A Biomimetic Approach to Rainwater Harvesting Strategies Through the Use of Buildings

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ABSTRACT

Water is limited and strategic basic life source as well essential factor for the continuation of life. There is no alternative to water in the nature. Access to safe water resources is a common vital requirement for all organisms. In today's world, global warming, pollution, climate change and the rapid increase of the world population have necessitated more water use; the water resources have started to decrease, and the sustainability of those water resources has become a critical issue. After that the humans are faced with the fact that the water resources are limited, they have begun to seek for alternative solutions for the acquisition and preservation of water efficiently. In these quests, the issue of collecting rainwater has begun to be considered as a solution to water-related problems in the buildings. While humans are looking for answers to how to obtain rain water, many plants and animal species use limited water resources with sustainable methods which give tips to humans on potential water resources and modes of use. For this purpose; the study of rainwater harvesting, which has a critical aspect in terms of ensuring the sustainability of water resources, and of the most strategic environmental issues of the century we are in, has been examined. The living creatures those who succeeded in obtaining water by various techniques in the nature were researched. Innovative approaches to rainwater harvesting, one of the most promising alternatives for achieving water in the face of decreasing water resources and increasing demand, have been addressed through biomimicry and constructions in the architecture of the future. The aim of the work in this context is to realize the potential of collecting, storing and reusing rainwater in buildings which are designed with biomimetic approaches in terms of rainwater harvesting methods to contribute to the solution of water related problems in the buildings and to present possible design and manufacturing methods.
Keywords: Rainwater Harvesting, Biomimicry, Water, Architecture, Buildings

INTRODUCTION

Rainwater harvesting; it is an important alternative with the potential to increase the usable domestic water, to protect the underground water and to ensure its sustainability. It is defined as the process of catching, transferring and storing rainwater for future use. Societies that are aware of the importance of preserving and gaining water in primitive periods have developed collecting rainwater technologies and structures to use in agricultural, domestic and public area. Today, the rainwater collecting technique has begun to be regarded as one of the most important modern water resources as a solution to water shortage problems (Traboulsi, 2015).

In Australia; up to 50% of the water required for toilet, laundry, hot water and outdoor irrigation is provided by rainwater harvesting in residential buildings (Eroksuz and Rahman, 2010). A significant percentage of the non-potable water requirement of multi-purpose buildings in New York is also supplied by rainwater harvest (Basinger, Ontalto and Lall, 2010). In Syria, thanks to rainwater collecting, an increase of up to 35 MCM (million cubic meters) is achieved in water acquisition (Mourad and Berndtsson, 2011). Similar studies in Sweden, Brazil and the UK have also shown that rainwater harvesting can lead to high incidence of drinking water savings (Villarreal and Dixon, 2005, Fewkes, 1999).

In the scope of this study, the rainwater collection which has a critical prescription in terms of the sustainability of the water resources which is one of the most strategic environmental subjects of the century have been investigated and also the living creatures that reached the water resources even in limited possibilities in the nature and managed to collect and use water with various techniques were examined. In addition, in the face of reduced water resources and increased demand for water, innovative approaches to rainwater harvesting, one of the most promising alternatives to water acquisition, in biomimicry and architectural futurism through constructions have been addressed. In this context, it is aimed to realize the potential of rainwater collection, storage and reuse of buildings which are designed by biomimetic approaches in terms of rainwater collection methods, which is a contribution to the solution and sustainability of water related problems in buildings and to suggest possible design production methods in this regard. Since the study is a literature study in the general framework, literature research related to the subject has been made and related theses, articles, magazines, books, internet, personal archives have been utilized within the scope of literature studies. Within the scope of the study, traditional rainwater harvesting methods used throughout history and rainwater harvesting methods used in modern structures were examined. On the other hand, the ways in which land-dwelling creatures acquire water have been investigated and potential innovative water collection approaches designed in the context of biomimicry with these relationships have been investigated.

TRADITIONAL WATER HARVESTING METHODS IN BUILT ENVIRONMENTS

Throughout history, traditional rainwater harvesting methods have been used that play a vital role in meeting water needs. These methods have been developed based on the amount of rainfall, the nature of the land, the type of soil, the geology and topography of the regions and have been used to store and preserve water as well as collecting water (Upadhya, 2009). Numerous water collection techniques have been developed and used, from systems based on simpler techniques to systems based on complex industrial techniques. The following are some typical traditional techniques that have been used in various geographies for the collection of rainwater, groundwater and surface waters since the early ages and the human approach to water collection.

