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Decentralised passive water harvesting

A possible solution for a water paradigm shift in urban areas

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Con una popolazione globale prevista di circa 10 milioni entro il 2050, è necessario un cambio di paradigma nella gestione dell'acqua per evitare instabilità e disastri. L'acqua è un bisogno fondamentale per l'umanità e le tecniche millenarie di raccolta e stoccaggio dell'acqua meteorica potrebbero tornare ad essere una valida alternativa. Questo articolo esamina la raccolta passiva decentralizzata dell'acqua come potenziale soluzione in ambienti urbani. Utilizzando due concetti biomimetici, lo studio illustra il potenziale di un cambiamento di paradigma nell'uso dell'acqua meteorica attraverso un dialogo qualitativo. Comprendere il potenziale di questo nuovo approccio è fondamentale per raggiungere gli SDG e affrontare l'urbanizzazione globale e il cambiamento climatico.

Sistemi decentralizzati di raccolta dell'acqua, Raccolta passiva dell'acqua, Acqua meteorica, Progettazione biomimetica, Urbanizzazione

With approximately ten billion people predicted by 2050, a paradigm shift in global water management is required to prevent instability and growing water-related catastrophes. Water is an essential need for humankind, and the ancient practices of collecting and storing meteoric water may once again be a viable alternative.This article investigates decentralised passive water harvesting as a potential solution in urban settings. Through a qualitative discussion, this paper highlights the opportunities for a paradigm shift in the use of meteoric water using two biomimetic water harvesting concepts. Understanding this new approach's potential is critical to attaining the SDGs and addressing global urbanisation and climate change.

Decentralised Water harvesting Systems, Passive Water Harvesting, Meteoric Water, Biomimetic Design, Urbanisation

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An overview of water collection and the motivations behind it

With a projected global population of almost 10 billion people by 2050 and an increasingly growing global middle class, developing ecologically responsible and scalable solutions becomes critical (IGSsS-G, 2019, pp. 79-83). Water is a vital and essential resource for humans and other living species on Earth, and it is also one of the most threatened. This necessitates a range of water management measures at various levels (Brears, 2020, pp.46). One of the numerous opportunities to alleviate urban stress is the development and implementation of passive and decentralised water collection systems. These solutions may save purified municipal water, avoiding the need of municipal chlorination and fluoridation treatments, and reduce or eliminate the costs of pumping water from higher altitudes. Many water management solutions have advanced significantly in the last two decades [1], but the advancement of water harvesting in urban systems is still relatively immature. Decentralised passive urban water harvesting, which has the ability to ease urban water pressure, is proposed as a novel option to fill this gap. For the purpose of better understanding how design might aid in urban decentralised passive water harvesting systems, this paper conducts a qualitative investigation into the relationships between context, design, and technological innovation with two conceptual case studies.

Decentralised Passive Water Harvesting

Metropolitan water harvesting, or the collecting of meteoric water precipitation (rain, snow, fog, or dew), is one of the integrated water management technologies being promoted in many cities to address stormwater runoff and supply alternate home water supplies [2]. Hybrid systems using meteoric water collecting and centralised water infrastructure are more cost effective, energy efficient, and resilient than updating the centralised water infrastructure (Reitano, 2011, pp. 85). As a result of the rapid adoption of decentralised water structures, hybrid systems are emerging. Blue roofs, green roofs, green walls, sustainable urban drainage systems, and many more types of urban water harvesting are discussed in the literature. While very efficient and generally applied in new urban areas, these systems are not always retrofittable and cannot be used in combination with other water recovery systems unless built-in.

