Universidad Continental

FACULTAD DE INGENIERÍA

Escuela Académico Profesional de Ingeniería Ambiental

Tesis

Rainwater harvesting system as a strategy for adaptation on climate change: a review

Heidy Gabriela Ruiz Martínez
Jose Vladimir Cornejo Tueros

Para optar el Título Profesional de
Ingeniero Ambiental

Huancayo, 2022

PUBLICACIÓN - RUIZ MARTINEZ HEIDY GABRIELA

INFORME DE ORIGINALIDAD

37%	34%	30%	24%
INDICE DE SIMILITUD	FUENTES DE INTERNET	PUBLICACIONES	TRABAJOS DEL ESTUDIANTE

FUENTES PRIMARIAS

1	cris.continental.edu.pe Fuente de Internet	5%
2	link.springer.com Fuente de Internet	4%
3	Submitted to Tikrit University Trabajo del estudiante	3%
4	pure.hw.ac.uk Fuente de Internet	1%
5	Submitted to University of Western Sydney Trabajo del estudiante	1%
6	www.frontiersin.org Fuente de Internet	1%
7	Submitted to University of Stellenbosch, South Africa Trabajo del estudiante	1%
8	borneoscience.ums.edu.my Fuente de Internet	1%
9	scholar.sun.ac.za Fuente de Internet	

1 %

10	Tiara Suci Rhamadita, Oki Setyandito, Novandy, Martin Anda. "Study of rainwater harvesting as a water conservation in mall building in South Tangerang", IOP Conference Series: Earth and Environmental Science, 2023 Publicación	1 %
11	Submitted to Wageningen University Trabajo del estudiante	1 %
12	www.ejurnal.poltekkes-tjk.ac.id Fuente de Internet	1 %
13	Kamaleddin Aghaloo, Ayyoob Sharifi. "A GIS-based agroecological model for sustainable agricultural production in arid and semi-arid areas: The case of Kerman Province, Iran", Current Research in Environmental Sustainability, 2023 Publicación	1 %
14	Submitted to University of Birmingham Trabajo del estudiante	1 %
15	spiral.imperial.ac.uk Fuente de Internet	1 %
16	Ana Carolina Rodrigues de Sá Silva, Alex Mendonça Bimbato, José Antônio Perrella Balestieri, Mateus Ricardo Nogueira Vilanova	1 %

et al. "EXPLORING ENVIRONMENTAL, ECONOMIC AND SOCIAL ASPECTS OF RAINWATER HARVESTING SYSTEMS: A REVIEW", Sustainable Cities and Society, 2021
Publicación

---

17 H Mukaromah. "Rainwater Harvesting as an Alternative Water Source in Semarang, Indonesia: The Problems and Benefits", IOP Conference Series: Earth and Environmental Science, 2020 — 1 %
Publicación

---

18 Submitted to Heriot-Watt University — 1 %
Trabajo del estudiante

---

19 discovery.ucl.ac.uk — 1 %
Fuente de Internet

---

20 journals.ut.ac.ir — 1 %
Fuente de Internet

---

21 Gabrielle Nunes da Silva, Letícia Delduque Alves, Isabella Escobar dos Santos, Daniele Maia Bila et al. "An assessment of atmospheric deposition of metals and the physico -chemical parameters of a rainwater harvesting system in Rio de Janeiro Brazil, by means of statistical multivariate analysis", Ambiente e Agua - An Interdisciplinary Journal of Applied Science, 2020 — <1 %
Publicación

22	Jung Eun Kim, Daniel Humphrey, Jan Hofman. "Evaluation of harvesting urban water resources for sustainable water management: Case study in Filton Airfield, UK", Journal of Environmental Management, 2022 Publicación	<1 %
23	Submitted to Queensland University of Technology Trabajo del estudiante	<1 %
24	Submitted to UOW Malaysia KDU University College Sdn. Bhd Trabajo del estudiante	<1 %
25	Submitted to University of Reading Trabajo del estudiante	<1 %
26	ijiset.com Fuente de Internet	<1 %
27	Submitted to Deakin University Trabajo del estudiante	<1 %
28	Submitted to Imperial College of Science, Technology and Medicine Trabajo del estudiante	<1 %
29	samafind.sama.gov.sa Fuente de Internet	<1 %
30	Submitted to Far Eastern University Trabajo del estudiante	<1 %

31	Santosh Nandi, Vinay Gonela. "Rainwater harvesting for domestic use: A systematic review and outlook from the utility policy and management perspectives", Utilities Policy, 2022 Publicación	<1 %
32	assets.researchsquare.com Fuente de Internet	<1 %
33	Thuy Thi Nguyen, Peter M. Bach, Markus Pahlow. "Multi-scale stormwater harvesting to enhance urban resilience to climate change impacts and natural disasters", Blue-Green Systems, 2022 Publicación	<1 %
34	Submitted to University of Sunderland Trabajo del estudiante	<1 %
35	iwaponline.com Fuente de Internet	<1 %
36	jppipa.unram.ac.id Fuente de Internet	<1 %
37	www.fao.org Fuente de Internet	<1 %
38	www.semanticscholar.org Fuente de Internet	<1 %
39	Submitted to University of New South Wales Trabajo del estudiante	<1 %

