72S30 -545/MR
Rated Maximum Power(Pmax) [W]	530	535	540	545
Open Circuit Voltage(Voc) [V]	49.30	49.45	49.60	49.75
Maximum Power Voltage(Vmp) [V]	41.31	41.47	41.64	41.80
Short Circuit Current(Isc) [A]	13.72	13.79	13.86	13.93
Maximum Power Current(Imp) [A]	12.83	12.90	12.97	13.04
Module Efficiency [%]	20.5	20.7	20.9	21.1

Figure 3.1.2.12 Electrical Parameters of Solar Panels

To find hourly energy production of the panels, the following calculations should be made:

$$262\ x\ 545\ W = 142{,}790{,}00\ W = 142.79\ kW \tag{3.18}$$

Hourly production rate of those 262 solar panels will be 142.79 kW. However, not all the produced energy can be used as it is. Yield of the solar panels, as mentioned before and can be seen on Figure 3.1.2.12, was around 20% and when the reduction applied to this calculation, hourly energy production rate will be:

$$142.79\ kW\ x\ 0.20 = 28.56\ kW \tag{3.19}$$

After the 20% module efficiency calculation, solar panels will produce a usable energy of 28.55 kW. As it was mentioned before, solar panels are producing a direct current electric and other electrical equipment cannot use it. Therefore, it should be transferred to alternative current by using an inverter. Selected inverter for this project is Huawei brand SUN2000-215KTL-H0 Smart String Inverter. Technical data of the selected inverter will be as following:

General	
Dimensions (W x H x D)	1,035 x 700 x 365 mm (40.7 x 27.6 x 14.4 inch)
Weight (with mounting plate)	≤86 kg (189.6 lb.)
Operating Temperature Range	-25°C ~ 60°C (-13°F ~ 140°F)
Cooling Method	Smart Air Cooling
Max. Operating Altitude without Derating	4,000 m (13,123 ft.)
Relative Humidity	0 ~ 100%
DC Connector	Staubli MC4 EVO2
AC Connector	Waterproof Connector + OT/DT Terminal
Protection Degree	IP66
Topology	Transformerless

Figure 3.1.2.13 General Properties of Selected Inverter

Input	
Max. Input Voltage	1,500 V
Max. Current per MPPT	30 A
Max. Short Circuit Current per MPPT	50 A
Start Voltage	550 V
MPPT Operating Voltage Range	500 V ~ 1,500 V
Nominal Input Voltage	1,080 V
Number of Inputs	18
Number of MPP Trackers	9
Output	
Nominal AC Active Power	200,000 W
Max. AC Apparent Power	215,000 VA
Max. AC Active Power (cosϕ=1)	215,000 W
Nominal Output Voltage	800 V, 3W + PE
Rated AC Grid Frequency	50 Hz / 60 Hz
Nominal Output Current	144.4 A
Max. Output Current	155.2 A
Adjustable Power Factor Range	0.8 LG ... 0.8 LD
Max. Total Harmonic Distortion	< 1%

Figure 3.1.2.14 Input-Output Values of Selected Inverter

It can be seen from the figures above that, maximum AC active power can be 215 kW per hour. Which is an enough value for the selected quantity and properties of the solar panels. Therefore, one inverter will be enough for using the solar system. Since the dimensions of the inverter are 1.035 x 0.7 x h 0.365 m, it will be easy to install it to one of the solar panel's supports. Since solar panels are thought to work for 9 hours a day, total energy that will be provided by solar panels will be:

$$28.56\ kW\ x\ 9\ hours = 257.04\ kW \tag{3.20}$$

Total daily energy demand for UV disinfection method calculated as 1,176 kW and 257.04 kW will be produced by solar panels, the amount of energy that generator should produce will be:

$$1{,}176\ kW - 257.04\ kW = 918.96\ kW \qquad (3.21)$$

However, as it can be seen on the Figure 3.1.2.12, 545 W is the maximum producible energy by the solar panels. Real values are different from the possible maximum outcome that might happen. From the Formula 3.21, the maximum possible outcome was based on the calculation. The real calculated value on Formula 3.14 should be used in the further calculations to calculate total solar energy that will be produced by solar panels. The value calculated on Formula 3.14 was 19.82 kWh production rate and this value should be converted to a daily total value by following formula:

$$19.82\ kWh\ x\ 9\ hours = 178.38\ kW \qquad (3.22)$$

Daily solar energy production will be 178.38 kW by solar panels. The energy amount that must be produced daily by generator is:

$$1{,}176\ kW - 178.38\ kW = 997.62\ kW \qquad (3.23)$$

Generator will provide a total of 997.62 kW energy daily. Since generator and solar panels will work together on the daylight period, hourly energy production rate of the generator will be:

$$58.8\ kWh - 19.38\ kWh = 39.42\ kWh \qquad (3.24)$$

Generator should work with 75% efficiency during the daylight period to be as much cost efficient as possible during the disinfection process. Since the generator has 75 kWh energy production rate, with 75% efficiency, generator will produce:

$$75\ kWh\ x\ 75\% = 56.25\ kWh \qquad (3.25)$$

For generator to be able to produce this much energy, total fuel cost of the generator on the daylight period will be:

$$25.72\ USD/h\ x\ 75\%\ x\ 9\ hours = 173.61\ USD \tag{3.26}$$

On the nighttime period, generator's fuel cost will be:

$$25.72\ USD/h\ x\ 11\ hours = 282.92\ USD \tag{3.27}$$

Therefore, total daily fuel cost of the generator will be:

$$282.92\ USD + 173.61\ USD = 456.53\ USD \tag{3.28}$$

The price of generator, solar panels and inverter have a great importance. Costs of the items mentioned before, are shown on the table below.

Table 3.1.2.1 Cost Breakdown of Equipment

Item Name	**Total Price (USD)**
Generator Cost	10,460.00
Fuel Cost (30 Days)	13,695.90
Solar Panel Cost (For 262 panel and all the required equipments)	146,247.00
Installation Cost	7,519.32
Total	**177,922.22**

Total energy cost of the UV disinfection system is 177,922.22 USD.

3.2 Ozone Disinfection System Cost Calculations

Ozone disinfection method requires some machinery, just like UV disinfection system. Therefore, apart from the pump itself, it will have a huge impact for the cost calculations. As mentioned above, the ozone will be used in gas form in this disinfection method. There must be a proper installation of piping from the ozone generator to the tank, where the dirty seawater will be stored. In addition, there must be a good piping in between ozone generator and oxygen generator.

3.2.1 Ozone Disinfection System Cost Calculations

Price aspect is important as mentioned before for this project. Guolin Company prices ozone and oxygen generators together for 6,000.00 USD. In addition to this ozone system, a cooling system should be included to the whole system to cool off the ozone disinfection device. A small chiller or tap water can be used. In this case, water supply systems are assumed to be destroyed by the first impact of the earthquake. Therefore, another water pump can be used to supply water to the system to help ozone device to cool off. A pump as strong as the one that was getting used to supply seawater to the system can be used. Therefore, the cost and energy consumption can be added to ozone disinfecting system. The pump’s cost was 10,150 USD per pump and it makes a total cost of 16,150.00 USD for this ozone disinfection system.

However, external pipes from oxygen generator to ozone generator and ozone generator to water container should be added to the cost. Approximately 50 meters of doubled oxygen hose will be enough with spare ones. Unit price of this hose is 1.45 USD/meter and the total cost will be 72.50 USD.

