Sponge Town: Addressing Water Crisis for Future Urban Development in Malaysia

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Abstract According to United Nation, water crisis could affect 5 billion people by 2050 due to climate change, increased demand and polluted supplies. The main issue of the water crisis is rapid increasing of population and rapid urbanization; the water catchment area is decreasing due to deforestation for development. The aim of the project is to address the water crisis for the future development by the propose Sponge Town in every district of Kuala Lumpur which is to create water sensitive and sustainable master plan with storm water collection, rainwater harvesting, and atmospheric water harvesting design. The project proposal has the potential to minimize the water supply from the centralized water treatment plant, minimize the water disruption case in future and minimize the non-revenue water as well as flash flood. The design targets 100% usage of rainwater, storm water and atmospheric water as portable water supply as well as to increase the awareness of water conservation in public.

Keywords Water crisis · Urbanization · Deforestation · Water sustainable plan · Storm water · Atmospheric water

1 Introduction

Water is a basic element in our life, even though it occupied 70% in our earth, but the portable water for consumption is only occupied 2% out of 70% water in the earth; the rest of the water is sea water which cannot be consumed. Out of 2% mentioned above, only 10% is used for household and the rest is for agriculture and industry.

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According to United Nations International Children's Emergency Fund (UNICEF), currently 633 million people who do not have access to clean water (WWF Org. [1]), while the current world population is 7.68 billion (Water shortage could affect 5 billion people by 2050 due to climate change, increased demand and polluted supplies).

Malaysia has 990billion m^3 annual runoff water, while Peninsular Malaysia has 147 billion m^3 out of 990billion m^3 of runoff water. When the runoff water drops on the ground, only 6% of the water soaked into the ground due to the impervious ground surface then become ground water, 57% of water become surface runoff water (also known as storm water) which will be discharge to the river and sea by drainage construction; finally, 37% of water will be evaporated to the atmosphere due to the high temperature (United Nations Org [2]).

Malaysia has suffered two times water crisis during 2008 and 2014, respectively; the water level of reservoir is dropping due to hot and dry climate condition and causes many water disruption cases. According to statistic from Ministry of Energy, Green Technology and Water, Selangor, is considered as the highest water consumption and almost 0% water reserved margin compare to other state.

The current water supply scheme is depending on the centralized water treatment plant. The water is captured from the water catchment area (forest) and stored at dam; it functions as a water supply and flood control; however, the construction of dam and reservoir will cause environmental issues. The centralized water treatment plant has caused many water disruption issues due to the burst pipe, leakage, shutdown of water treatment plant and sudden increasing of water demand. Due to the rapid development, nowadays, the improper planning and design of drainage as well as the impervious surface in the development site have caused many flooding cases. Pipe burst cases have seriously caused 32.6% of non-revenue water, the government targets to reduce non-revenue water to 30% by 2020.

Rapid increasing of population and rapid urbanization, for example Klang Valley, therefore, it caused treatment water supply unable to achieve the water demand. The current population in Klang Valley is 7.7 million people. Due to the rapid urbanization, deforestation is a necessary process to acquire land; therefore, the people start to cut down all the tree for development. In fact, the forest is one of the main sources of water with a large water catchment area, but now only 45% of total land 2008. Climate change, it caused the increasing of rate of water evaporation due to the increasing of temperature in global warming.

2 Literature Review

This paper tried to address water crisis issue which is caused by rapid growth of population, land development and climate change which has caused the water evaporation to the atmosphere. The water resources pollution due to the discharge of untreated domestic or industrial waste into river and uneconomical for treatment of water from river as well as up to 55% of storm water falls in to urban area become surface runoff water.

Usage of storm water in downstream River Basin as a source for treated water supply which is written by Ir. Dr. Hasnul Mohamad Salleh, Director General, Water Supply Department, keTTHA. This journal has provided methodology of storm water management to tackle water crisis issue for the future. Besides that, few case studies that also related to storm water management have been reviewed in this journal, Marina Barrage from Singapore will be taken as case study for addressing the water crisis issue (Salleh HM et al. [3]).