40	dergipark.org.tr Fuente de Internet	<1%
41	Lucas Niehuns Antunes, Enedir Ghisi, João Carlos Souza. "Stormwater harvested from a permeable pavement for use in the fire extinguishing system and non-potable uses of a building: a case study", Urban Water Journal, 2021 Publicación	<1%
42	Submitted to Nottingham Trent University Trabajo del estudiante	<1%
43	Thaíssa Jucá Jardim Oliveira, Aníbal da Fonseca Santiago, Maria Célia da Silva Lanna, Gislaine Fongaro et al. "Rural blackwater treatment by a full-scale Brazilian Biodigester Septic Tank: microbial indicators and pathogen removal efficiency", Environmental Science and Pollution Research, 2021 Publicación	<1%
44	Submitted to University of Greenwich Trabajo del estudiante	<1%
45	polodelconocimiento.com Fuente de Internet	<1%
46	pdfs.semanticscholar.org Fuente de Internet	<1%

47	Beni Jequicene Mussengue Chaúque, Marilise Brittes Rott. "Solar disinfection (SODIS) technologies as alternative for large-scale public drinking water supply: Advances and challenges", Chemosphere, 2021 Publicación	<1 %
48	ejournal2.undip.ac.id Fuente de Internet	<1 %
49	wasat.irehenvit.com Fuente de Internet	<1 %
50	Karen Bañas, Miguel Enrico Robles, Marla Maniquiz-Redillas. "Stormwater Harvesting from Roof Catchments: A Review of Design, Efficiency, and Sustainability", Water, 2023 Publicación	<1 %
51	C Morales-Figueroa, L A Castillo-Suárez, I Linares-Hernández, V Martínez-Miranda, E A Teutli-Sequeira. "Treatment processes and analysis of rainwater quality for human use and consumption regulations, treatment systems and quality of rainwater", International Journal of Environmental Science and Technology, 2023 Publicación	<1 %
52	Mohammad A. Alim, Ataur Rahman, Zhong Tao, Bijan Samali, Muhammad M. Khan, Shafiq Shirin. "Suitability of roof harvested	<1 %

rainwater for potential potable water production: A scoping review", Journal of Cleaner Production, 2020

Publicación

53	ouci.dntb.gov.ua Fuente de Internet	<1 %
54	Carlos Alfredo Bigurra-Alzati, Ruperto Ortiz-Gómez, Gabriela A. Vázquez-Rodríguez, Luis D. López-León et al. "Water Conservation and Green Infrastructure Adaptations to Reduce Water Scarcity for Residential Areas with Semi-Arid Climate: Mineral de la Reforma, Mexico", Water, 2020 Publicación	<1 %
55	Arianna Cauteruccio, Luca G. Lanza. "Rainwater Harvesting for Urban Landscape Irrigation Using a Soil Water Depletion Algorithm Conditional on Daily Precipitation", Water, 2022 Publicación	<1 %
56	Kaitlin Mattos, Elizabeth King, Cara Lucas, Elizabeth Hodges Snyder, Aaron Dotson, Karl Linden. "Rainwater catchments in rural Alaska have the potential to produce high-quality water and high quantities of water for household use", Journal of Water and Health, 2019 Publicación	<1 %

57	Submitted to University of Hull Trabajo del estudiante	<1 %
58	ojs.southfloridapublishing.com Fuente de Internet	<1 %
59	Iman Saeedi, Ali Reza Mikaeili Tabrizi, Abdolreza Bahremand, Abdolrassoul Salmanmahiny. "A soft systems methodology and interpretive structural modeling framework for Green infrastructure development to control runoff in Tehran metropolis", Natural Resource Modeling, 2022 Publicación	<1 %
60	Samia Richards, Lakshminarayana Rao, Stephanie Connelly, Anjali Raj et al. "Sustainable water resources through harvesting rainwater and the effectiveness of a low-cost water treatment", Journal of Environmental Management, 2021 Publicación	<1 %
61	etda.libraries.psu.edu Fuente de Internet	<1 %
62	ltu.diva-portal.org Fuente de Internet	<1 %
63	theses.hal.science Fuente de Internet	<1 %

64 Iman Saeedi, Mohsen Goodarzi. "Rainwater harvesting system: a sustainable method for landscape development in semiarid regions, the case of Malayer University campus in Iran", Environment, Development and Sustainability, 2018
Publicación
<1 %

65 Agnieszka Stec. "Sustainable Water Management in Buildings", Springer Science and Business Media LLC, 2020
Publicación
<1 %

66 Cristina Morales-Figueroa, Ivonne Linares-Hernández, Verónica Martínez-Miranda, Elia Alejandra Teutli-Sequeira et al. "Electro-galvanic alkalization and treatment of rainwater to obtain drinking water.", Environmental Technology, 2023
Publicación
<1 %

67 Jean Poll Alva-Araujo, María de los Ángeles García-Hernández, Asunción Guadalupe Morales Mendoza, Refugio Rodríguez-Vázquez et al. "Assessment of a Photoreactor with Immobilized Nanoparticle TiO2 Films for the Purification of Rainwater", Environmental and Earth Sciences Research Journal, 2021
Publicación
<1 %

68 Md Abid Hasan, Haseeb Md. Irfanullah. "Exploring the potentials for rainwater use for
<1 %

the urban poor in Bangladesh", Water Policy, 2022
Publicación

Excluir citas	Apagado	Excluir coincidencias	Apagado
Excluir bibliografía	Apagado		

PAPER • **OPEN ACCESS**

Rainwater harvesting system as a strategy for adaptation on climate change: A review

To cite this article: Ruiz Martínez Heidy Gabriela and Cornejo Tueros Jose Vladimir 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1121** 012007

Rainwater harvesting system as a strategy for adaptation on climate change: A review

Ruiz Martínez Heidy Gabriela[1] and Cornejo Tueros Jose Vladimir[1]

1 Universidad Continental, Huancayo, Junín, Perú
E-mail: 73371145 @continental.edu.pe

Abstract. In the face of increasing water scarcity aggravated by climate change, the rainwater harvesting system is a technique that increases the water supply for various purposes. The objective of this research is to analyse the recent literature published on the rainwater collection system, for which the systematic review method was used. The main form of rainwater catchment are roofs, but the material used is important because it can affect the quality of the water. Some physicochemical parameters of rainwater may be within the standards for human consumption, but it is contaminated by pathogenic microorganisms, which represents a risk to public health if it is consumed without prior treatment, so it is mainly used for irrigation and flushing toilets. However, this system has been implemented mainly in rural areas to satisfy their basic needs, including human consumption, because these places do not have access to the central drinking water system. Given this scenario, treatment technologies are being developed that are easy to operate and maintain, such as solar disinfection and filtration for drinking water purposes. This study provides a global overview progress of research related to the rainwater harvesting system.

