Article **Journal of Urban and Sustainable Development**
December 2023 Vol.9 No.25 12-17

Rainwater harvest, an alternative for water supply for human consumption

Cosecha de agua de lluvia, una alternativa para el abastecimiento de agua para consumo humano

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DOI: 10.35429/JUSD.2023.25.9.12.17 Received: July 30, 2023; Accepted December 30, 2023

Abstract

One of the millennium development goals is to have the world population without sustainable access to safe drinking water and basic sanitation. Another challenge of the millennium also states that every human being has the right to clean water, which implies access to minimum quantity and quality values to meet their basic needs; however, rapid urbanization, industrialization and population growth, have reduced the availability of drinking water. In this sense, several alternatives have been practiced in order to solve this problem. Recent studies have demonstrated the economic, social and environmental benefits of harvesting rainwater in different regions, water harvesting systems provide flexible solutions that can properly meet the needs of existing and future demands. The overall objective of this research was to monitor the quality of water stored in rainwater harvesting systems installed in the state of Zacatecas, Mexico this technology was developed by a group of researchers CA-177 of the Autonomous University of Zacatecas. The determination of cations Na +, K +, Mg2 +, Ca2 + and trace elements was performed by atomic absorption (AA Team ThermoScientific ICE 3300) under the NMX-AA-012-200-SCFI APHA standard. Results indicate that quality of water stored in tanks receiving rainwater meets the Mexican Standard NOM-127-SSA1-1994 and WHO for human consumption. It is concluded that physico-chemical and biological characteristics of harvested water is suitable for all purpose, demonstrating that this technology is inexpensive and represents a sustainable alternative to supply water in marginal areas of Zacatecas and Mexico.

Rainwater, Tank reservoir, Acceptable quality

Resumen

Uno de los retos del milenio es que la constante población en crecimiento tenga un acceso sustentable al agua limpia con una calidad adecuada para consumo. Este reto implica valores de calidad y cantidad para conocer las necesidades básicas; sin embargo, la pronta urbanización, industrialización y crecimiento poblacional han reducido la disponibilidad del agua potable. En este sentido, diversas alternativas se han llevado a la práctica para la solución de este problema. Estudios recientes han demostrado beneficios económicos, sociales y medio ambientales al cosechar el agua de lluvia de diferentes regiones alrededor del planeta. Los sistemas de cosecha de agua de lluvia proporcionan soluciones flexibles que pueden cumplir ampliamente las necesidades de las demandas de agua actuales y futuras. El objetivo general de este trabajo fue monitorear la calidad de agua almacenada en los sistemas de cosecha de agua de lluvia instalados en diferentes puntos de Zacatecas, México, tecnologías que fueron diseñadas por investigadores del CA-UAZ-177 "Uso y conservación de los recursos hídricos", de la Universidad Autónoma de Zacateas "Francisco García Salinas". Se determinaron diversos cationes como: Na +, K +, Mg2 +, Ca2 + y elementos traza mediante la adsorción atómica (AA Team ThermoScientific ICE 3300) regulados por la norma estándar NMX-AA-012-200-SCFI APHA. Los resultados indican que el agua almacenada en estos sistemas cumple con las normas oficiales (nacionales e internacionales) para consumo humano. Se concluye que las características físico-químicas del agua cosechada es adecuada para tal propósito, demostrando que esta tecnología es económicamente factible y representa una alternativa sustentable para el abastecimiento de agua en zonas marginadas de esta región semiárida de México.

Cosecha de agua de lluvia, Región semiárida mexicana, Calidad del agua de cosecha

Citation: GONZÁLEZ-TRINIDAD, Julián, VEYNA-GÓMEZ, Ana Isabel, JÚNEZ-FERREIRA, Hugo Enrique, BAUTISTA-CAPETILLO, Carlos Francisco and ROBLES-ROVELO, Cruz Octavio. Rainwater harvest, an alternative for water supply for human consumption. Journal of Urban and Sustainable Development. 2023. 9-24:12-17.

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Introduction

One of the developing sustainable objectives by UNO, is to reduce the half of population without access to clean water and basic services of disinfection. In this sense, an increase of 3.3 million of low-cost housing is estimated at 2007 to 6.4 million of housing by 2050 without access. Climate change worsen the situation mainly with the rainfall events (increasingly prolonged periods or devastating events) (UNO, 2008).

Since the whole population, by human rights, have right to access to clean water, the previous will imply to supply water in quantity and quality in order to satisfy the basic needs that in the worst case it will be 60 liters/person/day (WHO, 201720). In order to achieve a good service this will imply in good benefits to health worldwide. A highest water consume produces two improvements to the system: the modernization of the integrated system to supply to more population and heath improvements.