Approaches In Water Harvesting Issue Throughout History

Minos civilization, known to have lived in Greece in prehistoric times, developed remarkable technologies to collect and transport water to settlement areas in Cretan and other islands (Mays and friends, 2013). The traces of these technologies are found in many settlements. As a method of collecting rainwater, they have constructed hydraulic structures consisting of channeled stones and transferred the collected water to the cisterns with the aid of these channels. These structures, which are generally made of rectangular sections, were also built on the roofs; rainwater was collected and transported to nearby cisterns thanks to these structures. The technique of transporting water to cisterns with collection systems is still being implemented in the rural areas of the Helen Islands (Yannopoulos and friends, 2016).

As Koutsoyiannis and Patrikiou pointed out, cities in ancient Greece were built in the driest regions. Although the exact cause is unknown, it is thought that dry climate is assumed to be more favorable (protection against cataracts and floods) and healthier (protection from water-related diseases). These cities established in areas under water insufficiency, narrow cisterns, which are known as bottle cisterns, have been widely used, with long, large bottle-shaped rainwater cisterns. Rectangular and circular sectioned storage tanks were found in many public and private buildings in Greece (Yannopoulos and friends, 2016).

During the Roman Empire period, rainwater harvesting became one of the branches of art and science, focusing on various technologies such as channels, aqueducts, and great progress recorded. The Yerebatan cistern, one of the glorious examples of Roman period, is one of the important examples of this construction [URL1].

In the Middle Ages, the Delhi Sultans in India built numerous water reservoirs, stepped wells, canals, tanks and water-related structures to efficiently manage water resources. They also distributed loans and financial assistance to encourage farmers to build their own rainwater harvesting systems and wells. Large and small water tanks were built in many parts of the country [URL1].

Traditional water harvesting techniques

Rooftop water collection. The roof water collection system is mainly for obtaining drinking water. In this system, the rainwater falling into the roofs of houses and other buildings are collected by means of a chain of channels and stored in the suitable tanks. The application is generally used at the level of individual households in areas with high rainfall. This method, shown in Figure 1, has been used in many parts of the world (Technical Document, 2004).

Figure 1. Rooftop water collection technique used in Madhya Pradesh villages (*Technical Document*, 2004)

Stepped Water Well. One well-known example of a rainwater harvesting technique is underground steps in India and Pakistan that function as a large cistern for collecting seasonal monsoon rainwater (Bradshaw, 2008). Stepped water wells, also known by different names such as Baudi, bawdi, bawri, baoli, bavadi and bavdi seen in Figure 2, have been developed to collect rain water. These stepped wells have a unique water collection system. The gigantic open surface of the well behaved like a rainwater pipe that collects water and sends it under the well. These structures are also large structures of high archaeological significance, which have been built since ancient times, especially in honor of kings and queens. Apart from basic necessities, they sometimes served for water sports (Murugesan, 2014).

Figure 2. Stepped water well in Rajasthan, India [URL2]

Tanka/Kund/Kundi. These water storage tanks, known as Tanka, Kund or Kundi, which can be constructed in various places such as squares, houses or outdoor farming areas, are a method of collecting rainwater used to supply drinking water from rain in arid regions. These constructions, which can be constructed in different shapes and sizes with local materials, could be used for both large communities and individual households. In these structures, examples of which are shown in Figure 3, there are entrance holes in the ground to facilitate the entry of rainwater into the tank. During the collection of the rainwater, the sections where the water inlet is located are covered with wire nets so that the garbage does not enter the well. The edges of the well are coated with lime and ash for disinfecting in water. In addition, most structures have a dome-shaped lid to protect water from evaporation and prevent evaporation (Chairman, 2011). With this simple traditional method, in most cases, enough water can be collected and stored throughout the year.