Keywors: *Harvesting, quality, rainwater, treatment*

1. Introduction

In the last hundred years, the demand for water has increased six times worldwide and has continued to increase by an estimated 1% each year since the 1980s, especially in emerging, middle- and low-income countries, due to various factors such as economic development, population growth and changing consumption patterns [1, 2, 3]. Climate change exacerbates water stress, so that by 2050, more than 570 cities are expected to have 658 million people facing a 10% decrease in freshwater availability and the self-purification capacity of lentic and lotic water bodies will be lost due to the decrease of dissolved oxygen in the water due to the increase in temperature [2].

On the other hand, groundwater has been used in large quantities over the last few decades, especially in agriculture, which has resulted in the long-term depletion of groundwater sources, saline intrusion of coastal aquifers, and water pollution due to the excessive use of pesticides [4, 5]. In addition, severe droughts aggravated by climate change cause water deficits in agriculture, which translates into a risk mainly for the rural population by reducing agricultural yields [4, 6].

A study carried out in 4 countries of Southeast Asia (Cambodia, the Philippines, Indonesia, and Vietnam) showed that the deficiency of sanitary services, including hygiene, were the cause of millions of episodes of illness and premature deaths per year, which demonstrates the need for that the water meets the quality requirements and does not pose a risk to human health [7].

In this scenario, it is necessary to look for other sources of water resources such as seawater desalination or reuse of treated water, but these require high energy consumption that could contribute to an increase in greenhouse gas emissions or, in other cases, the cost is so high that many countries (especially developing countries) cannot access these options. However, there are other alternatives such as rainwater harvesting (RWH) [3], so this work aimed to analyse the worldwide implementation of rainwater harvesting system, the uses of harvested rainwater, its physicochemical and microbiological quality and the treatment technologies being developed.

2. Methodology

The study was based on the systematic review (SR) method, which has developed into a well-known standard for accessing, evaluating, and synthesizing scientific information using the guidelines established by the Collaborative for Environmental Evidence (CEE) [8], which are specific for application to environmental management, and the University of Maryland Research Guide, which establishes the steps for conducting a systematic review [9].

Four international databases were used for the publication selection process: Proquest, Science Direct, Scopus and Springer. The search for articles was performed by using combinations of the keywords shown in Table 1, together with Boolean operators.

Table 1. List of search terms and Boolean operators used to identify scientific articles.

Search team	Boolean Operator	Search term	Year of publication
Rainwater	AND	Advantage	2016 -2021
Rainwater harvesting	OR	Assessment	
Rainwater system		Harnessing	
		Quality	
		Recollection	
		Treatment	
		Use	

3. Studies around the world

The literature reports that rainwater harvesting system has been used for decades but has been gaining more importance due to the increasing global water scarcity and water stress faced by many of the countries. Various factors, such as population growth, urbanization, pollution of water resources, and changes in rainfall regime caused by climate change, aggravate this situation [10, 11, 12, 13, 14 ,15, 16, 17]. Few countries are conducting research on the rainwater harvesting system even though this system is used and known in almost every country in the world. Figure 1 shows the countries that have conducted research around the world and have been included in this study.

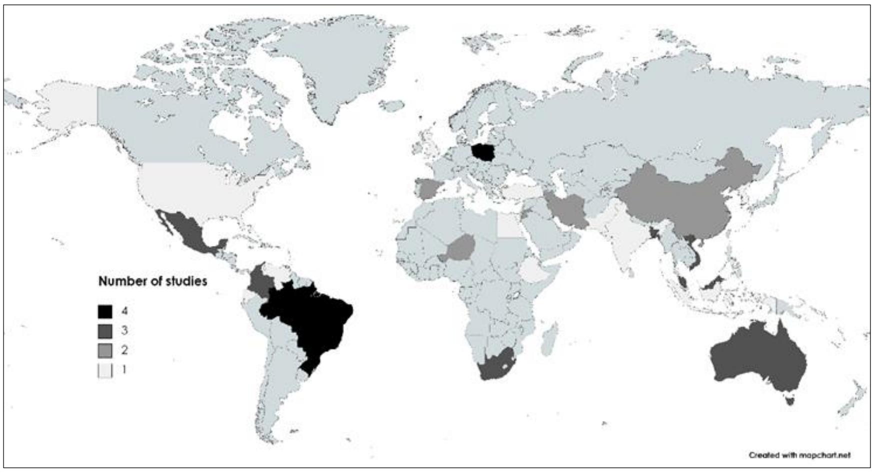

Figure 1. Countries included in the study

Brazil and Poland are the countries with the highest amount of research worldwide. However, 46.2% of the countries conducting research are in the Asian continent, 23.1% in America, 15.4% in Africa, 11.5% in Europe and 3.8% in Oceania. These results can be related to the baseline analysis of water stress carried out by the UN [3], where almost all the countries in South Asia face limitations of water availability between high and extremely high.