As a conclusion, usage of storm water as a source for portable water has the potential to reduce risk of flooding, as well as huge cost water supply project such as dam and pipeline. Besides that, this method is more economic for storm water treatment compared to river water, and it can create water recreation and tourist attraction point for public as well. However, currently there are no specific guidelines for storm water utilization, and the storm water should be well monitored and control source of pollution to ensure the storm water is of high quality.

Water harvesting from fog using building envelops, the journal has provided the best practice of atmospheric water harvesting method by carried out experimental and analysis. There are three types of fog harvesting systems which are mesh collector system, chemical fog collector and flat fog condenser; experiment with the three types of systems has been carried in South America, Middle East Countries, South Africa and India (Caldas et al. [4]).

There are three systems used for fog harvesting:

(1) Mesh collector system and piping, there are three types of material for the mesh which are polypropylene Rachel mesh, stainless and polymer mesh and three-dimensional net structure mesh made of polymers
(2) Chemical fog collector, this system functions as a device that include chemical absorption and desorption processes. Chemical condensers are more complex and involve the construction of a frame to include all the constituting elements. Water harvesting from air by using kind of chemical compound which is called hygroscopic salt in a hydrogel-derived matrix.
(3) Flat fog condenser, this system is to collect the water from fog by using condensation on cold surfaces during the night.

As the conclusion, the yield of a fog harvesting system is affected by several climatic factors, such as wind direction and speed, relative humidity and temperature. Throughout the experiment, mesh collector system and piping are the most effective compared to other systems which has the potential to collect 3–6 L/sq. m/day. Therefore, fog harvesting integration on building envelop has the potential to solve water issue; however, maintenance requirements and risk of premature failure are important issues to consider when designing fog collectors. This especially applies to the possibility of integrating such components in a façade, where circumscribed malfunctioning can still globally affect the building.

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

This journal has reviewed a few traditional water harvesting methods which are roof top water collection; this method generally use for individual household with high rainfall and Stepped Water Well—large structure, and enough water can be collected and stored throughout the year before proceeding to bio-mimetic approach. Biomimetic study is the imitation of the systems as well as elements of nature to solve the human problems. The journal has covered two building case studies which is to tackle water crisis issue with atmospheric water and rain water harvesting strategies which is analysed from the biological study of Namibia desert beetle, Moloch lizard and Cactus.

Namibia desert beetle is a kind of insect that lives in the Namib Desert, Atlantic Ocean in South Africa, while Namib Desert is considered as serious arid regions in the world. Namibian desert beetle drinks by separating water particles that are infrequently found in the system from air. This water collection process can be carried out by 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. Besides that, the hills are covered with a material that is water absorbing (hydrophilic). With this feature, water is collected in the most efficient way. 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. With 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 gravitational force. There are two building case studies that is influenced by the Namibia Desert beetle which are Namibia University Hydrological Centre Building and Las Palmas Water Theatre (Aslan and Selçuk [5]).

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 lie in efficient water harvesting system. The unique system of this cactus line consists of well-distributed cone spikes and tricot 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 [6]).

The Namibian University Water Science Centre building design 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 [7]).

Las Palmas Water Theatre

Las Palmas Water Theatre is proposed as an open-air theatre 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 harbour was condensed in these blinds and the water obtained as a result of the system was directed to the channels to be stored (Aslan and Selçuk [5]).

Rainwater Use System in Building Design—A Case Study of Calculation and Efficiency Assessment System

This paper was written by Dr. Cheng li Cheng, Associate Professor, Department of Architecture, National Taiwan University of Science and Technology, Taipei, Taiwan. The paper has reviewed the current water crisis issue in Taiwan, more than 2 billion people can't access clean water for drinking. Water shortage is considered as serious issue in Taiwan even though Taiwan is considered as one of the countries that is rich rainy and high humidity. The new construction of huge dam is considered as not environmentally friendly. The incorporation of mini dam into urban design and building design is acceptable throughout the review and discussion with Government and water expert. This paper can assist the Architect and designer with the computer program to simulate the efficiency of rainwater use and help the decision-making when doing the building design (Li-Cheng [8]).