Figure 3. Tanka [URL3]

RAINWATER HARVESTING STRATEGY IN MODERN CONSTRUCTIONS

Typically, rainwater harvesting systems consist of 3 basic elements; which are collection system, transportation system and storage system. Rainwater harvesting is the basis for modern green practices that manage rainwater using an ecological and natural process to create healthy urban environments (Habibullah, 2014). These systems are classified according to factors such as the size and nature of the catchment areas and whether the systems are in the urban or rural environment.

There are successful examples of rainwater collection systems in various countries of the world. At the World Trade Center in New York, rainwater is collected on the roof and used to water the surrounding park and cool it down. This saves 25% of the energy used for building cooling. Rainwater collected at Frankfurt Airport Terminal B is used for washing irrigation and toilet. In Germany, the Marburg Tennis Court is irrigated with rainwater supplied. In the Bommer Automobile Washing Plant in Überlingen, rainwater is used for car washing. Rainwater is used in toilet reservoirs on fourteen floors of a twenty-five-storey Sony Center in Berlin. In the United States, it is known that there are rainwater storage systems in hundreds of thousands of homes. Most of them are made for garden irrigation and plant cultivation and 20% of them are made for drinking water purposes (Tanık, 2016).

THE IMPORTANCE OF WATER FOR LAND LIVING CREATURES AND THE NATURE'S WATER HARVESTING STRATEGIES

Namib Desert Beetle (Stenocara)

The Namibian desert beetle (Stenocara) is a species of insect that lives in the Namib Desert, which is coastal to the Atlantic Ocean in South Africa. Namib Desert is one of the most arid regions of the world; however, The Namibia beetle is able to survive here by meeting the need for water thanks to the intense mist layer on the ocean coast between 60 and 200 days of the year that can go as far as the interior (Brown and Bhushan, 2016).

Figure 4. Namibia desert beetle and water collection principle [URL4]

The Namibian desert beetle drinks by separating water particles that are infrequently found in the system from air and wind. This water collection process can be carried out in the most basic principle thanks to the unique structure of the back. There are mounds and cavities scattered randomly and irregularly on the back of the beetle. These gaps extending between the toppings are covered with a material exhibiting similar properties with wax. The characteristic of this material is its effective transmission by pushing the water. On the other hand, the hills are covered with a material that is water-absorbing (hydrophilic). With this feature, water is collected in the most efficient way. As shown in Figure 4, the insect rises above the hind legs in the fog, turning the head in the direction in which the wind comes, and secures the body at forty-five degrees. Thanks to this posture, the water particles in the system hit the back of the beetle with the effect of the wind and stick to the hydrophilic hills. When the water grains adhered to the overheads reach a self-weight, they begin to slip towards the slopes and reach hydrophilic spaces. Water droplets descending into these cavities are being rolled towards the mouth of the beetle under the influence of hydrophobic structure and gravity so that the insect meets the water that is needed (Kurugöl, 2011).

Moloch Lizard

Moloch horridus, also known as the thorny devil lizard, is a species of lizard that lives in arid regions in Australia and has extraordinary ability to meet its water needs. This type of lizard can cope with thirst by acquiring the water in the air, water deposits and wet sand with superior techniques through its unique structure in arid climates (Brown and Bhushan, 2016). There are many superimposed vessels and capillary channel nets at micro scale in the skin of the Moloch lizard. As a basic principle in the technique of collecting water, the capillary pressure created by these channels is utilized (Comanns and others, 2016).

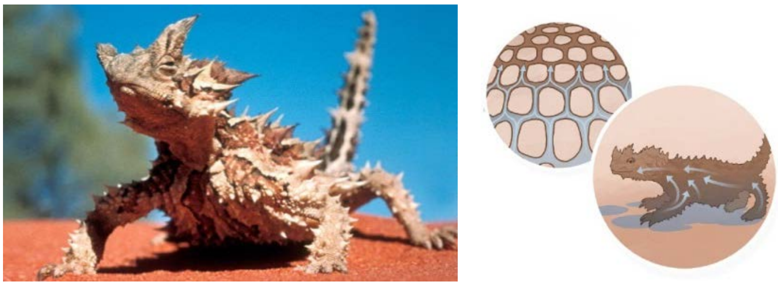

Figure 5. Moloch horridus and water collection principle (Brown and Bhushan, 2016)

This pressure created by the ductwork allows the water to be absorbed from water deposits, air and wet sand, like a sponge (Comanns and others, 2016).