4. Rainwater harvesting system

It is defined as a technique to collect and store water in a catchment area in which rain falls as roofs of buildings, which can also include the capture of land runoff [18], followed by a system that transports rainwater to a storage facility, which can be a tank, for later use using simple or complex equipment [12, 19]. It consists of several components, of which the main ones are catchment area, transport system, storage capacity and distribution network [3].

4.1. System reliability

The RWH system can reach a reliability close to 100%, meaning that it can meet the total water demand [13], which depends on the size of the area where rainwater is captured; the amount of annual precipitation, which is why data from multi-year weather stations of each study area are generally used before implementing the collection system [19, 20, 21, 22] and water demand to perform water balance and determine the reliability of a system [15].

During the health emergency caused by COVID-19, it was determined that rainwater could cover between 94.5% and 238.5% of the water demand for disinfection [23]. However, in areas with strong seasonal variations, it may not be possible to cover the demand for water throughout the year. [16, 24].

4.2. Economic viability

There are different results regarding whether the RWH system is economically viable. In some areas of Australia it is not feasible to implement this system with the current price of water [15], while in other places the RWH system is a cheaper source of water compared to national network water, bottled water or other water sources and that its implementation proves to be economically feasible in various scenarios [11, 25] such as in residential buildings by saving potable water [26]; in universities [10, 27, 28, 29]; in schools, where at the same time students are encouraged to become aware of sustainability [30]; in homes and residential buildings [20, 31, 32, 33]. In addition, it reduces greenhouse gas emissions by reducing energy consumption [31].

Within the components for the implementation of the system, the cost of the tank represents more than half [13], even up to 95%, of the total cost [22] and the replacement of materials 50% [15], so [12] recommend including recharge wells to increase groundwater as an economic solution.

4.3. Rainwater harvesting

The most common form of collection is on the surface of the roofs of houses, buildings, universities, schools, hospitals, etc. [34] as can be seen in figure 2, where the uptake in roofs represents 70%. However, attention has been paid to the type of roofing material such as clay tiles, wood, corrugated steel sheets, cement, galvanized iron, concrete, fiber cement, aluminum, asbestos or zinc [16, 22, 35, 36] due to the impact they have on water quality and the runoff coefficient of the material, which affects the amount of water that can be collected. Shaheed R. et al. [37] determined that the highest quality water is collected from a steel roof, followed by an asphalt tile roof, galvanized iron and, finally, a concrete tile roof. Galvanized iron is considered one of the ideal materials to collect rainwater with better quality, since the pollutants can be completely washed off in the first discharge. However, many of these materials are coated with heavy metals such as zinc, lead or aluminum [10, 38, 39] that can be leached with water and even more, if the rain has an acid pH. Tran S. H, et al. [17] concluded that the roofing material for the catchment notably influences the quality of rainwater, where the flat concrete roofs were dirtier than the sloped clay tiles.

Galvanized iron roofs are even considered capable of reducing the number of microorganisms and inhibiting their growth due to the high temperature it can reach under sunlight and ultraviolet light [34, 40, 41] or that cement roofs can favour the pH by increasing its value owing to the alkaline nature of some materials such as concrete and limestone that contain calcium carbonate ($CaCO_3$) and Magnesium carbonate ($MgCO_3$) [19, 40].

Asphalt areas such as roads, parking lots and sidewalks are also evaluated for rainwater catchment, since they are considered impervious surfaces [42]. Awad A. et al. [43] proposed a design for streets and sidewalks that allow the flow of rainwater to be collected through openings on the side of the sidewalks, pass through a layer of gravel and reach reservoirs located under the street. A similar situation is already evident in Poland where rainwater is collected on a diversion road [44] and stored in a system of infiltration reservoirs which act as lagoons, as in the University of Islamabad. where three lakes act as a rainwater catchment system [45].

Green areas and uncovered soil are also part of the assessment of the amount that can be collected by surface runoff [42]. Awad A. et al. [43] evaluate in an agricultural area, the rainwater harvesting potential in a dam located between two gently sloping hills by surface runoff. Green roofs (vegetated roofs) can retain and store rainwater reducing runoff and flood risk [13].