Adoption of decentralised passive water harvesting on a large scale would be a huge step toward achieving sus-

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tainable urban water use. Decentralised passive water collection systems are devices that can be integrated into the building to harvest and/or store meteoric water with little or no assistance from electrical sources. These are alternative environmental solutions that can be integrated with the general domestic and centralised system. This solution is twofold: it alleviates pressure on the centralised water system and empowers the user to manage household water more independently and responsibly. Depending on the quality of the water harvested or the presence of small-scale water treatment systems, the water can be used for different non-potable or potable purposes, including flushing toilets, feeding washing machines, vehicle washing, irrigation systems and so on. To illustrate and clarify this opportunity, this article discusses two case studies in which a biomimetic approach was used to build two different conceptual solutions for two distinct types of water precipitation, fog and rainwater.

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Overview of the Urban Fog Collector System concept. In California, the first author of the study investigated and developed this project under the supervision of Prof. Cristiano Toraldo di Francia (UNICAM) and Prof. Jonathan Reich (CAL POLY)

Urban Fog Collector System (UFCS)

UFCS is a roof-mounted modular fog collection device created specifically for the California coast [fig. 01]. Despite its wealth, California is one of the US states most hit by annual and prolonged drought. This is due to ageing water infrastructure, high per capita water consumption, and climate change. Fog is the most common meteorological phenomenon, especially in the San Francisco area, where up to 112 days of severe fog have been reported per year. According to the literature, classic nets in California can capture between 1 and 10 L/m^2/day, but can reach up to 40 L/m^2/day in some areas (Hiatt et al., 2012; Domen et al., 2014). As such, in places like California, fog collection systems could be used to supplement domestic water supplies.

The net's nodes often prevent water from draining into a tank in classic fog collection systems. This normally requires manual harvesting with sticks. UFCS, being a project designed for urban areas, had to be completely autonomous without human interaction to function properly. For this reason, the UFCS network was completely redesigned using a biomimetic approach [fig. 02]. The bio-inspired mesh is composed of two different weave thicknesses, with the thicker initial section mimicking the Namibian beetle's back, which is composed of a hydrophobic surface covered in smooth, hydrophilic bumps. While the weave's thinnest section has a rounded shape inspired by spider webs. Due to its water-repellent properties, this texture is capable of capturing and drawing even the tiniest drops of moisture towards the wider weave. This maximises water collection while also improves water control by reducing water loss from the collector. Their combined shielding coefficient is 60 percent, which ensures air flow through the net and humidity deposition.

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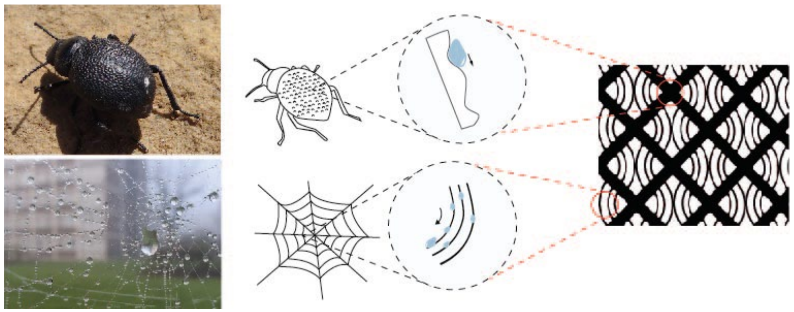
Overview of the Namibian beetle and spider's web's bio-inspiration approach.
The texture of the thick weave combined with the thin hydrophobic weave creates optimal circumstances for fog collection