Figure 3.2.1.1 8 mm Oxygen Hose (Olensi, 2022)

Moreover, from ozone generator to water container, a hose that has 21 mm outer and 16 mm inner dimension can be used. The hose has 3-meter length and the price is approximately 11.67 USD/meter. There should be spare hoses apart from the one that is on use. 6-meter length of spare hose will be enough and total need of 21 mm hoses will be 9 meter. Therefore, total cost will be 105.03 USD. Total cost of the unit can be seen on the figure below:

Table 3.2.1.1 Cost Breakdown of Ozone Disinfection Method

Item	Unit Cost (USD)	Quantity	Total Cost (USD)
Ozone & Oxygen Generator	6,000.00	1 set	6,000.00
Cooling System & Generator	10,150.00	2 pcs.	20,300.00
Ozone Hose	11.67	9 m	105.03
Oxygen Hose	1.45	50	72.50
Structural Modifications	-	-	124,800.00
Miscellaneous	-	-	78,000.00
Maintenance	-	-	3,000.00
TOTAL	**-**	**-**	**232,277.53**

Structural modifications and miscellaneous items were taken from the UV disinfection system calculations to make convergent approach. Total cost of ozone disinfection method, without energy cost, is 232,227.53 USD.

3.2.2 Ozone Disinfection System Energy Calculations and Costs

Energy consumption values were mentioned above on the technical datasheets of the equipment. There will be three main energy consumer on this disinfection method, which are the pump, the oxygen generator and ozone generator. The system is thought to work for 20 hours a day. Energy consumption rate of the pump was given on the previous chapter as 37 kW per hour and 740 kW per day, for 20 hours of work time. Ozone generator equipment has an energy consumption of 2 kW per hour and daily, the total energy consumption by this equipment is:

$$2\ kW\ x\ 20\ hours = 40\ kW \tag{3.29}$$

40 kW/day value is applicable if Guolin brand CF-G-1-150g is used for this project. Ozone generator is in need of an oxygen generator to get the required amount of ozone to enter the system. Therefore, the price and required space should be considered as well. The oxygen generators brand is also Guolin with the model GFNC 1.0. Product details are shown below of both ozone and oxygen generators:

No.	Item	Parameter	Reference Picture
1	Equipment name	Ozone generator	
2	Model	CF-G-2-150g	
3	Ozone Capacity	150g/h	
4	Ozone purity	148mg/L	
5	Power supply	220V/50Hz/1ph	
6	Power rate	2.0KW	
7	Ozone outlet connection	G1/2" Internal thread	
8	Cooling water connection	G1/2" Internal thread	
9	Dimension（L*W*H）	800*600*1700mm	
10	Cabinet material	Carbon Steel Cabinet	

Figure 3.2.2.1 Product Details of Guolin Ozone Generator

As shown on the figure below, oxygen generator has a 1.35 kW energy consumption rate. Assuming the oxygen generator will work as the same amount of time as ozone generator, which is 20 hours a day, required daily energy to supply is:

$$1{,}35\ kW\ x\ 20\ hours = 27\ kW \tag{3.30}$$

No.	Item	Parameter	Reference Picture
1	Equipment name	Oxygen generator	
2	Model	GFNC1.0	
3	Oxygen capacity	1.0Nm3/h	
4	Oxygen purity	90±3%（it could be reached after startup with 5min）	
5	Power supply	220V/50Hz/1ph	
6	Power rate	1.35KW	
7	Connection	Φ8connection	
8	Rated gas inlet flow (NM3/h)	13	
9	Max. output pressure （MPa）	0.12	
10	Atmospheric dew point of intake air	≤15C	
11	Dimension（L*W*H）	645*505*560mm	
12	Weight	72kg	

Figure 3.2.2.2 Product Details of Guolin Oxygen Generator

Total energy consumption of the system, including the tank, will be:

$$40\ kW + \ 27\ kW + 740\ kW = 807\ kW \tag{3.31}$$

In addition, for cooling of the system, another pump should be used just to draw water off from sea and cool the system. It was assumed that, this pump would work on 50% efficiency. Therefore, the pump will consume:

$$740\ kW\ x\ 0.5 = 370\ kW \tag{3.32}$$

According to the calculations, total energy needed for the system will be:

$$807\ kW + 370\ kW\ = 1{,}177\ kW \tag{3.33}$$

For one day of work, ozone disinfection will need 1,177 kW of energy. However, as per the earlier calculations, there must be a 20% increment for the energy consumption rate as well. When the 20% increment applied to the energy values, assumed total energy consumption value of the system is:

$$1{,}177\ kW\ x\ 1.20 = 1{,}412.40\ kW \quad (3.34)$$

To provide 1,412.40 kW of energy to the system, 70.62 kW hourly energy production is needed. The generator selected above will also be able to provide the energy demand for ozone disinfection system. Solar system, as mentioned on previous chapter, can provide 19.82 kW of the energy needed. Therefore, in the daytime generator will need to produce hourly:

$$70.62\ kW - 19.82\ kW\ = 50.80\ kW \quad (3.35)$$

To provide 50.80 kW of energy, generator should be on 75% efficiency level. Hourly generator fuel cost was calculated earlier on Formula 3.10 and for the daytime period, hourly total fuel cost of the generator on 75% efficiency level will be:

$$25.72\ USD/h\ \ x\ 75\% = 19.29\ USD/h \quad (3.36)$$

For 9 hours of working time, daytime fuel cost will be:

$$19.29\ USD/h\ \ x\ 9\ hours = 173.61\ USD \quad (3.37)$$

At nighttime, generator will work on 100% efficiency. Therefore, it is not necessary to make a reduction on hourly cost of the generator. For 11 hours of working time, nighttime fuel cost will be:

$$25.72\ USD/h\ \ x\ 11\ hours = 282.92\ USD \quad (3.38)$$

Total daily fuel cost of the generator for ozone disinfection method will be:

$$173.61\ USD + 282.92\ USD = 456.53\ USD \quad (3.39)$$

On the following table, total energy costs for the ozone disinfection method can be found:

Table 3.2.2.1 Total Energy Costs of Ozone Disinfection Method

Item Name	**Total Price (USD)**
Generator Cost	10,460.00
Fuel Cost (30 Days)	13,695.90
Solar Panel Cost (For 262 panel and all the required equipments)	146,247.00
Installation Cost	7,519.32
Total	**177,922.22**

3.3 Chlorine Disinfection System Cost Calculations

Chlorine disinfection system is one of the most used disinfection method in the world. Chlorine will be used in gas form and it was mentioned before that there might be some taste or odor of the chlorine. Apart from the informative aspect of the chlorine, cost aspect will be a huge factor while deciding the best method to use. There will be two main different costs of the chlorine disinfection method, as previous ones. First one is the equipment and structural costs, second one is energy costs of the system.

3.3.1 Chlorine Disinfection System Cost Calculations

Since gas formed chlorine will be used in the system, on the figure below, the costs of variant disinfection methods per m^3 can be seen. It can be seen on the figure below, other disinfection methods' costs are present too. However, this figure will only be used for chlorine cost calculations. While calculating other methods' costs, this table will not be considered as an example. Furthermore, on the table below, not only one type of chlorine based disinfection material exists. There are chlorine, chloramines and chlorine dioxide existing on the table as well. However, only gas formed chlorine will be considered on the table.