3 Methodology

The review of case studies and interview as the part of methodology, 海绵城市 Sponge Cities from China will be the first case study, the concept was initiated with Zhongshan Shipyard Park by landscape architects, Kongjian Yu. Surface water flooding is currently viewed as the most serious water-related issue in many of the China's large cities due to rapid urbanization, land-use change and the process of rapid socio-economic development. In 2014, the China established the concept of the 'Sponge City'; the concept is not only addressing urban flood risk, but also taking a proactive approach to collection, purification and reuse of urban storm water in Chinese cities to address future climatic extremes (floods and droughts), as well as transform the urban planning process whilst promoting the conservation and creation of greener landscapes in urban areas (Hanley [9]).

While, an interview had been conducted at 12 pm, 9 April 2019, in office, Level 14, School of Engineering and Advance Technology, University Technology Malaysia, Kuala Lumpur. The interview has taken around 1 h. First 12 min is introduction of both parties and master thesis title. The second part was taken 7 min for Questionnaire of Sponge Cities review, and the third part was taken 10 min to review her project, 'Water Resilience Cities/Climate Sensitive Urban Design'. After that, roughly 30 min for tutorial session. The questionnaire is attached with the overview of Sponge Cities, China as well as their design strategies and features.

The questionnaires are as shown below:

(1) Have you ever heard about Sponge City? And what do you think?
(2) What is your opinion regarding the attached case studies?
(3) What is your opinion regarding the feasibilities of application of 'Sponge Town' concept to Malaysia context?
(4) What do you think about rain water, storm water and atmosphere water?
(5) What if these waters to be collected by building and treated for consumption?
(6) What is your suggestion for the solution of water crisis in Master Planning and Architecture for the future?

4 Results and Discussion

Throughout the case studies of 海绵城市 Sponge Cities from China, Sponge City construction guideline, urban context and strategies as well as the design features have been obtained (Fig. 1).

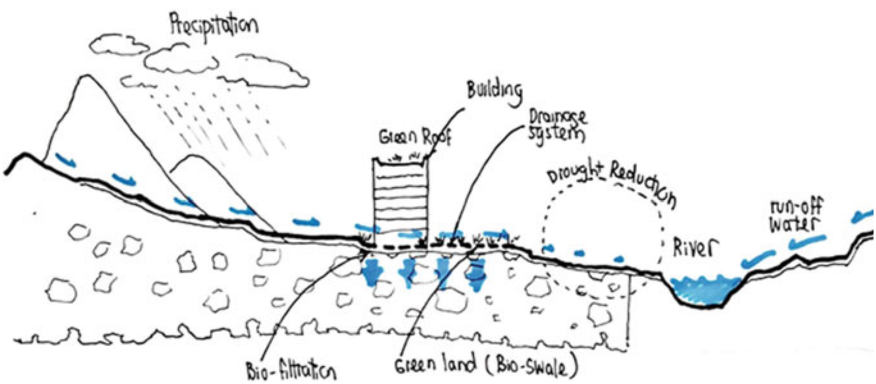

Fig. 1 Sponge city conceptual diagram

Guideline of Sponge City Construction

(1) The guideline to be applied to the new urban development strategies in Chinese cities.
(2) Increase the area of urban land able to absorb surface water discharges by approximately 20%.
(3) Retain or reuse approximately 70% of urban storm water by 2020 and further reuse up to 80% of storm water by 2030s.
(4) Propose the drain runoff up to 1:30 years 24-h rainfall, while the current runoff at 1:1 year rainstorm (187 mm/24 h).
(5) Minimum 1.5 m width for green infrastructure.

Urban Context

The site is in high density area. Downstream area, the mountain functions as the large water catchment area which is considered as upstream are where the upstream water will discharge to the river by gravitational force, therefore, the upstream water flows should be reduced effectively by absorbing major rainfall and reducing runoff. Harvested rainwater should also be used for urban water features and citizens' daily living (Figs. 2 and 3).

There are 30 cities been selected to implement Sponge City concept. While, Chongqing is a pioneer in the development of a solution for the optimization of sewer and storm water networks. Each of the Sponge City area is around 18.7 km^2.