In other sense, the rapid urbanization, industrialization, and constant growth population, affects the water availability and water degradation as one of the biggest problems. Against this, government institutions are looking for sustainable alternatives helping to solve this issue. Recent studies have shown benefits in these aspects: economics, social and environmental, at collecting/harvesting water for housing roofs in order to satisfy a low-medium proportion of the water demand in individual vulnerable housing or rural communities (Young, et al. 2010).

Harvesting water systems proportionate flexible solution that could proper satisfy the current and future water demands (Preti, P. and Ataur R. 2021). One of the main advantages of adopting these technologies is the low maintenance costs, accessibility and building easiness in common houses, besides being a sustainable alternative of water supply (Fayez, et al., 2009; Méndez et al., 2011).

Rain water quality remains inside the storage deposit properly designed, operated and maintained, water must be protected against solar radiation and external agents must be avoided to enter to the tank, sediments also must be controlled through filters. These technologies guaranty water supply for vegetable gardens and human consumption (Al-Salaymeh, et al., 2011).

Based on the previous, this research work consisted on measuring the water quality of harvesting water in reservoirs in order to satisfy the water demands in vulnerable family houses and low-income communities in a central-north Mexican arid region. As specific objectives the physical, chemical, biological, metals characterization will be performance to harvesting water in order to compare these parameters with the ones reported by the Mexican Official Norms that regulates these values for use and human consumption.

Materials and methods

Zacatecas state is located in Mexico north, between high mountains and plain terrain, in the coordinate's 100° 43' y 104° 22' west and 25° 7' y 21° 1'north and at 2400 m.a.s.l. At the north Zacatecas is adjacent to Durango and Coahuila and at the east with Nuevo Leon and San Luis Potosi, in the south with Guanajuato, Jalisco and Aguascalientes, meanwhile at the west in next to Nayarit. Zacatecas has 73 103 km2 (INEGI, 2010). It is the number eight of the states in Mexico and represents 3.8% the total country surface (Figure 1).

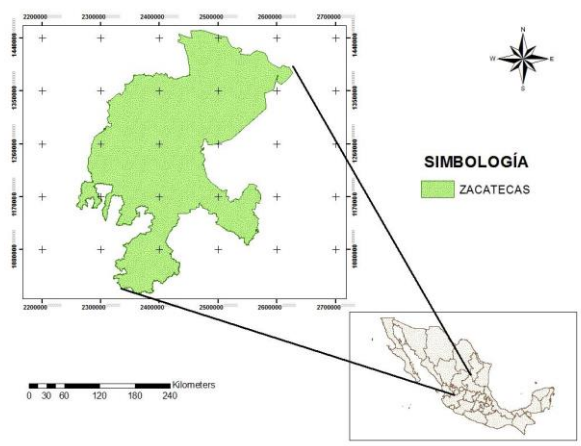

Figure 1 Zacatecas state location

ISSN 2414-4932

The weather is semiarid with a W classification and rains in summer and winter with an annual average of 492 mm and a mean annual temperature of 18°C and 1990 mm mean evaporation (CONAGUA, 2010). Harvest systems have been installed in Zacatecas state mainly in the municipalities of Valparaíso, Monte Escobedo, Guadalupe, Genaro Codina, Pinos, Mazapil, Villanueva, Moyahua, among others, in order to supply drinking water and backyard irrigation (Figure 2).

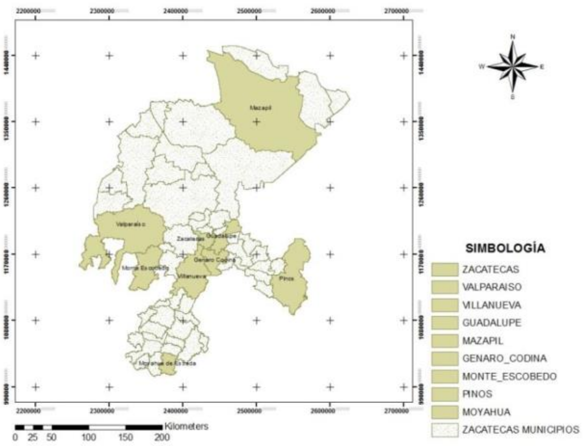

Figure 2 Water harvesting systems location

Water sampling from the storage reservoirs

The illness related with water pollution for human consumption have a great repercussion on human health. Official norms worldwide stablish the maximum standards for each element depending on the country. In Mexico, the current norm NOM-127-SSA1-1994 (DOF, 2022) stablished these limits for water quality.

In order to evaluate the water quality collected in the storage tanks, it is recommended to analyze the following elements Ca2+, Mg 2+, Na+, K+, Fe, SO42-, Cl-(main ions), besides the field measurements of pH, electric conductivity and temperature (Al-Salaymeh et al., 2011). All measurements were performed with specific equipment and work team at the Autonomus University of Zacatecas in the hydro-geochemical laboratory.