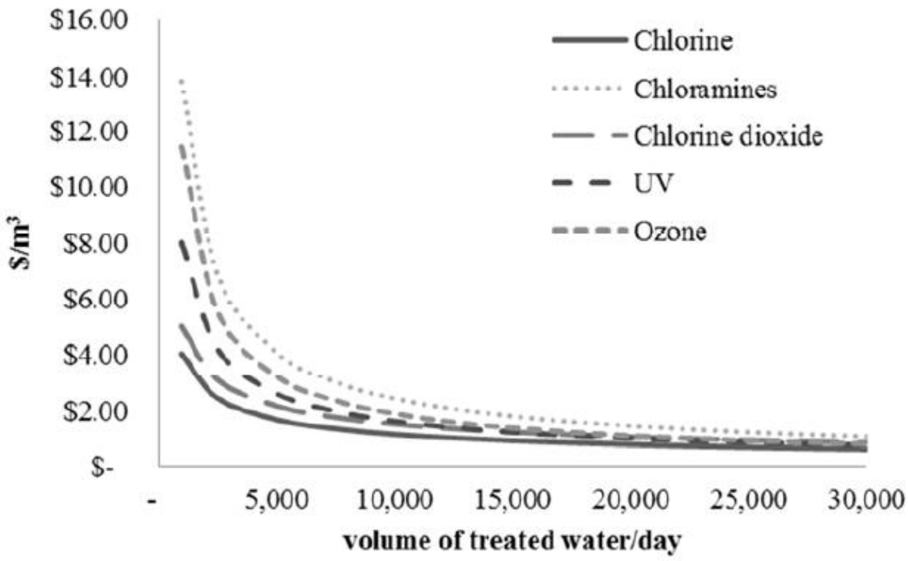

Figure 3.3.1.1 Cost per Cubic Meter of Treated Water (Moghadam and Dore, 2012)

It can be seen on the figure above that, disinfection with chlorine costs are varying between 1 and 2 USD/m³ and this value goes down with the increment of the water mass treated per day. The amount needed to be disinfected for this chlorine disinfection assumption will be around 10,000 m³/day. Therefore, total cost per volume will be around 1.50-1.75 USD. To be on the safe side, 1.75 USD value will be used on the calculations. The total cost of the disinfection process will be as following:

$$9{,}159.62\ m^3\ x\ 1.75\ USD = 16{,}029.34\ USD \qquad (3.40)$$

The approximate amount of the disinfection process itself costs 16,029.34 USD per day. This value must be calculated for one month due to making a healthy comparison between disinfection methods. Total cost of chlorine disinfection process will be:

$$16{,}029.34\ USD\ x\ 30\ days = 480{,}880.20\ USD \qquad (3.41)$$

Table 3.3.1.1 Chlorination and UV Disinfection Annual Cost Analysis (Tak and Kumar, 2017)

Flowrate (MLD)	Total O&M cost (chlorination) (INR-million)	Total O&M cost (chlorination and dechlorination) (INR-million)	Total O&M cost (UV) (INR-million)	UV vs. chlorination (savings) (INR-million)	UV vs. chlorination - dechlorination (savings) (INR-million)
8	0.060	0.076	0.022	0.038	0.054
10	0.070	0.093	0.027	0.047	0.067
20	0.144	0.179	0.052	0.092	0.126
30	0.214	0.264	0.078	0.137	0.187
40	0.284	0.350	0.102	0.183	0.248
50	0.354	0.435	0.129	0.225	0.306

From the figure above, total value of chlorination and dechlorination will be 0,070 Indian Rupees for 1 liter, if the facilities flow rate is around 50 million liters per day. That value approximately equals to 0.00092 USD per liter. Therefore, total operation and maintenance cost can be calculated, since the required amount of water is 9,159,620 liters per day, the operation and maintenance cost will be:

$$9{,}159{,}620\ liter\ x\ 0.00092\ USD = 8{,}426.85\ USD \qquad (3.42)$$

8,426.85 USD amount will be used only for operation and maintenance items for chlorination for one year. It should be calculated for one month of operation and maintenance value to make an even comparison between the disinfection methods.

$$8{,}426.85\ USD\ /\ 12\ months = \ 702.23\ USD/month \qquad (3.43)$$

Apart from those items, the structural modification and facility costs should be included in this calculation. Since the structural modification costs were calculated for UV disinfection systems, the amount will approximately be the same. Therefore, 124,800 USD for structural modifications can be used directly in this calculation, since it was a. Hence, all the costs of one-month long chlorine disinfection will be as following:

Table 3.3.1.2 Total Costs of Chlorine Disinfection

Item Name	**Total Price (USD)**
Chlorine Disinfection (30 Days)	480,880.20
Structural Modifications	124,800.00
Operation & Maintenance (30 Days)	702.23
Total	**606,382.43**

Total cost of this disinfection process will be approximately 606,382.43 USD including disinfection itself, structural modifications and operation & maintenance items. Prices should be increased by 20% to stay on the safe side, since there can be many variables that can change in time and only authorities can research some of the variables. Therefore, increased total price of the chlorine disinfection method can be found on the table below:

Table 3.3.1.3 Total Costs of Chlorine Disinfection (20% increased)

Item Name	**Total Price (USD)**
Chlorine Disinfection (30 Days)	577,056.24
Structural Modifications	124,800.00
Operation & Maintenance (30 Days)	842.67
Total	**727,658.91**

3.3.2 Chlorine Disinfection System Energy Calculations and Costs

Energy consumption value of the chlorine disinfection system can be assumed as 0.0090 kWh/m^3, since the maximum energy need for complete removal occurrence of E.coli bacteria is 0.0090 kWh/m^3 (Nanayakkara et al, 2012). Therefore, daily energy consumption of the system will be:

$$0.0090\ kWh/m^3\ \ x\ 9{,}159.62\ m^3 = \ 82.43\ kW \qquad (3.44)$$

As all the disinfection method energy calculations were done, the pumps energy should be added to the system.

$$82.43\ kW + 740\ kW = \ 822.43\ kW \qquad (3.45)$$

There must be an increment applied to the calculated energy consumption value to be on the safe side. Similar to previous calculations, 20% increment must be applied to make a sensible comparison.

$$822.43\ kW\ x\ 1.20 = 986.92\ kW \qquad (3.46)$$

Daily energy need of the system is 986.92 kW. Calculating hourly consumption is required to find fuel cost of the generator, since, by the help of the solar panels; generator is not required to work at 100% efficiency. Therefore, hourly energy consumption of the system is:

$$986.92\ kW\ /\ 20\ hours = 49.35\ kWh \tag{3.47}$$

The selected generator is able to meet the required hourly energy, since the capacity of the selected generator is 75 kWh. Hourly energy production rate of the solar panels is 19.82 kWh. On the 9 hours of daytime period, required hourly energy production value for generator can be found with the following calculation:

$$49.35\ kWh - 19.82\ kWh = 29.53\ kWh \tag{3.48}$$

To produce enough energy for the system on the daytime period, selected generator must work on 50% efficiency. Hourly fuel consumption of the generator while working with 50% efficiency is:

$$25.72\ USD/h\ \ x\ 50\% = 12.86\ USD/h \tag{3.49}$$

Daytime working period of the generator will be 9 hours, therefore total fuel cost for the daytime is:

$$12.86\ USD/h\ \ x\ 9\ hours = 115.74\ USD \tag{3.50}$$

On the 11 hours of nighttime period, generator must work a minimum of 75% efficiency level. Hourly fuel consumption of the generator while working with 75% efficiency is:

$$25.72\ USD/h\ \ x\ 75\% = 19.29\ USD/h \tag{3.51}$$

Since the nighttime period will be 11 hours, total nighttime fuel cost of the generator will be:

$$19.29\ USD/h\ \ x\ 11\ hours = 212.19\ USD \tag{3.52}$$

Total daily fuel consumption of the generator will be:

$$212.19\ USD + 115.74\ USD\ =\ 327.93\ USD \qquad (3.53)$$

Since the daily fuel consumption cost has been found, monthly fuel consumption cost of the system can be found as following:

$$327.93\ USD\ x\ 30\ days\ =\ 9{,}837.90\ USD \qquad (3.54)$$

After all the cost calculations, total energy cost of the system can be found on the following table:

Table 3.3.2.1 Total Energy Costs of Chlorine Disinfection Method

Item Name	**Total Price (USD)**
Generator Cost	10,460.00
Fuel Cost (30 Days)	9,837.90
Solar Panel Cost (For 262 panel and all the required equipments)	146,247.00
Installation Cost	7,519.32
Total	**174,064.22**

Total energy cost of the chlorine disinfection method is 174,064.22 USD for one month.