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Wind is another very important element for collecting fog. Through its funnel-shaped frame, the wind is channelled through the net, allowing humid air to be harvested. The frame is composed of aluminium and is fastened beneath the roof tiles, similar to gutters, for optimal stability and corrosion resistance. As seen in fig. 03, the UFCS structure may be easily installed on a wide variety of california roof types and styles due to its user-friendly structure. When water is collected in the biomimetic net, it falls by gravity and the net's structure until it reaches the gutter. The collected water is routed through pre-installed gutters and must eventually end up in an internal or external storage tank. Additionally, apart from collecting fog, the framework may be rotated 90 degrees to shad the building on sunny California days.
There are a few considerations to take into account when determining the compatibility and applicability of fog collectors like UFCS in urban areas. The first is the type of water collected. Precipitation varies according to geographic location, and in addition to fog, it is possible to gather other meteoric water. The system should be capable of processing different forms of meteoric water. The second is the availability of space. Fog collectors must be connected to a 24-hour water tank. Water consumption and fog precipitation determine tank capacity. In many urban areas, space is limited, and too many collectors can necessitate larger tanks, which can be problematic. The third is the climate. Evaporation may be a concern in warmer locations, and collectors designed to limit evaporation may be more appropriate. In colder areas, freezing may be an issue, making freeze-resistant collectors more appropriate. The fourth is the intended use of the collected water. In some cases, it may be necessary to purify the water for drinking, while in other cases, it may be sufficient to simply use it for irrigation or other non-potable uses (Franconi, 2012).

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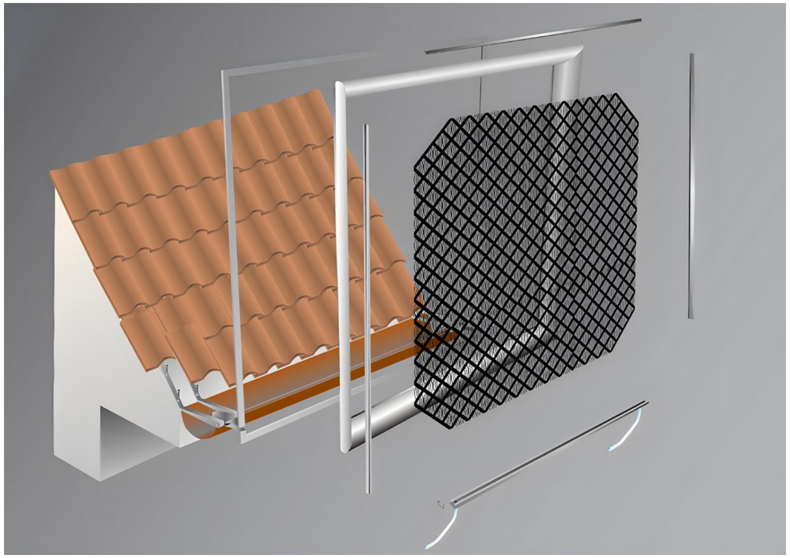
Technical detail of Urban Fog Collector System



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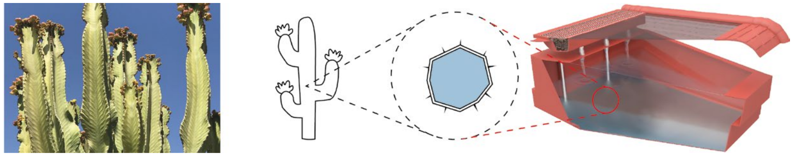
An overview of the Smartegola concept. This project was developed by the first author under the supervision of Prof. Cristiano Toraldo di Francia (Università degli Studi di Camerino)

Smartegola

The second decentralised passive water harvesting device presented in this research is Smartegola [fig. 04]. This product is developed primarily for usage in the Mediterranean region where rainfall is the primary water precipitation. Here, rainfall can vary greatly from year to year. However, according to the World Meteorological Organisation, the average annual rainfall is about 610 l/m^2.
Smartegola is inspired by succulent plants, which can store water within and use it as needed [fig. 05]. Smartegola, meaning "smart tile" in Italian, is intended to replace the conventional Mediterranean roof tiles. The system, which is formed of multiple Smartegolas, can collect all rainwater that falls on the roof, filter it, and distribute the weight of the water evenly over the roof surface. Smartegola's lower part is designed with bumps to slow rainwater flow and increase water collection in the next tile even during heavy rain. When water enters the Smartegola, it is initially filtered using various-thickness sand filters. Following that, once collected, the water is cleaned against hazardous germs and viruses using the sun's UV rays for a minimum of six hours, making the water drink-