Cactus

Many cactus species live in arid environments and have a very tolerant structure to drought. It is known that one of Opuntia microdasys survival systems of cactus species lies in efficient water harvesting system. The unique system of this cactus line consists of well distributed cone spikes and tricot (feather bulge) clusters in the cactus body. The water accumulates on these small feathers of the microstructure (tricom) and flows towards the spine when the droplets reach a sufficient size. With the help of surface energy and Laplace pressure principles, the water moves to the root of the plant and reaches the cactus (Ju and others, 2012).

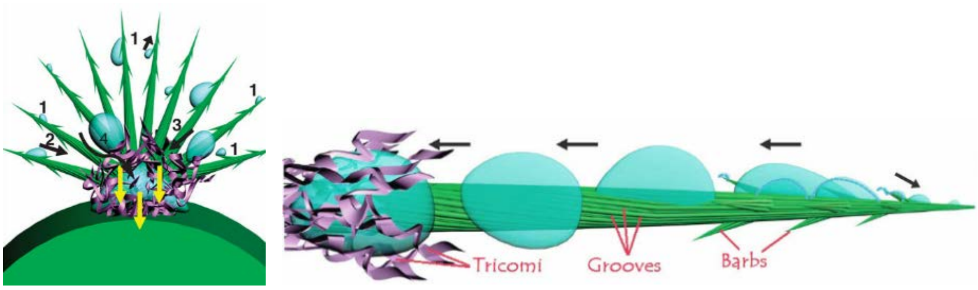

Figure 6. Cactus water collection system (Ju and others, 2012).

Other Living Species

Many plant species living in arid regions have improved structural characteristics that can collect water from the fog or the air. Stipagrostis, a kind of grass grown in the Namibian desert, is one of the plant species that have the ability to collect water from the fog. It was observed for the first time in 1980 that it was collected on the leaves before the water droplets merged and flowed to the root of the plant. The leaves, which have a fine long form, have longitudinal protrusions that pour liquid flow through the roots. Cotula fallax grown in South Africa is another plant species with an airborne water harvesting system. The Cotula plant also catches the damp in the fog with the help of the thin fur on the leaves. When the water droplets on the fur reach adequate weight, they flow towards the root of the plant (Brown and Bhushan, 2016).

INNOVATIVE WATER HARVESTING APPROACHES WITH BIOMIMESIS AND CONSTRUCTIONS

Biomimesis, bioimitation or biomimicry is a new and revolutionary science that analyzes the process of nature and adapts them to human use. Biomimicry credited to literature by Benyus at the end of 1990s; Greek bios: life, mimesis: derived from the words imitate. Biomimicry is the design and production of materials, structures, and systems that are modelled on biological entities and processes (Benyus, 1997). According to Benyus, biomimicry aims to be able to see nature as model, counselor and criterion. This framework is inspired by the systems of the living creatures that collect water in their own way in the below, and the structures designed together with the innovative water harvesting systems are discussed.

Namibia University Hydrological Center Building

The Namibian University Water Science Center building designed was inspired by the water harvesting system of the Namibia beetle by the British architect Matthew Parkes. The Namibian University Water Science Center building designed was inspired by the water harvesting system of the Namibia beetle by the British architect Matthew Parkes. The building is located behind a wall with a high, curved and nylon net surface that faces the ocean and catches the damp in the ocean-breezing air so that the water can be efficiently retained. In this wall of nylon nets, the net surfaces are shaped like the bumpy structure found in the shell of the Namibia bug. The system is combined with the infrastructure of the building and the water caught by this nylon surface is guided and stored in the underground water reservoirs through the channels with the help of gravity (Maglic, 2012).