3.4 Reverse Osmosis Desalination System Cost Calculations

Reverse osmosis method is one of the easiest methods among all the mentioned methods. There will not be any chemicals or extra equipment to execute this process. The only thing needed is a closed system with two exits and a traverse membrane with a pump, which will create the desired pressure for the system. Pressure will force the seawater to pass through the membrane to execute the desalination process. Cost calculations for reverse osmosis method will be two parts as other disinfection system cost calculations.

Since the desalination process of water is a costly process, when compared to disinfection methods, capital, equipment and energy costs are expected to be higher than other water disinfection methods as well.

3.4.1 Reverse Osmosis Desalination System Cost Calculations

The reverse osmosis plant should be built, operated and every plant needs maintenance. Therefore, while calculating the total cost of a desalination plant, every item should be considered. Many of the items that will be on the calculations are uncertain because of the fact that there should be a deep investigation for every item for changing conditions and technologies. Government itself and governmental organizations, as mentioned before should do those investigations; therefore, some assumptions should be applied in order to reach to a convenient result, even though there are not enough data to work with. Seawater desalination cost calculations can be seen on the figure below:

Table 3.4.1.1 Summary of Worldwide Seawater Desalination Costs (World Bank Group, 2019)

Desalination Method		Capital Costs (million USD/MLD)		O&M Costs (USD/m³)		Cost of Water Production (USD/m³)	
		Range	Average	Range	Average	Range	Average
MSF		1.70 – 3.10	2.10	0.22 – 0.30	0.26	1.02 – 1.4	1.44
MED-TVC		1.20 – 2.30	1.40	0.11 – 0.25	0.14	1.12 – 1.50	1.39
SWRO Mediterranean Sea		0.80 – 2.20	1.20	0.25 – 0.74	0.35	0.64 – 1.62	0.98
SWRO Arabian Gulf		1.20 – 1.80	1.50	0.36 – 1.01	0.64	0.96 – 1.92	1.35
SWRO Red Sea		1.20 – 2.30	1.50	0.41 – 0.96	0.51	1.14 – 1.70	1.38
SWRO Atlantic and Pacific Ocean		1.30 – 7.60	4.10	0.17 – 0.41	0.21	0.88 – 2.86	1.82
Hybrid	MSF/MED	1.50 – 2.20	1.80	0.14 – 0.25	0.23	0.95 – 1.37	1.15
	SWRO	1.20 – 2.40	1.30	0.29 – 0.44	0.35	0,85 – 1.12	1.03

Note: Costs are at 2016 values. MED-TVC = multiple effect distillation with thermal vapor compression; MLD = million liters per day; MSF = multistage flash distillation; O&M = operation and maintenance; SWRO = seawater reverse osmosis.

As it can be seen on the table above, seawater reverse osmosis costs are varying for different cost perspectives. On the table, costs were calculated for million USD costs for million liters of water daily. The reason being is the capacity of the desalination plants are huge which that research had done. However, it can be thought for one USD for one liter of water daily, since the aim of the paper focuses on a relatively smaller portion as in the first place and interpolating the results for a larger portion of water need. Therefore, focusing on the costs on the SWRO on Mediterranean Sea will give the closest results to this research. Capital costs are pointed as 1.20 USD per 1 liter of water daily as average, operation and maintenance costs are 0.35 USD per 1 liter of water daily as average and finally, the cost of water production is 0.98 USD per 1 liter of water daily as average. Apart from other disinfection methods, for reverse osmosis, there is a capital cost value, which stands for one-time expenses like installation of the plant from scratch. All the construction and installation costs were thought to be in this average cost value. It was pre-determined on the previous sections that how much water is needed. By that information, daily costs can be calculated as following:

$$9{,}159{,}620\ liter\ x\ 1.20\ USD/liter = 10{,}991{,}554\ USD \tag{3.55}$$

For capital (one-time) costs, 10,991,554 USD should be spent for constructional and other one-time costs.

$$9{,}159.62\ m^3/day\ x\ 0.35\ USD/m^3 = 3{,}205.86\ USD/day \tag{3.56}$$

Operation and maintenance costs are 3,205.86 USD when the pre-determined amount of water have put in the calculations. Since the amount is for one day, this should be considered on the final sum-up of the calculations.

$$9{,}159.62\ m^3/day\ x\ 0.98\ USD/m^3 = 8{,}976.43\ USD/day \tag{3.57}$$

Finally, for the cost of water production, approximately 9,000.00 USD will be in need daily. As mentioned before, this cost is daily and while calculating the final total cost, all of this items should be taken into consideration.

Since this project focuses on a very small period after an earthquake happens, calculations will be done for one month of usage of this disinfection plant. Therefore, total costs of this project will be as following:

Table 3.4.1.2 Total Costs of Reverse Osmosis Process

Item Name	Total Price (USD)
Reverse Osmosis Disinfection (30 Days)	269,293.90
Operation & Maintenance (30 Days)	96,175.80
Total	**365,469.70**

The total cost amount for reverse osmosis process will be 365,469.70 USD for 1 month of usage, apart from the constructional costs. As the other seawater disinfection methods, to be on the safe side, costs should be increased by 20% to stay on the safe side, due to the many unknown criteria:

Table 3.4.1.3 Total Cost of Reverse Osmosis Process (20% increased)

Item Name	Total Price (USD)
Reverse Osmosis Disinfection (30 Days)	323,152.68
Operation & Maintenance (30 Days)	115,410.96
Total	**438,563.64**

The 20% increment will help the price values to stay on the safe side as mentioned before and with this increment, total cost will be 438,563.64 USD without capital costs. Capital costs should be added to the calculations for reverse osmosis desalination process to see the total costs. As it was calculated before, capital costs for reverse osmosis desalination process is 10,991,554 USD. Likewise the other cost calculations, this cost value should be increased by 20% as well. Therefore, total safe value for the capital costs of reverse osmosis process will be:

$$10{,}991{,}554\ USD\ x\ 1.20 = 13{,}189{,}864.80\ USD \qquad (3.58)$$

Total cost breakdown table of the reverse osmosis desalination process, including capital costs, can be seen on the table below:

Table 3.4.1.4 Total Costs of Reverse Osmosis Process (Including Capital Costs)

Item Name	Total Price (USD)
Reverse Osmosis Disinfection (30 Days)	323,152.68
Operation & Maintenance (30 Days)	115,410.96
Capital Costs (20% increased)	13,189,864.80
Total	**13,628,428.44**

Total cost of the reverse osmosis method is 13,628,428.44 USD, with the addition of the capital costs. The capital costs of this desalination method is massively greater than the water disinfection methods, since the plant must be bigger and well constructed and furnished with serious equipment to execute the desalination process. The reason is, water desalination process is harder than water disinfection process in general. Salt particles inside the water mass should be eliminated with a high elimination rate, in order survivors to drink the water without any salty taste.