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able (SODIS method). This is possible due to the clear top of Smartegola. To maintain the water cleaned the system should be connected directly to the household water supply [fig. 06]. Alternatively, the collected water may be used solely for non-domestic uses.
In addition to passive water collecting, Smartegola has several other important characteristics. Indeed, the upper surface incorporates a clear photovoltaic glass that allows sunlight to pass through similarly to normal glass but also generates electricity called Onyx Solar. According to the company, photovoltaic glass is able to generate between 28 and 34 wp/Sqm. On a sunny day, this equals to between 100 and 120 kWh. Additionally, Smartegola can function as a ventilated roof due to the vents in the upper layer that allow air to flow through the roof space. This helps to keep the space beneath the roof cooler. This

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Overview of the succulent plant's bio-inspiration approach

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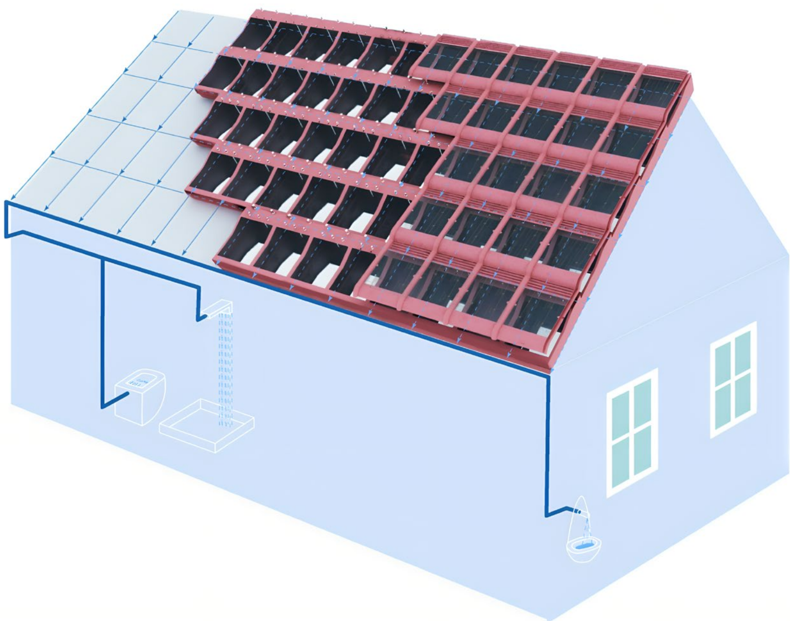
Technical detail of Smartegola system



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can assist to extend the life of the roof and prevent mould formation.
There are a few considerations to take into account when determining the compatibility and applicability of rain collectors like smartegola in urban areas. The first is the rainfall patterns. The amount, intensity, duration, and frequency of rainfall may vary by region or season. This should be analysed to determine whether the installation of this type of technology is cost-effective. The second is suitability of the hosting structure. It's critical to understand if the structure is suitable to support the weight of the system to identify potential structural issues. The third is the climate of the area. The climate is unsuitable for this sort of collectors if temperatures frequently drop below zero and the water freezes.

The design of decentralised passive water harvesting

Water consumption will rise in the future as a result of population expansion, urbanisation, agriculture, and industry. Water scarcity may stem from pollution, climate change, and poor water management [3]. To develop hybrid harvesting systems, further research and development are urgently required. Water is one of our time's most serious challenges, but it is frequently overlooked and underestimated (Kinkade-Levario 2007). Decentralised water collection systems must be multifunctional in order to be viable in the future. As noted in the case studies, both UFCS and Smartegola collect meteoric water in addition to fulfilling other functions such as roof ventilation, solar energy collecting, and home shading. Integration of these systems with other features and technologies may be an effective strategy to gain clients to invest in these products. During the design phase, the long-term cost-effectiveness of implementing these technologies should also be considered. The design can have a significant impact on these characteristics. In essence, designers must consider urban environments, water precipitation, and social elements before deploying decentralised passive water harvesting systems. Because the development and use of these systems may have an impact on city master plans, policies should be harmonised and strengthened to facilitate this transition (Irwin, 2015; Ceschin et al., 2016). Collaboration with local communities and other stakeholders is also essential for achieving a water-based community vision.