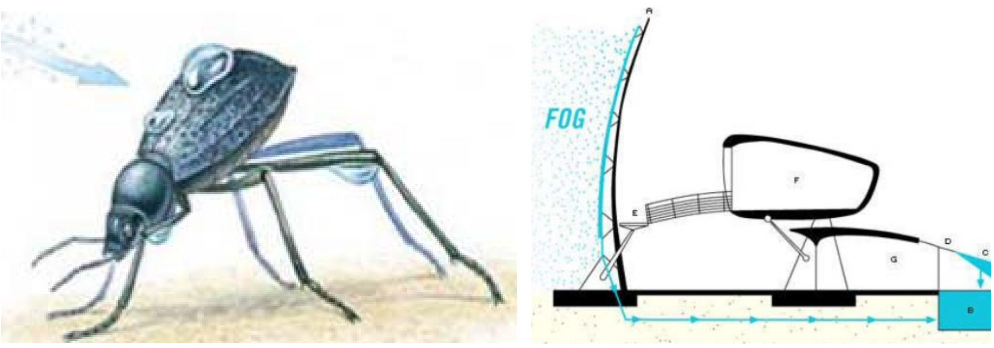

Figure 8. Namibia Bug and Namibia Hydrology Center [URL4-5]

Las Palmas Water Theatre

Las Palmas Water Theatre is proposed as an open-air theater by Grimshaw Architects, inspired by the water collecting system of the Namibian desert bug. In Las Palmas Water Theatre's surface design and positioning, the strategy of the Namibian desert beetle is imitated. The surface covered with a series of vertical evaporation "blinds" is oriented to look at the sea and sea breeze. The moist air that hit the surface with the wind from the harbor was condensed in these blinds and the water obtained as a result of the system was directed to the channels to be stored (Singh and Nayyar, 2015).

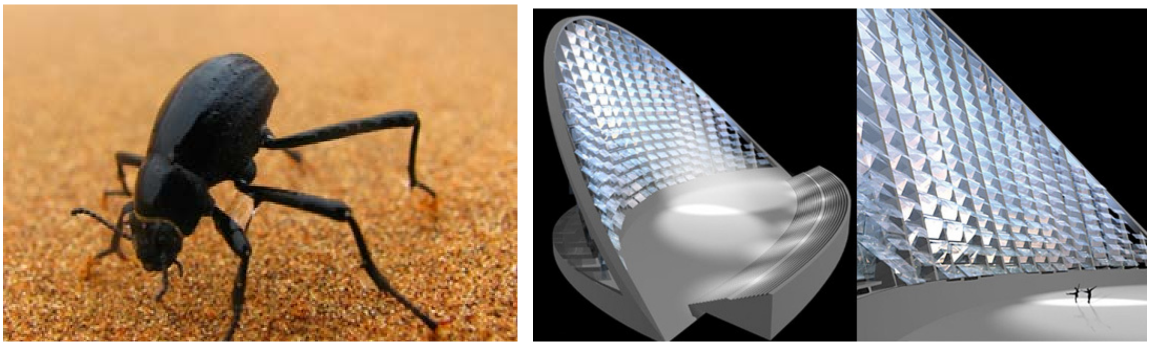

Figure 9. Namibia beetle and Las Palmas Water Theatre [URL4-6]

Warka Tower

The Warka Water Tower was proposed by Arturo Vittori as an alternative water source. This inexpensive and easy-to-install tower is designed with basic elements such as shape and form, without the need for complex engineering and construction requirements (Azzi and Beyrouthy, 2015). The Warka Tower does not require any electrical power or any other energy, but only produces water depending on the natural environment such as gravity, condensation and evaporation. [URL7]

Figure 10. Warka Tower [URL7]

Warka Tower's water harvesting technique and the design of the structure system have been a source of inspiration for many plants and animals that can use water in the air. Namib bugs, lotus flower leaves, spider webs and integrated fog collection system in cactuses; it has been used in Warka Water's plating and material selection. It is inspired by termite hives for the geometry of the user and the shape of the airflow [URL7].