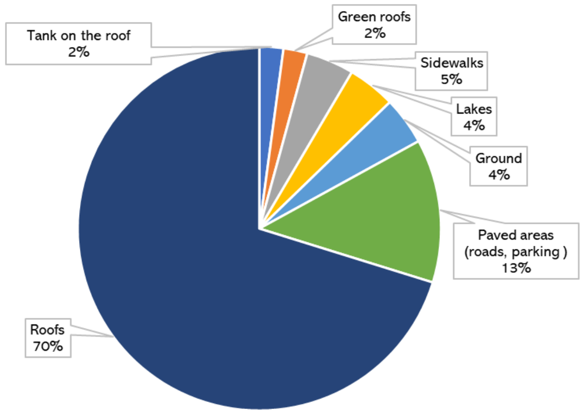

Figure 2. Ways of collecting

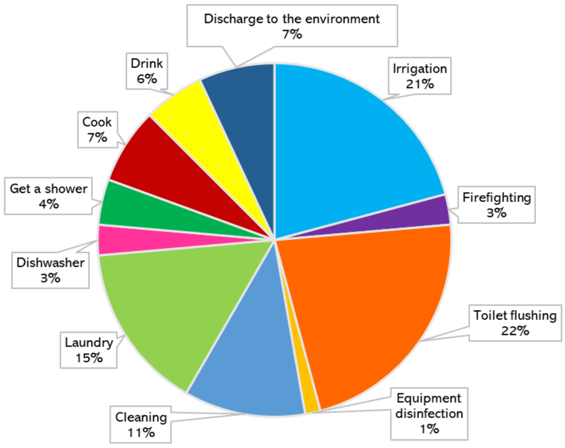

Figure 3. Uses of collected rainwater

5. Uses of rainwater

More than 60% of the investigations carry out studies, whether in terms of quantity, quality, or financial viability, based on rainwater being used as a source of drinking water. However, currently, within the main activities where the collected rainwater is used is for irrigation of plants and toilet flushing, representing 21% and 22%, respectively (See Figure 3). Tariqul Md. Et al. [46] conclude that the collection of rainwater increased the intensity of the crop up to 300%, mainly in vegetables compared to cereals and horticultural crops. On the contrary, Zdeb M. et al. [40] considers that rainwater is not a safe source to irrigate fruit crops or others that are going to be consumed directly due to the presence of bacteria that indicate faecal contamination.

Most research suggests that rainwater be used in household toilet flushing [15, 25, 26], but the collection system can also be implemented of rainwater in schools to reduce to reduce the amount of drinking water consumed (up to 57.97%) in cleaning activities and flushing toilets, and at the same time promoting environmental education using this system as a tool to sensitize students about rational use and aware of drinking water [30].

Washing clothes is one of the activities that consumes a large amount of water, which is why [26, 41, 47], evaluate replacing drinking water with water of rain specifically for this activity. After evaluating the quality of rainwater, the result was obtained that it is suitable to be used directly in washing clothes even up to 30 days after being stored, in addition, it has additional benefits, since having a low hardness reduces the amount of detergent used and prevents limescale build-up in washing machines [41].

In rural areas, mainly in developing countries, harvested rainwater is considered as one of the main sources of drinking water to meet basic needs, such as cooking, drinking, hand washing and showering [34, 35, 36, 48]. By contrast, in urban areas it is used as a complementary source to save drinking water in activities such as flushing toilets, watering, washing clothes, cleaning in general, etc. [26, 49, 50].

6. Physicochemical and microbiological quality of rainwater

To determine the use of collected rainwater, the physicochemical and microbiological parameters are evaluated, which must be within the range of national and international standards. The current trend seeks to compare the values of the parameters that indicate the quality of the collected rainwater with the quality values for irrigation and for human consumption. To this end, treatment technologies are being developed to ensure that rainwater meets quality parameters and is considered a safe source of drinking water.

It is reported that rainwater quality parameter values hang on several factors, such as the number of dry days before precipitation [17, 35, 42, 51, 52], quality of the air and materials of the catchment system [31, 37], but it is one of the alternatives that does not contain high levels of pollutants, so it does not need large treatment units [22, 37, 51]. According to the microbiological quality of rainwater, direct human consumption is not one of the recommended activities unless purifications are carried out [42]. Despite this, some of the physicochemical parameters that are evaluated may be within the standards for water for human consumption [22, 41, 48].

6.1. Physicochemical quality of rainwater

In general, rainwater is considered to have a good physicochemical quality [19, 34]. However, industrial areas can contain organic compounds [19, 34] and inorganic compounds in higher amounts and other pollutants compared to urban areas [37].

It is also reported that when rainwater is analysed before it meets the catchment surface, it has a low concentration of metals, but the first millilitres of precipitation have a high number of pollutants [49]. The main metals that have been found are Ca, K and Na in higher concentrations, which can be suspended in the form of fine particulate material and in the form of aerosols. In addition, Cu, Zn, Fe [49], sulphates [14], and phenols [17], were detected in rainwater that may be related to emissions of the automotive fleet by the combustion process in vehicles [39].

6.2. Microbiological quality of rainwater

Microbiological contamination is the main factor that affects the quality of rainwater, since high values of pathogenic microorganisms are reported [19, 35] which represents a risk for the public health if it is used without prior treatment [34].

Animals' droppings and dust are the main cause of microbiological contamination [17, 34, 39, 48, 53]. The leaves of trees and shrubs that accumulate on the roof can produce organic materials which can provide nutrients to microorganisms [30, 34, 53].

The main microorganisms found in rainwater are faecal coliforms, total coliforms, *Escherichia coli* [16, 34]. *Pseudomonas spp*., [17, 54, 55], *Legionella spp*. considered as a "new or emerging pathogen in drinking water" [53] and *Salmonella spp*. [41]. So, its presence makes it essential to use a disinfection method before use.

7. Treatment technologies applied to rainwater

This section shows the various technologies that are being developed for the treatment of rainwater. Many of these technologies seek to be as simplified as possible, easy to operate and maintain [36], because the rainwater collection system has been implemented mainly in rural areas to meet basic demands, including human consumption [11, 34, 35, 45, 49, 56].

Table 2. Rainwater treatment technologies.