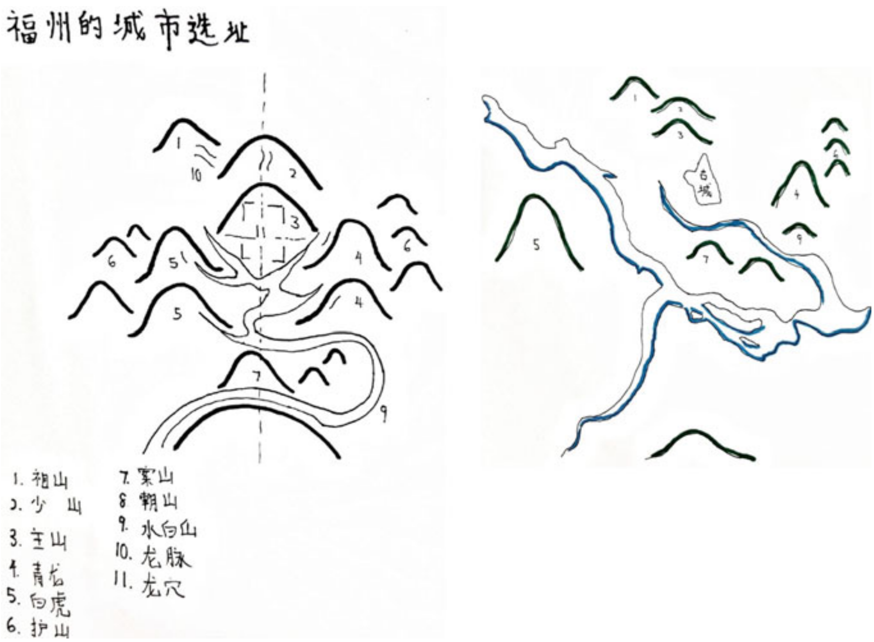

Fig. 2 Urban context of propose Sponge Town

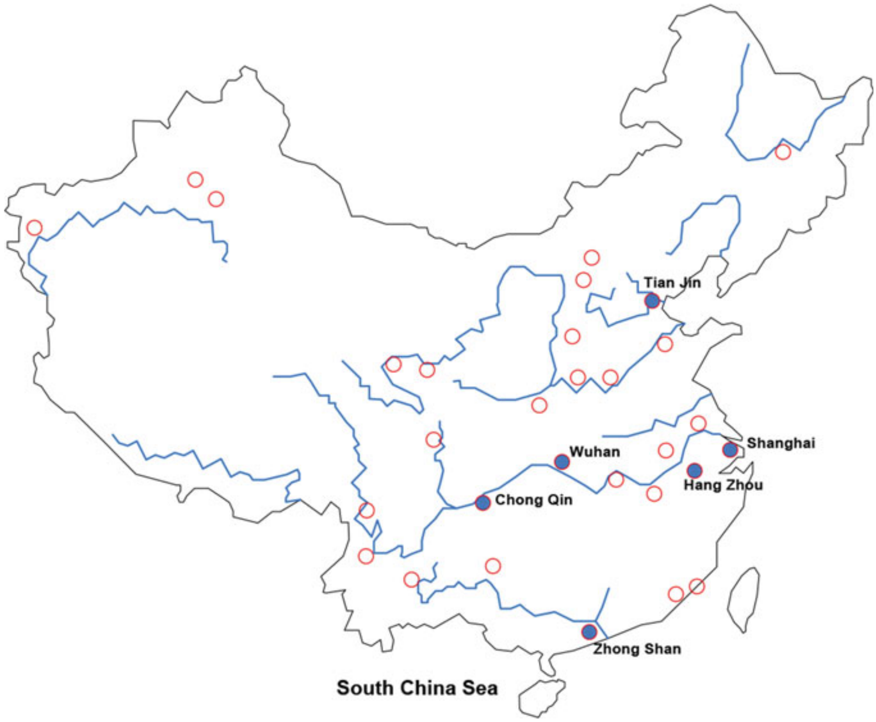

Fig. 3 Proposed locations of Sponge city, China

Design Features

(1) Permeable Pavement
(2) Green Roof
(3) Complex Bio-Detention
(4) Artificial Pond
(5) Artificial Wetland
(6) Rain-Garden
(7) Bio-Swales
(8) Vegetation Buffer.