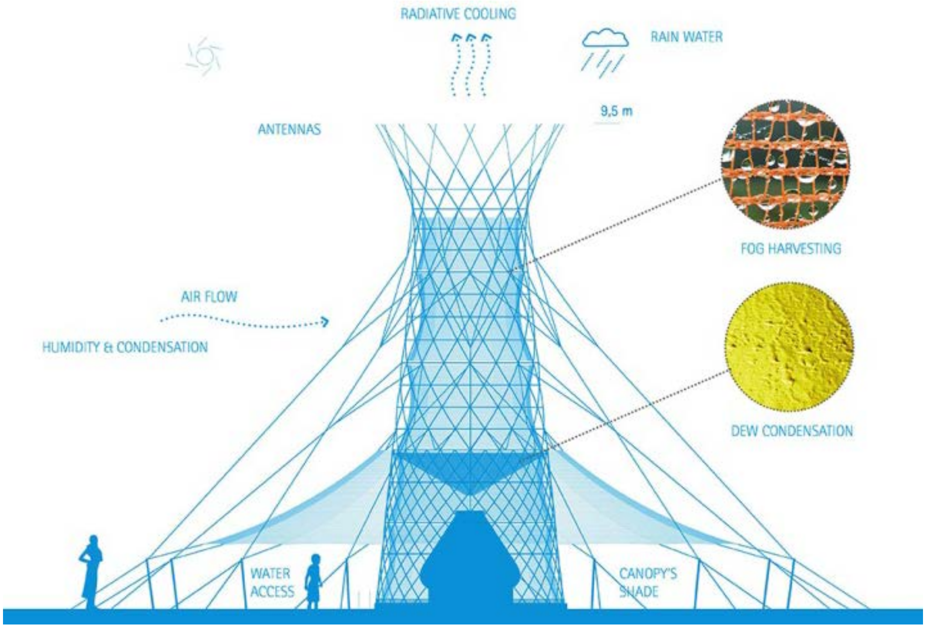

Figure 11. Warka Tower [URL7]

Chaac Ha

Chaac Ha is designed by a group of students in Mexico as a simple water harvesting prototype that can collect water from the air. The design is inspired by the structural features that a Bromeliad-like plant has developed to capture water. It is also inspired by the spider web. The plant, inspired by Chaac Ha, has hydrophilic leaves covered with plumage for water retention. Chaac Ha's membrane surface is designed to mimic the features and form of the leaf surface of the plant to create a fabric surface that attracts damp in the air. In addition to the design of the membrane used, the arrangement of the leaves has also been imitated in Chaac Ha's design. The structural basis of the production is simulated to the characteristic features of the spider web (Omran, 2013). The material and the shape of the water collecting surface is inspired by bromeliad leaves. The membrane and the radial skeleton supporting the central collection tank are inspired by the spider web.

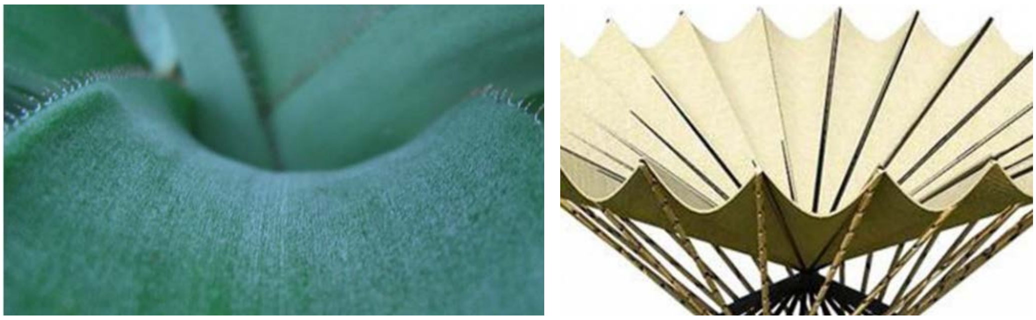

Figure 12. Bromeliad leaf and hydrophilic membrane [URL8]