Reference	Country	Type of treatment	Main parameters evaluated	Efficiency obtained	Purpose of use

Teixeira and Ghisi, 2019 [57]	Brazil	Granular filter / Membrane filter	Turbidity, ammonia (NH_3), nitrate (NO_3).	Granular filter: Removal 13% turbidity, 34% NH_3 y 10% NO_3. Membrane filter: 11%, 32.1% y 13.6%	Non-potable uses (flushing toilets, watering gardens and cleaning sidewalks) and direct contact activities (bathing and hand washing)
Du et al., 2022 [58]	China	Gravity-driven membrane bioreactor + electrochemical oxidation disinfection (GDMBR-EO)	Total phosphorus Turbidity, COD, Total number of bacteria	Reduction up to 41.9%, slight increase, 38.9%, complete disinfection of bacteria	-
Quintero et al., 2017 [38]	Colombia	Sand filter + Heterogeneous photocatalysis + Pasteurization	Turbidity, coliforms	Removal: 60%, 100% respectively	Complementary activities except human consumption
Pineda et al., 2021 [36]	Ecuador	Three-stage biofiltration: 1) crushed gravel, 2) ceramic spheres 3) silica sand or natural zeolite + ultraviolet disinfection (UVD)	Fe^{2+}, Mn^{2+}, E. coli, TC, FC	Better efficiency using zeolite, Eliminates even 87%, 82%, 100%, 70%, 100% during the first 90 days.	Rural communities without access to drinking water
Martínez-García et al., 2020 [59]	Spain	V-trough reactor / Compound Parabolic Collector (CPC)	*Escherichia coli, Salmonella enteritidis Enterococcus faecalis* and *Pseudomonas aeruginosa.*	Similar efficiency to eliminate pathogens	Drinking water
Khayan et al., 2019 [39]	Indonesia	Filtration tube with gravel mollusk + Activated carbon	Pb, Turbidity, pH	Reduction up to 94.47%, 72%, increase from 4.2 to 7	It is being used as drinking water in tropical communities.
Shaheed et al., 2017 [37]	Malaysia	Combined activated carbon and sand filtration (CACSF)	BOD_5, TSS, NH_3, *E. coli*	Reduction up to: 59%, 100%, 93%, 100% de *E. coli* in tributaries with less 30 UFC/mL.	High potential for drinking water
Nawaz and Baig, 2018 [45]	Pakistan	SwissPak three-stage portable water filter: silica sand, granulated chlorine and carbon block	Turbidity, TDS, alkalinity, hardness, chloride, nitrate, phosphorus, total coliforms	Removal up to 94%, 37%, 32%, 43%, 34%, 97%, 64%, 100% respectively	Domestic use, drinking water
Fitobór and Quant, 2021 [52]	Poland	Microfiltration	Turbidity	Reduction up to 99% only with adequate pretreatment	Drinking water
McMichael et al., 2021 [55]	South Africa	Electrochemically assisted photocatalytic (EAP)	*Escherichia coli* and *Pseudomonas aeruginosa*	Average logarithmic reduction: 5.5 for *E. coli* and 5,8 for *P. aeruginosa.*	-
Strauss et al., 2016 [54]	South Africa	Solar pasteurization (SOPAS)/ Solar disinfection (SODIS	*Escherichia coli, Legionella, Pseudomonas* spp.	reduction of more than 99% of *E. coli* in both. SODIS: 75.22% *Legionella*, 58.31 *Pseudomonas.* SOPAS: 94.7% *Legionella*, 99.61 *Pseudomonas.*	Irrigation, domestic purposes (cooking, washing clothes)

Köse-Mutlu, 2021 [14]	Turkey	Nanofiltration	Organic matter and sulfates	Elimination of more than 99% for both	Drinking water

Solar disinfection treatments have a high possibility of supplying safe drinking water to populations living in places with high solar irradiance, in addition, it represents a low cost, high performance, long useful life and low maintenance [38, 59], however, caution should be exercised regarding microorganisms that may remain in a viable but non-culturable (VBNC) state if only treated by solar photoinactivation [36, 55] such as *Legionella spp*. and *Acanthamoeba spp*. [53].

Another of the most common treatments carried out is filtration due to its easy conditioning, but it seeks to combine it with other processes to increase the efficiency of pollutant removal and thus increase the quality of the treated water (See Table 2).

Regardless of the treatments that are developed, the use of a first discharge during each rain event that allows the removal of the first millimeters of water before reaching the storage facility represents one of the best ways to eliminate impurities that come from both the atmosphere and accumulation in the catchment areas [11, 17, 19, 22, 25, 26, 31, 35, 49, 50, 51, 52, 55, 57].

8. Conclusions

The rainwater harvesting system has been investigated in areas with severe water limitations such as South Asian countries and is considered an option water supply for non-drinking and drinking purposes. The main form of rainwater catchment are roofs, followed by roads, parking lots and sidewalks that are considered impervious areas. In addition, a special interest should be taken in the type of material that is used for the collection of rainwater, since it can alter its quality.

Mainly in rural areas, the rainwater harvesting system has been implemented and is considered a source of drinking water that seeks to satisfy the demand for water in basic needs, including activities such as direct consumption, for which treatment technologies that are easy to operate are being developed. and maintain as solar disinfection and filtration.

However, worldwide the main activities where rainwater is used are the irrigation of crops and gardens and in the discharge of toilets, although it is also becoming important for the use in washing clothes, since it is an activity domestic that consumes a lot of water.

9. References

[1] UNESCO WWAP (World Water Assessment Programmed). 2019. *The United Nations world water development report 2019: leaving no one behind.* (París: UNESCO).

[2] UNESCO, UN-WATER. 2020. *United Nations World Water Development Report 2020: Water and Climate Change.* (París: UNESCO).

[3] United Nations (UN). 2021. *The United Nations World Water Development Report 2021: Valuing Water.* (París: UNESCO).

[4] FAO and FIDA. 2013. *Collection and storage of rainwater. Technical options for family farming in Latin America and the Caribbean.* (Santiago de Chile: Maval Ltda.).