3.4.2 Reverse Osmosis Desalination System Energy Calculations and Costs

Energy consumption rate of the reverse osmosis process was given on the table below, besides other disinfection methods. Only reverse osmosis method energy consumption rates will be taken into consideration, as it was done similar on the previous chapters. On the table below, areas with the green marks will be taken into consideration.

Table 3.4.2.1 Energy Consumption Amounts of Seawater Disinfection Methods (Encyclopedia of Desalination and Water Resources (DESWARE), 2013)

	MSF (Multi-Stage Flash)	**MED (Multi-Effect Distillation)**	**MVC (Mechanical Vapor Compression)**	**RO (Reverse Osmosis)**
Electrical Energy Consumption (kWh/m³)	4 - 6	1.5 – 2.5	7 - 12	3.5 – 5.0
Thermal Energy (kWh/m³)	50 - 110	60 - 110	None	None
Electrical Equivalent for Thermal Energy (kWh/m³)	9.5 – 19.5	5 – 8.5	None	None
Total Equivalent Energy Consumption (kWh/m³)	13.5 – 25.5	6.5 - 11	7.0 – 12.0	3.0 – 5.5

The amount of electrical energy that might be created utilizing a particular amount of thermal energy and the proper turbine generator is referred to as "electrical equivalent." These calculations do not take into account the energy used to build or renovate the goods used in the process. It can be understand from the table above that, 3.5 – 5.0 kWh/m³ energy will be required for a reverse osmosis process. To be on the safe side, it can be thought that reverse osmosis process will require 5.0 kWh/m³ energy. Since the daily-required amount of water for Avcılar is 9,159.62 m³, total energy requirement for one day will be:

$$9{,}159.62\ m^3\ x\ 5\ kWh/m^3\ = 45{,}798.10\ kWh \qquad (3.59)$$

This calculation was made based on the total water need for Avcılar population theoretically but the pump used for on the system will provide more water enough for the system. Hence, the system is thought to work for 20 hours a day and the pump has a 480-m³ water inlet per hour, daily consumption will be:

$$480\ m^3/h\ x\ 20\ hours\ x\ 5\ kWh/m^3\ = 48{,}000\ kWh \quad (3.60)$$

Daily energy required for reverse osmosis method to provide enough water for Avcılar population will be 48,000 kW for 20 hours of work daily. Energy costs will be calculated on the following sections.

Apart from the total costs of the reverse osmosis process, energy consumption is very important to see if this disinfection method is viable or not. Again, the reverse osmosis system is thought to work 20 hours a day for one month. Energy costs of various water disinfection methods are as following:

Table 3.4.2.2 Energy Consumption of Seawater Disinfection Methods (World Bank Group, 2019)

Desalination Method	MSF	MED	MED-TVC	SWRO
Electrical energy (kWh/m^3)	3.4 – 4.5	1.5 – 2.5	1.2 – 1.8	3 - 7
Electrical equivalent of thermal energy (kWh/m^3)	5.6 – 8.0	5 – 8.5	4.0 – 5.5	None
Total equivalent electrical energy (kWh/m^3)	9.0 – 12.5	6.5 - 11	5.2 – 7.3	3 - 7
Note: MED = multiple effect distillation; MSF = multistage flash distillation; SWRO = seawater reverse osmosis; TVC = thermal vapor compression.				

The required electrical energy on the table above is ranging 3 to 7 for seawater reverse osmosis process. By staying on the safe side, 7 kWh/m^3 value should be used, which is a maximum value of the specified range. Despite the required amount of daily water is 9,159.62 m^3, hourly water intake should be considered in order to reach the result in a simple way. The plant is thought to work 20 hours a day, therefore the hourly intake was decided before as 480 m^3/h, which is the capacity of the pump. For one hour, the systems energy need will be:

$$480\ m^3/h\ x\ 7\ kWh/m^3 = 3{,}360.00\ kW \quad (3.61)$$

3,360 kW will be the hourly energy consumption of the reverse osmosis disinfection plant. To find the daily consumption, this value should be multiplied by 20 hours, which plant will be working:

$$3{,}360\ kW/h\ x\ 20\ hours = 67{,}200\ kW/day \quad (3.62)$$

The total daily energy need of the reverse osmosis plant will be 67,200 kW. Since the total daily energy need of the reverse osmosis method is reasonably higher than the other methods, solar panels will not be used for this disinfection method. Solar panels will produce 19.82 kW; and this amount is not sufficient when compared to the energy need. Therefore, usage of solar panels will not provide any advantages to the cost aspect and energy providing aspect.

The generator must have a minimum of 3.50 MW of hourly energy production rate to be able to satisfy the system need. Therefore, three generators with 1.32 MW power each will be enough for the system. Selected generator to satisfy the need is Haitai Power brand, HTD-1320GF model 1.32 MW generator. Cost of each generator is 163,000.00 USD and total generator cost for three generator is:

$$163{,}000.00\ USD\ x\ 3\ pcs. = 489{,}000.00\ USD \quad (3.63)$$

The equipment cost of three generators is 489,000.00 USD. Apart from the equipment cost, fuel cost has a great importance when it comes to calculating total energy costs. Fuel consumption rate can be found from the technical datasheet below:

Cylinder No.	12 60° Vee form
Bore ×Stroke	160×190mm
Displacement	45.84L
Start Method	24V Starter
Compression Ratio	13.6:1
Crankshaft Rotation Direction	Inverse Hour (From Flywheel)
Cooling Method	Closed Water Cooling
Aspiration Type	Turbocharged and intercooled
Speed Governor	Electronic
Fuel consumption rate	200g/kw.h
Fuel consumption	310L/h
Lubricating Oil Capacity	178 L
Coolant capacity	207L
Lubricating oil Temperature	＜121℃
Lubricating oil Pressure	276-414 Kpa
Exhaust Temperature	＜550°C

Figure 3.4.2.1 Technical Datasheet of Selected Generator

Fuel consumption of the selected generator is quite high when compared to the 75 kW generator, which will though to be used by water disinfection methods. Hourly fuel consumption cost of the generator when it is working on 100% efficiency will be:

$$310\ L/h\ x\ 1.48\ USD/L = 458.80\ USD/h \tag{3.64}$$

Since the generator will work 20 hours a day, daily fuel consumption of the system will be:

$$458.8\ USD/h\ \ x\ 20\ hours = 9{,}176.00\ USD \tag{3.65}$$

This fuel consumption amount is daily and for one generator. Monthly costs can be calculated as following:

$$9{,}176.00\ x\ 30\ days\ x\ 3\ pcs. = 825{,}840.00\ USD \tag{3.66}$$

Monthly fuel cost of the generators will be 825,840.00 USD. On the table below, total energy costs of the reverse osmosis method can be seen:

Table 3.4.2.3 Total Energy Costs of Reverse Osmosis Method

Item Name	Total Price (USD)
Generator Cost	489,000.00
Fuel Cost (30 Days)	825,840.00
Total	**1,314,840.00**

Total energy costs of the reverse osmosis method calculated as 1,314,840.00 USD for one month of usage.

3.5 Comparison of Disinfection Methods

Among all seawater disinfection methods, four of them were chosen. Various vital information about all the methods and cost calculations were made. However, all the methods should be compared with each other and one should be selected among four of them. Not only is the cost aspect important but also applicability and energy consumption rates. Of course, cost aspect would be the most critical aspect to think.

UV disinfection method has a great applicability and easy-to-access tools to execute the disinfection process. Besides, UV disinfection method is able to kill most of the harmful substances that seawater contains. Particle size is not that important too, when compared with other disinfection methods mentioned above. Energy consumption level is not on a critical level; therefore, energy cost will not be high. There are two very important parts while using UV disinfection method while disinfection of seawater. First one is using the correct UV dosage to be as efficient as possible. Second one is related to the first one, which is photo reactivation. It may happen due to the wrong settings of the UV dosage on the disinfection system. Dosage is the most important criteria for this disinfection method.