Sedum lineare, 华文名为佛甲草, it is originating in East Asia. It is considered as an ideal plant for 'greening' of flat-roofed buildings in Shanghai, China, due to factors such as its ability to tolerate cold and drought, little need for soil and its roots' lack of penetrating ability as well as naturally filtration function through its leave.

5 Findings from Interview

The result and findings from the interview with Dr. Wan Nurul Mardiah are shown in Table 1:

Table 1 Interview result and findings

Q	*Answer from questionnaire*	
1	Have you ever heard about Sponge City? And what do you think?	
	Yes. It's a very good concept to be applied to face the climate change and to enhance the resiliency of cities	
2	What is your opinion regarding the attached case studies?	
	It is multifunctional and address the climate issue as well as to create spaces for the public	
3	What is your opinion regarding the feasibilities of application of 'Sponge Town' concept to Malaysia context?	
	Yes, it can be applied, but we need a collaborative effort from different disciplines to provide technical input to propose better design solution	
4	What do you think about rain water, storm water and atmosphere water?	
	It needs to address locally, close-loop system	
5	What if these waters to be collected by building and treated for consumption?	
	This is the ideal solution	
6	What is your suggestion for the solution of water crisis in Master Planning and Architecture for the future?	
	A revision of the current document such as UBBL, Design guideline to incorporate measures to increase water resilience of cities	
Row	*Transcripts for Sponge Town concept*	*Findings*
9–15	"…reducing the dependency to the mega structure, for example, we have all those…" "Water treatment plant, dam and reservoir…" "Yes, all those are very high cost infrastructure, so when we have Sponge Town, sponge concept design in place, we look at the non-conventional practices, and we look into low maintenance, because we let the nature to do its job."	The current water supply scheme and infrastructure are high cost and high maintenance Passive design is highly recommended instead of active design due to environmental issue
23–26	"…within the area, then how it would actually show that amount of rainfall, would be solved within the Sponge Town, so how much, I mean cubic meters water would be able for that area to, I mean hold on the water before been released…"	The methodology of rain water harvesting calculation • Precipitation of location (m) • Catchment area (m^2) • Amount of water harvesting (m^3)
30–34	"…For example, UTM KL, is being discharged to the river, but ideally, we have Sponge Town, we have a Sponge Campus, all the runoff should retain in the campus as well, it should not be running to somewhere else…"	The storm water should be collected instead of flowing to the river
Timeline	*Tutorial session*	*Findings*

(continued)

Table 1 (continued)

10:18	"The calculation of the water surface runoff. Did you do that for your site? It's better if you can do that…"	Permeability Studies Site mapping and land surface analysis studies as methodology • Permeable percentage • Estimate water surface runoff • Guideline of stormwater runoff from keTTHA • Study the topographic analysis of the site to understand the water flow • Study the surface runoff water discharge direction • 800 m of coverage area to do mapping study
10:33	"This is basically reference of how you calculate the water surface runoff. We have the manual; I think you can get from keTTHA in Malaysia…" "I think for you to do the mapping just now, it's the best if you can provide radius, because it will directly give you the estimation of surface runoff water. And then where it discharges the surface runoff water, and just to highlight which is high land and which is low land"	
13.25	"Maybe you can provide the protractor to highlight 800 m which is including school part, residential part, commercial part" after you can start to categorize it into which is permeable surface, which is impermeable surface…."	
18:07		Software for water calculation • ARCGIS & SWMM application
23:30	"If I were you, I will do the whole school (propose on the entire lot 56,995), student hostel, and then all the facilities, because right now, I also part of the…my research also resilience city, when you come to school, it also act as a place for 'pemindahan sementara', for example, there is flash flood, so when you have that school, rehabilitation area, the school need to be flood free area." "For example, the hall should be multi-functional, it can be used for school activities, as well as transit area for the flood victim for example any disaster event. Not only for flood, maybe there is something like happen around, for example this is near the river, so and then you need to provide access for logistic things, and all the… which is all the responses. For example, when there is Water Crisis, the school need to be had some barrier from water coming in, and they can have their own water retention pond inside, and also can be used for recreation area for student as well…" "So, If I were you, I will take the whole lot, and redevelop the whole school."	This project has to potential to upgrade the existing school as well as functions as rehabilitation for victim from flooding School spaces • Student hostel • Multifunctional hall • Transit house • River logistic • Emergency responses
27:22	"MRT Station is ready in place?"	Create the pedestrian pathway to link MRT station, propose site and the metropolitan batu park
27:41	"Yea, clear pedestrian path networking up to the here (the site), and also to the park, so now there is no pedestrian here? (pointing at the site accessibility to metropolitan park)	