[5] FAO. 2013. *Cope with water scarcity. A framework for action for agriculture and food security*. (Roma: FAO)

[6] FAO. 2020. *The State of Food and Agriculture 2020. Overcoming challenges related to water in agriculture*. (Roma: FAO)

[7] Mejía A, Castillo O and Vera R. 2016. *Potable water and sanitation in the new rurality of Latin America. water for development*. (Bogotá, Colombia: Panamérica Formas e Impresos)

[8] Collaboration for the environmental evidence. 2013. *Guidelines for Systematic Reviews in Environmental Management. In Version 4.2.*

[9] University of Maryland. 2013. *Steps of a Systematic Review - Systematic Review - Research Guides at University of Maryland Libraries*.

[10] Yan X, Ward S, Butler D and Daly B. 2018. Life cycle analysis and performance assessment of potable water production from harvested rainwater by a decentralized system. *Journal of Cleaner Production* **172** 2167–2173.

[11] Alim M A. et al. 2020. Feasibility analysis of a small-scale rainwater harvesting system for drinking water production at Werrington, New South Wales, Australia. *Journal of Cleaner Production* **270** 122437
[12] Gado T A and El-Agha D E. 2020. Feasibility of rainwater harvesting for sustainable water management in urban areas of Egypt. *Environmental Science and Pollution Research* **27**(26) 32304–32317
[13] López Machado N A. 2020. Use of green roofs for rainwater storage in urban environments. *La Granja* **32**(2) 54–71
[14] Köse-Mutlu B. 2021. Use of nanofiltration technology and process optimization through response surface methodology to remove natural organic matter and sulfates from rainwater. *Water Science and Technology* **83**(3) 580–594
[15] Preeti P and Rahman A. 2021. A Case Study on Water Demand, Economic Analysis and Reliability of Rainwater Harvesting in Australian Capital Cities. *Water* **13**(19) 2606
[16] Rahman Md A, Hashem Md A, Sheikh Md H R and Fazle Bari A S M. 2021. Seasonal variations in the southwestern coastal area of Bangladesh and quality assessment of harvested rainwater. *Environmental Earth Sciences* **80**(8) 325
[17] Tran S H. 2021. Assessment of cost and technical issues of on-site rainwater harvesting and treatment for drinking water supply. *Environmental Science and Pollution Research* **28**(10) 11928–11941
[18] Sustainable Earth Technologies. 2018. What is Rainwater harvesting? Rainwater Harvesting Methods and Techniques.Reference lists.
[19] Al-Batsh N. 2019. Assessment of Rainwater Harvesting Systems in Poor Rural Communities: Yatta Area, Palestine case study. *Water* **11**(3) 585
[20] Santos S M dos and de Farias M M M W E C. 2017. Evaluation of the potential of rainwater harvesting in a dry climate in a semi-arid region in north-eastern Brazil. *Journal of Cleaner Production* **164** 1007–1015
[21] Day J K and Sharma A K. 2020. Stormwater harvesting infrastructure systems design for urban park irrigation: A case study from Brimbank Park, Melbourne. *Journal of Water Supply: Research and Technology-Aqua* **69**(8) 844–857
[22] Anchan S S and Shiva Prasad H C. 2021. Feasibility of roof top rainwater harvesting potential: A case study of South Indian University. *Cleaner Engineering and Technology* **4** 100206
[23] Kanno G G. et al. 2021. Estimation of rainwater harvesting potential for emergency water demand in the era of COVID-19 in Dilla city, southern Ethiopia. *Environmental Challenges* **3** 100077
[24] Junde W, Yanzhao J and Xiaojuan T. 2020. Study on Analysis of Risk for Rainwater Collection and Utilization for Rural Safe Drinking Water Project. *IOP Conference Series: Materials Science and Engineering* **780** 072040
[25] Nnaji C C and Aigbavboa C. 2020. A Scenario-Driven Assessment of the Economic Feasibility of Rainwater Harvesting Using Optimized Storage. *Water Resources Management* **34**(1): 393–408
[26] Kuntz Maykot J and Ghisi E. 2020. Assessment of A Rainwater Harvesting System in A Multi-Storey Residential Building in Brazil. *Water* **12**(2) 546
[27] Saeedi I and Goodarzi M. 2020. Rainwater harvesting system in Malayer University campus, Iran: A sustainable method for landscape development in semi-arid regions. *Environment, Development and Sustainability* **22**(2) 1579–1598
[28] Solórzano-Villareal J O, Gómez-Núñez J and Peñaranda-Osorio C V. 2019. Methodology to estimate the relationship between consumption and rainwater collection in a building at the Metropolitan Autonomous University, Azcapotzalco Unit, Mexico. *Tecnología y ciencias del agua* **10**(6) 178–196
[29] Casas-Matiz E I and Malagón-Micán M L. 2019. Rainwater management on the campus of the University of America. *Gestión y Ambiente* **22**(1) 9–17
[30] El Tugoz J, Flor Bertolini G R and Teresinha Brandalise L. 2017. Capture and use of rainwater: the path to a sustainable school. *Revista de Gestão Ambiental e Sustentabilidade – GeAS* **6** 15