Ozone disinfection method is relatively cheaper than other disinfection methods and it has many advantageous sides. Ozone must be created from the oxygen existing in the air or from the oxygen, as the product of oxygen generator. Both ways will create the environment to execute this disinfection method. At least one ozone and one oxygen generator is needed for this method. In order to create a continuous disinfection by this method under abnormal conditions, usage of oxygen generator is vital because supplying water to the earthquake survivors must be done quick and precise. In addition to that, ozone is a natural disinfectant and it can kill most of the pathogens inside the water mass, as well as destroying metals such as iron, manganese and arsenic. There will not be any storage problems because oxygen generator is creating the needed oxygen by the ozone generator and ozone generator is supplying the ozone to clean the water. Only desired amount of oxygen and ozone is producing by this equipment, hence there is no need of storing the disinfectants. Ozone is doing a great job when it comes to eliminate any taste and odor in the water and ozone prevents water mass' flowering. Therefore, creating healthy and usable water for earthquake survivors. The pH level of the water will not change due to the presence of ozone inside of the water mass. Most importantly for the health aspect, ozone is not carcinogenic, which makes ozone disinfection very advantageous. However, like UV disinfection, ozone dosage must be under control in order to prevent toxicity to happen. There might be a reaction in between organic substances and ozone, which is something unwanted to happen for human health.

Chlorine disinfection will be executed with gas chlorine, which is on a gas form. It can dissolve inside the water mass and controls odor and taste of the water mass, like ozone. Unlike other disinfection methods, this method is the only continuous one. Chlorine keeps cleaning the water mass from the plant to end user. In addition to that, chlorine disinfection provides residual disinfection, which means eliminated organisms cannot come back to life. Chlorine disinfection method has a widespread usage; therefore, it is applicable and easy to use. Chlorine prevents sulfuric products to form inside the water mass. However, there are four important points, which should be taken into consideration for chlorine disinfection. These are pH level of water, chlorine dosage, time of contact and temperature of water. Points mentioned above have a great importance for the quality of this disinfection method.

Reverse osmosis disinfection method requires a semi-membrane which will prevent relatively bigger particles and microorganisms to pass through and let the clean water pass inside of it. Since there should be a pressure bigger than the osmotic pressure, there must be a reject stream, which will prevent system from breaking down. The water mass, which will hit the membrane and cannot pass through it, will use the stream to leave the system. Since there must be a constant pressure that should be applied to the system, energy costs are high when compared to other disinfection methods. However, different from other methods, reverse osmosis process requires a prior disinfection due to its disability to prevent relatively smaller particles. Since the energy consumption rate is very high when compared to other disinfection methods, solar panels will not be used as an energy source because the energy produced by solar panels will be very small and can even be negligible. Therefore, it does not make sense to spend a lot of money for this energy production method for reverse osmosis disinfection system.

As mentioned before, cost is a very important criterion while deciding which system to use. Therefore, cost comparison for installation, equipment and other costs can be found on the table below:

Table 3.5.1 Installation, Equipment and Other Cost Comparison Table

Disinfection/Desalination Method	UV Disinfection	Ozone Disinfection	Chlorine Disinfection	Reverse Osmosis Desalination
Disinfection Costs (USD)	36,607.95	16,150.00	577,056.24	323,152.68
O&M Costs (USD)	30,927.00	3,000.00	842.67	115,410.96
Structural and Equipment Costs (USD)	157,790.00	135,127.53	124,800.00	13,189,864.80
Miscellaneous Costs (USD)	78,000.00	78,000.00	78,000.00	78,000.00
Total Cost (USD)	**313,474.95**	**232,227.53**	**780,698.91**	**13,695,428.44**

It can be seen on the table that cheapest seawater disinfection method seems as ozone disinfection method. UV and chlorine disinfection methods, is following ozone disinfection method. Ozone disinfection method seems to be the cheapest among all other disinfection methods when it comes to disinfection costs. Chlorine is the most expensive method for the same aspect. Operation and maintenance is an important aspect too and the most expensive as operation and maintenance costs is reverse osmosis method. Ozone disinfection method seems to be the cheapest by operation and maintenance aspect. It should be remembered that, after the disinfection process, there must be a reverse osmosis desalination process to be applied to the disinfected water mass. Therefore, while calculating the total costs of the selected method, reverse osmosis desalination method's costs should be included as well.

Structural and equipment costs are quite close to each other for every method. The difference is coming from the pump and other electrical and non-electrical equipment costs. To make the all disinfection systems comparable, all the structural costs were taken as the same amount. Therefore, by equipment, installation and other costs, ozone disinfection method seems advantageous and cheapest among all others.

Miscellaneous costs were added to every disinfection and desalination system. The reason for that is, there might be some unseen costs like hiring an employee, buying new equipment or disinfectants. It is possible to have extra costs, since this project is mostly based on assumptions. It was mentioned before that, only government and its organs are able to research the unseen costs that are unclear right now. Apart from the equipment, installation and other costs, electrical consumption and electrical costs have importance as well. On the table below, electrical consumption rates of disinfection and desalination methods can be seen.

Table 3.5.2 Electrical Consumption Rates Comparison Table

Disinfection/Desalination Method	UV Disinfection	Ozone Disinfection	Chlorine Disinfection	Reverse Osmosis Disinfection
Energy Consumption (Hourly, kW)	58.8 kW	70.62 kW	49.34 kW	3,360.00 kW
Energy Consumption (Daily, kW)	1176 kW	1,412.40 kW	986,92 kW	67,200.00 kW
Energy Consumption (Monthly, MW)	35.28 MW	42.37 MW	29.61 MW	2,016.00 MW

Reverse osmosis method has the most hourly energy consumption with 3,360.00 kW. Energy cost of the reverse osmosis method will be higher than other methods. Chlorine disinfection method has the lowest energy consumption rate among all and it will cost less from other methods. Since solar panels will not be used on reverse osmosis method, to provide enough energy, generators with more power capacity will be used and the fuel costs will increase massively. It is obvious from the table below that, most of the electrical cost for UV, ozone and chlorine methods coming from solar panel costs. Since the critical period for this research is one month, solar energy prices seems to be higher. However, on long term, solar energy costs will be a lot less than the fuel costs. In addition to that, solar energy is environmental friendly when compared to diesel fuel. Solar energy will have more advantages by cost aspect and by environmental friendliness.

Table 3.5.3 Electrical Cost Comparison Table

Disinfection/Desalination Method	UV Disinfection	Ozone Disinfection	Chlorine Disinfection	Reverse Osmosis Disinfection
Solar Panel Cost (USD)	146,247.00	146,247.00	146,247.00	-
Generator Cost (USD)	10,460.00	20,920.00	10,460.00	489,000.00
Fuel Cost (Monthly, USD)	11,899.80	13,695.90	9,837.90	825,840.00
Total Cost (USD)	**168,606.80**	**180,862.90**	**166,544.90**	**1,314,840.00**

As it was mentioned before, reverse osmosis method is the most expensive method among all, since it is the desalination method, not a disinfection method. Despite solar panels are not using for this method, the cost is massively high. Chlorine and UV disinfection methods have approximately similar energy costs, followed by ozone disinfection method. Ozone disinfection method is not too high at cost since there is around 20,000.00 USD difference between them. By looking at energy costs, it is hard to choose the best method since UV, chlorine and ozone disinfection systems has approximately similar costs. Hence, comparing the total prices for each disinfection method will give a better understanding and it will give a clear idea to which disinfection method to choose by the cost aspect.