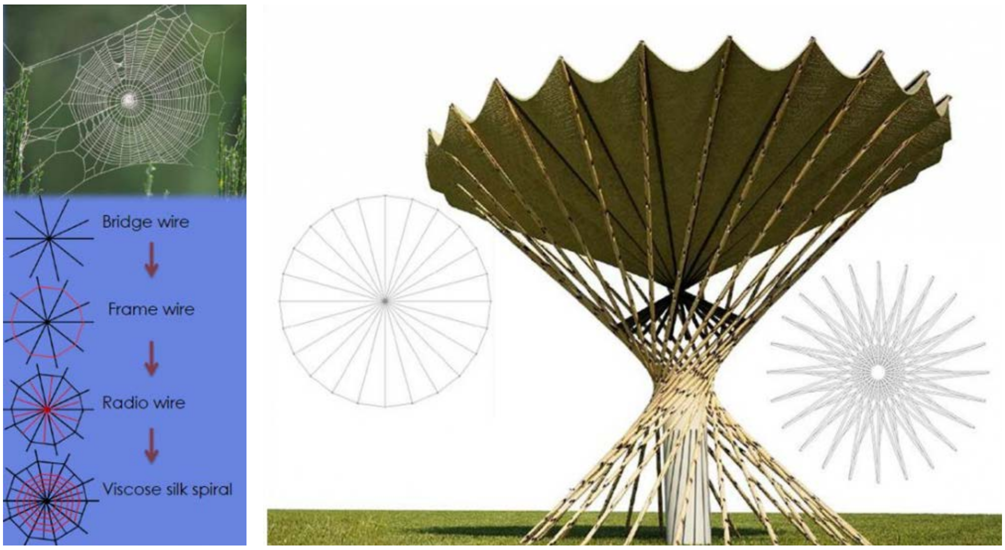

Figure 13. Spider web and Chaac Ha [URL8]

Inhabitat 2020 China

Foreseen in China, the Habitat 2020 building is a future example of a biomimetic architecture that combines high-tech ideas with basic cellular functions to create "living" structures that work like natural organisms. The approach to urban life inspired by nature is seen that city is a dynamic and ever-improving ecosystem. Habitat 2020 has radically altered the traditional surface perception of a building. On the facade of the building; a skin that is alive, breathing, and responsive to the circumstances has been imitated. The facade acts like a membrane that acts as a connection between the exterior and the interior of the building, while the alternatively proposed surface ensures that light, air and water enter the yard. It automatically positions itself and responds to sunlight. The mimicry skin is also designed to absorb water from the air to produce water (Rao, 2014).

Figure 14. Inhabitat 2020 China [URL9]

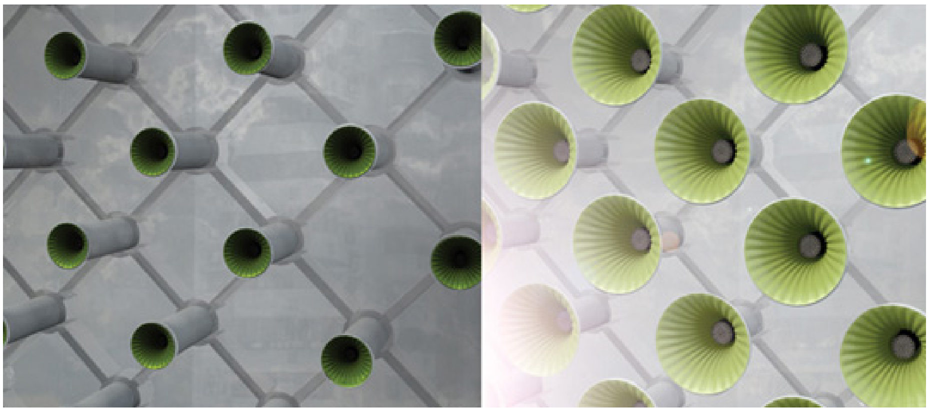

Figure 15. Water collection apparatus on the facade of the Inhabitat 2020 China's [URL9]

EVALUATION AND CONCLUSION

Water has been vital to the survival of the earth's living since the Earth's existence. Although water is a constantly renewable resource within the natural life cycle, water resources are seriously endangered, such as industrialization, environmental pollution, rapid population growth, unconscious use of water resources, improper agricultural practices, distorted urbanization, climate change and global warming. Many countries have begun to become water-poor. For this reason, in the scope of the study, the stories of living things reaching the water, which can fight with thirst even in environments with limited water resources, have been examined. Inspired by the methods of collecting water from these living creatures, it was researched what possible production methods could be designed in cooperation with nature and architecture. As a result of these researches it is predicted that highly productive rainwater harvesting systems can be produced thanks to the developed technologies and designs imitating the water collection techniques in the nature. It is also anticipated that these systems can be integrated into the building design.

The sustainable use of water resources and water conservation require the development and support of technologies for the collection and use of rainwater at the premises. In this respect, an important step will be taken to ensure the sustainability of ecological life, the more efficient use of underground and surface water resources, and the sustainable development of communities. The most likely way of salvation for humankind, which is beginning to feel the effects of lack of water nowadays, will be to develop a renewed water management policy by following the teachings of nature.

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