[31] Oviedo-Ocaña E R. et al. 2018. Financial feasibility of end-user designed rainwater harvesting and greywater reuse systems for high water use households. *Environmental Science and Pollution Research* **25**(20) 19200–19216
[32] Valdez M C, Adler I, Barrett M, Ochoa R and Pérez A. 2016. The Water-Energy-Carbon Nexus: Optimizing Rainwater Harvesting in Mexico City *Environmental Processes* **3**(2) 307–323
[33] Al-Qawasmi O. 2021. Feasibility of rainwater harvesting from residential rooftops: Jordan case study. *Applied Water Science* **11**(2) 30
[34] Kim Y, Dao A D, Kim M, Nguyen V A and Han M. 2017. Design and management of rainwater harvesting systems to control water quality for potable purposes: A case study from Cu Khe, Vietnam. *Water Science and Technology: Water Supply* **17**(2) 452–460
[35] Dao D A. et al. 2021. Assessment of rainwater harvesting and maintenance practice for better drinking water quality in rural areas. *Journal of Water Supply: Research and Technology-Aqua* 70(2): 202–216
[36] Pineda E, Guaya D, Rivera G, García-Ruiz M J and Osorio F. 2021. Rainwater treatment for the provision of drinking water to indigenous people in the Ecuadorian Amazon. *International Journal of Environmental Science and Technology*
[37] Shaheed R, Wan Mohtar W H M and El-Shafie A. 2017. Ensuring water security by utilizing lake water and roof-harvested rainwater treated with a low-cost integrated adsorption-filtration system. *Water Science and Engineering* **10**(2) 115–124
[38] Quintero A C, Vargas C A and Sanabria J P. 2017. Evaluation of a heterogeneous photocatalysis and pasteurization system for rainwater disinfection. *Ciencia e Ingeniería Neogranadina* **28**(1) 117–134
[39] Khayan K, Heru Husodo A, Astuti I, Sudarmadji S and Sugandawaty Djohan T. 2019. Health Impacts and Rainwater Treatment: Rainwater as a Source of Drinking Water. *Journal of Environmental and Public Health* 1–10
[40] Zdeb M, Zamorska J, Papciak D and Słyś D. 2020. The Quality of Rainwater Collected from Roofs and the Possibility of Its Economic Use. *Resources* **9**(2) 12
[41] Struk-Sokołowska J. et al. 2020. The Quality of Stored Rainwater for Washing Purposes *Water* **12**(1) 252
[42] Ranaee E, Abbasi A A, Tabatabaee Yazdi J and Ziyaee M. 2021. Feasibility of Rainwater Harvesting and Consumption in a Middle Eastern Semiarid Urban Area. *Water* **13**(15) 2130
[43] Awad A, Al Bajari F and Al Adday F. 2019. Rainwater Harvesting and Reuse in Jordan: A Case Study. *International Journal of Emerging Trends in Engineering Research* **7**(11) 398–402
[44] Zubala T and Patro M. 2021. Spatial and Time Variability in Concentrations of Selected Pollutants in the New Bypass Rainwater Harvesting System. *Water, Air, & Soil Pollution* **232**(5) 211
[45] Nawaz M H and Baig M A. 2018. Domestic three stage water-treatment option for harvested rainwater in water-stressed communities. *IOP Conference Series: Materials Science and Engineering* **414** 012030
[46] Tariqul Islam Md, Mohabbat Ullah Md, Mostofa Amin M G and Hossain S. 2017. Assessment of rainwater harvesting potential for farming system development in a hilly watershed of Bangladesh. *Applied Water Science* **7**(5) 2523–2532
[47] Angrill S. et al. 2017. Environmental performance of rainwater harvesting strategies in Mediterranean buildings. *The International Journal of Life Cycle Assessment* **22**(3) 398–409
[48] Igbinosa I H and Aighewi I T. 2017. Quality assessment and public health status of harvested rainwater in a peri-urban community in Edo State of Nigeria. *Environmental Monitoring and Assessment* **189**(8) 405
[49] Nunes da Silva G. et al. 2020. An assessment of atmospheric deposition of metals and the physicochemical parameters of a rainwater harvesting system by means of statistical multivariate analysis in Rio de Janeiro Brazil. *Ambiente & Água - An Interdisciplinary Journal of Applied Science* **15**(4) 31

[50] Rahmat, S N, Al-Gheethi A A S, Ayob S and Mohd Shahli F. 2020. Development of dual water supply using groundwater systems and rooftop rainwater harvesting. *SN Applied Sciences* **2**(1) 85
[51] Dissanayake J and Han M. 2021. The effect of number of tanks on water quality under sudden contaminant input in rainwater harvesting systems. *Science of The Total Environment* **769** 144553
[52] Fitobór K and Quant B. 2021. Is the Microfiltration Process Suitable as a Method of Removing Suspended Solids from Rainwater? *Resources* **10**(3) 21
[53] Dobrowsky P H, Khan S, Cloete T E and Khan W. 2016. Molecular detection of Acanthamoeba spp., Naegleria fowleri and Vermamoeba (Hartmannella) vermiformis as vectors for Legionella spp. in untreated and solar-pasteurized harvested rainwater. *Parasites & Vectors* **9**(1): 539
[54] Strauss A, Dobrowsky P H, Ndlovu T, Reyneke B and Khan W. 2016. Comparative analysis of solar disinfection versus solar pasteurization for the treatment of harvested rainwater. *BMC Microbiology* **16**(1) 289
[55] McMichael S. et al. 2021. Disinfection of rainwater under solar irradiation by electrochemically assisted photocatalysis. *Applied Catalysis B: Environmental* **281** 119485
[56] Mattos K, King E, Lucas C, Snyder E H, Dotson A and Linden K. 2019. Potential of rainwater catchments to produce high-quality water and high quantities of water for household use: A case study in rural Alaska. *Journal of Water and Health* **17**(5) 788–800
[57] Teixeira C A and Ghisi E. 2019. Comparative Analysis of Membrane and Granular Filters for Rainwater Treatment. *Water* **11**(5) 1004
[58] Du X. et al. 2022. Gravity-driven membrane bioreactor coupled with electrochemical oxidation disinfection (GDMBR-EO) to treat roofing rainwater. *Chemical Engineering Journal* **427** 131714
[59] Martínez-García A. et al. 2020. Assessment of a pilot solar V-trough reactor for solar water disinfection. *Chemical Engineering Journal* **399** 125719