Table 3.5.4 Total Cost Comparison Table

Disinfection/Desalination Method	UV Disinfection	Ozone Disinfection	Chlorine Disinfection	Reverse Osmosis Disinfection
Total Installation, Equipment and Other Costs (USD)	313,474.95	232,227.53	780,698.91	13,695,428.44
Total Energy Costs (USD)	168,606.80	180,862.90	166,544.90	1,314,840.00
Total Cost (USD)	**482,081.75**	**413,090.43**	**947,253.81**	**15,010,268.44**

By looking at the total costs of the disinfection methods, cheapest disinfection method seems like ozone disinfection method, followed by UV disinfection, chlorine disinfection, respectively. Ozone disinfection method's total energy costs are more than UV and chlorine disinfection method however, total installation, equipment and other disinfection cost is relatively less than UV disinfection method. In addition, ozone disinfection method has many advantages and easy to use. Total cost of ozone disinfection method makes it desirable to choose because cost is a very important factor while choosing the method. Not only the cost is a determinant factor but also ozone disinfection system's advantages. Therefore, ozone disinfection method should be chosen because it has big advantages on many aspects. In addition to the ozone disinfection method's cost calculations, reverse osmosis process's costs should be added to the final cost to see the result.

However, the total price of the disinfection and desalination methods' can be separated by the capital costs and energy costs. It may be possible to discard all of the capital costs and energy costs and only focusing to the disinfection costs. By doing this, only the disinfection, desalination and other compulsory costs can be seen. On the following table, mentioned costs can be seen:

Table 3.5.5 Total Cost Comparison Table (Without Capital and Equipment Costs)

Disinfection Method	UV Disinfection	Ozone Disinfection	Chlorine Disinfection	Reverse Osmosis Desalination
Disinfection Costs (USD)	36,607.95	16,150.00	577,056.24	323,152.68
O&M Costs (USD)	30,927.00	3,000.00	842.67	115,410.96
Miscellaneous Costs (USD)	78,000.00	78,000.00	78,000.00	78,000.00
Fuel Cost (Monthly, USD)	11,899.80	13,695.90	9,837.90	825,840.00
Total Cost (USD)	**157,434.75**	**110,845.90**	**665,736.81**	**1,342,403.64**

Ozone disinfection is still the cheapest method, when all other unwanted costs are neglected. On the table, ozone disinfection method costs 110,845.90 USD for one month of usage. Just for disinfecting, desalinating and operating the disinfection and desalination plants' cost can be seen on the table. Reverse osmosis desalination method's total costs 1,342,403.64 USD for one month of usage and m³ price will be:

$$1{,}342{,}403.64\ (USD/month)\ /\ 274{,}788.60\ m^3 = 4.885\ USD/m^3 \qquad (3.67)$$

With the fuel costs and other operational and desalination costs, reverse osmosis method will cost 4.855 USD/m³. The reason of the previous calculation is to see if the calculated values are close to the currently applying values in the world. For the current reverse osmosis desalination analyses shows that, on one of the worst conditions with zero-liquid-discharge will cost a total of 4.08 USD/m³ (Zhu et al, 2010). Since the calculations were made according to various assumptions and cost values were increased by 20% to stay on the safe side, the calculated value is very close to the current cost of the reverse osmosis process costs. It can be understood from this comparison that, calculated prices are safe and yet close to the current cost values, which will give a great understanding of the solution on the cost aspect.

However, disinfection and desalination processes should be done respectively to make the desired water mass both clean and unsalted for the survivors to drink. Therefore, total cost of the ozone disinfection method and reverse osmosis desalination method will be:

$$15{,}010{,}268.44\ USD + 413{,}090.43\ USD = 15{,}423{,}358.87\ USD \qquad (3.68)$$

After a post-earthquake situation in Avcılar/Istanbul, to supply enough clean water for earthquake survivors, which was assumed as 457,981 people as the population of Avcılar, 15,423,358.87 USD should be spent, in order to provide 9,159,620 liters of clean and drinkable water daily. Which is equal to 274,788,600 liters of clean and drinkable water for monthly usage. Therefore, unit cost of ozone disinfection and reverse osmosis desalination processes will be:

$$15{,}423{,}358.87\ USD\ /\ 274{,}788{,}600\ liters = 0.056128\ USD/liter \qquad (3.69)$$

To disinfect and desalinate one liter of water, 0.056128 USD should be spent. In other words, this amount can be recalculated by finding one cubic meter of waters disinfection and desalination costs.

$$15{,}423{,}358.87\ USD\ /\ 274{,}788.60\ m^3 = 56.128\ USD/m^3 \qquad (3.70)$$

To conclude, to disinfect and desalinate one m^3 of water, 56.128 USD should be spent. It seems like a large value when it is thought, however, it should be remembered that, disinfection and desalination processes are not easy and cheap processes to execute. The value of freshwater sources around the world must be understood and protective measures for water losses should be brought into force.

4. CONCLUSION AND FURTHER RECOMMENDATIONS

This project aimed a solution to a post-earthquake situation that expected in Istanbul, when it is impossible to reach freshwater sources due to the earthquake's destructive aspect on city's infrastructural elements. For this project, Avcılar province is selected as a base location to limit the calculations that will be made. It is thought that, 20 liters of water will be enough for daily drinking water need for one person. Therefore, calculations made accordingly and the result for daily water consumption is 9,159,620 liters for 457,981 people. To eliminate harmful substances and microorganisms inside the seawater, some disinfection methods should be executed. Disinfecting seawater is not an easy or cheap process and it requires drawing off water from sea, since it was thought that, it is impossible to reach any freshwater sources around the city after an earthquake. Drawing off water from the sea will be executed with one or more pumps, changing with the daily clean water production rate.

For disinfecting the seawater, UV, ozone and chlorine disinfection methods were compared with each other to select the optimal and cheapest disinfection method, as well as applicability of the system. UV disinfection system uses UV-C lamps to kill most of the harmful microorganisms inside the water mass. There will not be any chemicals to be used in this method; therefore, it is a "clean" method on chemical usage aspect. Since UV-C beams are extremely harmful for human beings, users of this method should be very careful, because even with the short amount of expose, skin and eyes might be seriously damaged. However, thanks to the UV-C beams, eliminated microorganisms will not come alive after the disinfection process, when the UV dosage is set to an optimal level. With usage of 254 nm wavelength beams, photoreactivation phenomenon will not occur and disinfected water mass will stay as it is. In addition, since there will not be any chemicals using for this method, this process will not harm the environment in the end. When the total costs calculated for UV disinfection method, 482,081.75 USD cost value was founded for 30 days of disinfection of water for 457,981 people in Avcılar.

Another disinfection method mentioned above was ozone disinfection method, which uses ozone gas in order to kill the harmful substances inside the water mass.

Producing ozone gas depends on oxygen, therefore both oxygen and ozone generators should be used for this process, since oxygen level in the air might not provide a rapid disinfection process, as it was expected. Ozone dosage should be set with care because of the fact that exposure of huge amounts of ozone, more than its need, will have toxic effects on human lives. Therefore, this process must be executed with attention. Ozone has many advantageous aspects, since the ozone is environmentally friendly and leaves the water mass after the disinfection ends. Odor and taste that can happen inside the water mass will be eliminated with ozone disinfection method and since it is a continuous method, it has higher chances for a complete disinfection. In addition, ozone prevents flowering and by this property of ozone, it is easier to store disinfected water in a container. Since it is not a chemical method, it is not carcinogenic and it can eliminate 99.9% of the microorganisms inside the water mass. However, it should be taken into consideration that, since ozone gas produced is mainly oxygen, there might be some corrosion inside the water mass that might happen due to the presence of some metals or chlorine based substances. If a proper filtering method is applied to the water inlet of the system, ozone disinfection method will be the first choice for its applicability and cost aspects. Total cost of the ozone disinfection method was calculated as 413,090.43 USD for 30 days of disinfection of water for 457,981 people in Avcılar.