Conclusions

There is no single solution to attaining water sustainability, either centralised or decentralised, but rather a range of choices that can meet both human and ecological needs. Water sustainability in cities requires integrated water management, which includes efficiency improvements, alternative water resource utilisation, and hybrid infrastructure development. Passive water harvesting on a decentralised scale, as illustrated by the two concepts examined in this paper, has enormous future potential. However, it is only via widespread adoption of these solutions that true systemic change can be achieved. While traditional water management innovation has increased the efficiency of centralised systems, a new paradigm is necessary in which meteoric water is considered as a crucial water resource throughout the entire water cycle of a city, rather than as a byproduct of other operations. Designers must be able to analyse design requirements in a range of settings in order to produce practical and cost-effective solutions. Product circularity standards should be considered for solutions that not only boost climate change resilience but also benefit the natural system and future economic growth (Badalucco, 2013).

ACKNOWLEDGMENTS

The authors would like to dedicate this paper to the memory of Prof. Cristiano Toraldo di Francia, who always encouraged us to look outside the box and never limited the thinking of others.

NOTES

[1] A well-known example of a fog collector designed to serve rural populations in underdeveloped countries with clean drinking water is Arturo Vittori's WarkaWater.

[2] Many pioneering examples from Asia, such as rainwater harvesting in Singapore, Vietnam, Korea, and China, provide a glimpse of what is possible.

[3] The World Health Organisation estimates that by 2025, half of the world's population will be living in water-stressed areas.

REFERENCES

Kinkade-Levario Heather, *Design for water: rainwater harvesting, stormwater catchment, and alternate water reuse*, New Society Publishers, Gabriola Island, **2007**, pp. 240.

Reitano Raffaella, "Water Harvesting and Water Collection Systems in the Mediterranean Area. The case of Malta", *Procedia Engineering* n. 21, **2011**, pp. 81-88.

Franconi Alessio, "Urban Fog Collect System", *Mappe. Luoghi, percorsi progetti nelle Marche* n. 0, **2012**, pp. 158-161.

Hiatt Cyrus, Fernandez Daniel, Potter Christopher, "Measurements of Fog Water Deposition on the California Central Coast", *Atmospheric and Climate Sciences* 02, n. 04, **2012**, pp. 525.

Badalucco Laura, *Oltre i confini di Leonia. Design, prevenzione dei rifiuti e innovazione*, Milano, Dativo, **2013**, pp. 64.

Domen Jeremy K., William T. Stringfellow, Mary Kay Camarillo, Shelly Gulati, "Fog Water as an Alternative and Sustainable Water Resource", *Clean Technologies and Environmental Policy* 16, n. 2, **2014**, pp. 235-49.

Irwin Terry, "Transition Design: A Proposal for a New Area of Design Practice, Study, and Research", *Design and Culture*, n. 2, **2015**, pp. 229-246.

Ceschin Fabrizio, Idil Gaziulusoy "Evolution of Design for Sustainability: From Product Design to Design for System Innovations and Transitions", *Design Studies* n. 47, **2016**, pp. 118-163.

Brears Robert C., *Developing the Circular Water Economy*, California (USA), Palgrave Pivot, **2019**, pp. 231.

IGSsS-G Independent Group of Scientists appointed by the Secretary-General, *The Future is Now. Science for Achieving Sustainable Development*, **2019**, pp. 216.

Fry Tony, Clive Dilnot, Eduardo Staszowski, *Defuturing: A New Design Philosophy*, London, Bloomsbury Visual Arts, **2020**, pp. 288.