(continued)

Table 1 (continued)

28:54	"So, when you talk about your concept here, the building and spaces, spaces within the field, you must have all this… for example, the parking, all parking should be permeable surface, and then when you have the hostel, all hostel shall not only rely on the main water supply, but also can rely on rainwater harvesting, for example used to flushing and irrigate the plant outside, make sure that all your design strategies included all those elements, for example you provide the green roof for the building…"	Water Strategies • Permeable surface design • Bioswale • Green roof
30.18	"…replace the existing surface to something more sustainable…"	
30:40	"…you also need to refer to universal design for rehabilitation school, for example, the ramp, width of the door to allow the ambulance and bed in emergency cases, all those thing…"	Universal design studies for rehabilitation
32:27	"…you have to look into technical, make sure you have all those technical data in your design…"	Explore all the technical data and detail drawing

6 Conclusion

As a conclusion, Water crisis will be getting serious as the rapid increasing population as well as the rapid development and urbanization. Therefore, water crisis should be taking in seriously way, the architectural building design has the potential to solve the water crisis issue for the future development. The solution should not limit to role of architect, but also to the other roles, for example, engineer, water expert, government and public awareness. The water should not be wasted and not letting it discharge to drain, river and sea where the sea water cannot be consumed as portable water.

The water should be collected and harvested, treated for our daily life consumption. The building design has the potential to collect the storm water by master planning with efficient storm water management, rainwater could be harvested by building roof top as well as building skin, besides that, the atmospheric water also has the potential to be harvested by the building envelops. Therefore, the future development and project should be designed to slowdown the flowing of water to the sea and make use of the rainwater, storm water and atmospheric water. Therefore, we suggest that our future building design should be functioned as a large water catchment device, like the forest. 'The best time to plant a tree was 20 years ago. The second-best time is now'—Chinese proverb.

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References

1. WWF Org (2017) World wide fund for nature. Saving Water in the quest to secure the future. Retrieved from http://www.wwf.org.my/media_and_information/media_centre/?uNewsID=24665. Accessed 4 Apr 2019
2. United Nations Org (2017) Department of economics and social affair. Retrieved from https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html. Accessed 20 Mar 2019
3. Salleh HM, Abidin NABZ, Bin MF, Rahman KS (2017) Usage of storm water in downstream river basin as a source for treated water supply 1–13
4. Caldas L, Andaloro A, Calafiore G, Munechika K, Cabrini S (2018) Water harvesting from fog using building envelopes: part I. Water Environ J 32(4):493–499. https://doi.org/10.1111/wej.12335
5. Aslan DK, Selçuk SA (2015) A biomimetic approach to rainwater harvesting strategies through the use of buildings 2(1):27–39
6. Ju J, Bai J, Zheng Y, Zhao T, Fang R, Jiang L (2012) A multi-structural and multi-functional integrated fog collection system in cactus
7. Maglic JM (2014) Biomimicry: using nature as a model for design. The University of Massachusetts Amherst
8. Cheng C-Li (2012) Rainwater use system in building design – A case study of calculation and efficiency assessment system. National Taiwan University of Science and Technology 1–13
9. Hanley S (2017) Shanghai experiments with "sponge city" technology. Retrieved from https://cleantechnica.com/2017/12/29/shanghai-experiments-sponge-city-technology/. Accessed 6 Apr 2019