Last seawater disinfection method that was researched was chlorine disinfection method. Chlorine is a chemical substance and it kills unwanted and harmful microorganisms with chemical reactions. Therefore, dosage must be set very carefully in order to prevent humans to get intoxicated. Chlorine disinfection will be done by gas chlorine, as known as pure chlorine and free chlorine should be inside the water mass by specified amounts. By doing this, chlorine will prevent microorganisms to reproduce by themselves. In addition to that, chlorine provides continuous disinfection inside the water mass, since specified amount of free chlorine are present inside the water mass as mentioned before. Another advantage of the chlorine disinfection method is that, since chlorine is using for a long time for different areas, it is easier to find authorized personnel to execute this disinfection process. Chlorine eliminates sulfides and odors that occur because of vegetation. In addition, chlorine is successful about eliminating hydrogen sulfide, ammonia and other nitrogenous substances. However, chlorine must have at least 30 minutes of contact time to execute the disinfection process. In addition to that, disinfection must be executed right before the transportation of the clean water mass, which means it cannot be stored under any circumstances. Seawater must be cleaned from mud before the chlorine disinfection method, since it is not possible to disinfect the water if there is mud inside. Total cost of the chlorine disinfection method was calculated as 947,253.81 USD for 30 days of disinfection of water for 457,981 people in Avcılar.

Reverse osmosis desalination method will be used to get all the salt ions from the seawater. Apart from the water disinfection process, this is an obligatory process as well to make the seawater completely drinkable. Reverse osmosis desalination method requires a continuous and huge amount of pressure and because of that, energy requirement and capital costs of this method is significantly high. Reverse osmosis method needs a semi-permeable membrane, which will have the pore dimension about 5 Angstrom, to hold all the salty ions, some microorganisms and other ions bigger than 5 Angstrom. Membrane will allow water particles to pass while holding other particles mentioned before. That way, water will be desalinated and will be ready to drink, after the disinfection process. Disinfection process must be executed before the desalination process in order to get the maximum efficiency from the water. The reason is, the less particles, ions and microorganisms that the water has, the successful the reverse osmosis method will be. There will be one water inlet and two water outlet to the system and it should be remembered that, the membrane must be placed traverse in order to make the membrane life longer by making the water do all the sweeping work to provide little pores from clogging. First water outlet will be the reject stream, which will lead the non-desalinated water mass out of the system. The second water outlet will carry the desalinated water to the water storage containers for further use. Since there will be a huge pressurized water coming to the system, the reject stream is mandatory to use, not only to carry the non-desalinated water away but also compensate the pressure. Total cost of reverse osmosis method was calculated as 15,010,268.44 USD for 30 days of desalination of water for 457,981 people in Avcılar.

By looking the data and calculations above, ozone disinfection method should be used in order to provide a healthy, environmental friendly and relatively cheap disinfection to the seawater mass to be disinfected. Other methods are viable options as well; however, the aim of the project is to find the most optimal method by looking at many aspects. Apart from the disinfection process, seawater must be cleansed from the salt inside to make the disinfected water drinkable. To provide that, reverse osmosis method should be used. At first glance, energy costs of the reverse osmosis desalination method seems to be massively high. However, desalination of seawater is not an easy or cheap method to execute. Since this is an obligatory process, sweater must face this desalination method as well as the disinfection method. By applying ozone disinfection and reverse osmosis desalination method, clean and drinkable water can be supplied to 457,981 people in Avcılar for 30 days. Total cost of this disinfection and desalination methods calculated as 15,423,358.87 USD, which costs for 56.128 USD per cubic meter of water.

As it was mentioned many times before, many assumptions had to be made in order to create some scenarios and to make some clear calculations based on those scenarios. The assumptions were made because only the government itself and its organs can make this kind of comprehensive research with all the angles covered and only that way the real costs can be found. There are many things that will make the calculations more precise, if they were known for this project.

For solar energy calculations, since the usable area cannot be exactly known, total area for solar panels were assumed. The solar energy cost and energy production calculations can be made more precisely if the area is known. Using more solar panels will decrease the fuel costs by generators and will make the project more environmentally friendly, after an earthquake, when environmental friendliness is needed the most.

Throughout the project, all of the negative possibilities have tried to get into consideration to calculate the worst-case scenario that can happen in the future, when the expected earthquake comes. One of the assumptions was that, 21 December 2022 date was predicated on while doing solar calculations. However, the exact date and time of the earthquake is still unknown and cannot be foreseen with the current technology level of the humanity. It will be too late to start to take precautions when the earthquake is detectable, maybe minutes or seconds before the destructive earthquake hits. Therefore, the calculations can be made more precisely if the exact date and time will be known. Solar panel energy calculations can be more precise as well and depending on that, the fuel costs of the generators will be decreased and the project will become more environmentally friendly.

Like the recommendation above, if the date and time is known, the temperature of the seawater and based on that, saltiness of the seawater can be known more precisely. Therefore, knowing this information will allow researchers to know the system behavior and system costs, since the working conditions of the systems will change completely. This information will directly affect the cost aspect of this project.

As it can be seen on the previous chapters, equipment and fuel costs was calculated according to today's economic situations. The economic situation will change in the future and it is an unknown fact that if it will increase or decrease. The prices will vary because economic factors have a big effect on this project.

Infrastructural damage will cause all the water need due to destruction of asbestos-based pipes, which are currently be using in infrastructure of the city. Earthquake will damage the pipes and right now, there can only be assumptions about how the pipes will react or what percentage of the pipelines will be destroyed after the earthquake. If this value can be known now, the amount of water need after the earthquake happens can be estimated more precisely and total cost will be found precisely based on the knowledge. According to the *Formula 1.5*, water supply will be much less than total usage and leakage under abnormal situations like an earthquake.

All the calculations and assumptions were made according to Istanbul region. Some of the parameters would change if the location changes. To see the differences between Istanbul and other random region, Zonguldak region can be selected to fulfill this operation. Like Istanbul, Zonguldak is a coastal city. Zonguldak is sharing borders with Black Sea and seismologically, North Anatolian Fault Line is considerably close to Zonguldak. The proximity of the location to the North Anatolian Fault Line is still a big threat to Zonguldak. However, mentioned fault line is directly lies under Istanbul but not Zonguldak. Therefore, expecting less destruction in Zonguldak will not be illogical. Of course, earthquake will damage all super and infrastructural elements but when compared with Istanbul, there will be less destruction in Zonguldak. Apart from that, the water was thought to be drawn off from Marmara Sea, which is a small sea when compared to Black Sea. The size difference between those two seas make Marmara Sea to be easily pollutable, since there are many ships that are passing through are dumping their oils and wastes into Marmara Sea. The same application is being applied to Black Sea region but thanks to its size, it cannot be as pollutable as Marmara Sea. However, not only the seismological and size related aspects are important, but also the water quality and water chemistry are important aspects too. Water quality is expected to be higher in Black Sea than Marmara Sea and the disinfection and desalination operations will not be as expensive as Marmara Sea region. Therefore, with less time needed, enough water can be supplied in Zonguldak region.

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