The samples were taken according to APHA-SMWW 2006 and the NMX-AA-005-SCFI-2013, the bottles used were washed the day before and left in a cleaning solution for at least 12 hours, then they were rinsed under running water and a second rinse with distilled water was applied (Figure 3).

Figure 3 Water samples

Determination of laboratory parameters

Na+, K+, Mg2+, Ca2+ cations and trace elements were performed by atomic absorption spectrometry, which is based on the amount of energy absorbed by an element atomized in a flame at a characteristic wavelength that is proportional to the element's concentration. in the sample, in a limited range of concentrations, determined in a ThermoScientific ICE AA 3300 Equipment under the NMX-AA-012-SCFI-2001 standard. Chlorides, Cl-, Sulfates and Bicarbonates.

Fecal coliforms, which is determined by a selective and differential enrichment test for the detection of microorganisms from the coliform group in various products and to investigate the presence of E. Coli by fluorescence (Preti, P et al., 2022). The DBC reagent contains the chromogenic substrate of the enzyme 5-bromo-4-chloro-3-indolyl-B-D-Galactopyranoside (X-GAL) for the detection of β-galactosidase (an enzyme indicative of the coliform group). In the hydrolysis of β-Dgalactosidase. X-GAL releases a chromogenic compound (indigo-blue) that turns the medium from light yellow to a blue-green color. It also contains the fluorogenic substrate of the enzyme 4-methyl-umbelliferyl-b-d-glucuronide (MUG) for the detection of β-glucuronidase (a specific enzyme for E. Coli). On β-glucuronidase hydrolysis, MUG releases 4-methylumbelliferone which fluoresces when exposed to ultraviolet light. Fluorescence distinguishes the presence of E. coli from the coliform group.

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Heavy Metals: The Thermo ICE 3300 Spectrometer is an efficient atomic absorption device engineered for elemental analysis of major, minor and toxic elements. This ergonomic design features improved software, an integrated oven vision system, an improved burner design, and an extensive self-optimization procedure.

Results

Geographical information systems

The locations of the water samples present a large variability in rainfall: 200 mm per year in the north region, 450 mm per year in the central region and 800 mm per year in the south (CONAGUA, 2010). Figure 4 shows the potential points where sample water were taken.

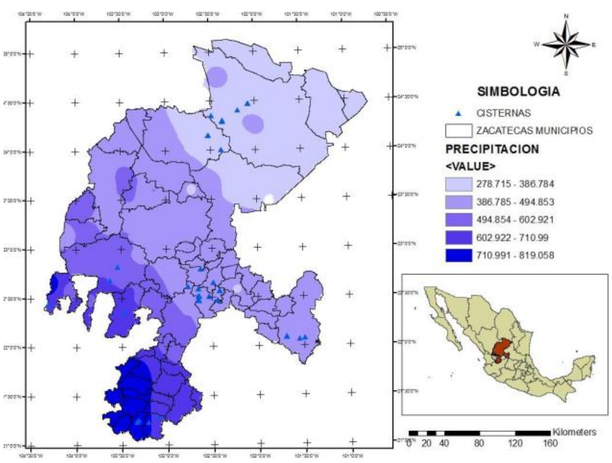

Figure 4 Spatial rainfall patterns in Zacatecas state

Results of water quality shows that the water could widely be used for human consumption with an acceptable value excepting for some pH values that were larger in some specific regions as it is shown in Figure 5.

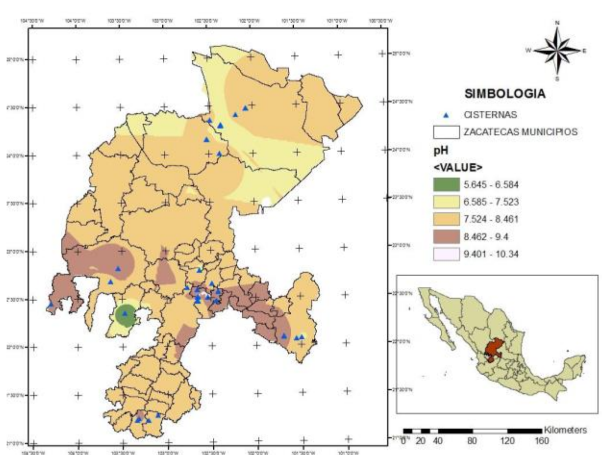

Figure 5 pH values spatial variation in storage tanks

Electric conductivity values in rainwater were between 12 y 312 μs/cm (Figure 6), concluding that the different materials in the roof affects the conductivity, there values were compared with the reported by Farreny et al., 2011; Mendez et al., 2011 and Gikas, et. al., 2012 and Baby et al. 2019 with similar values to the ones of this research.

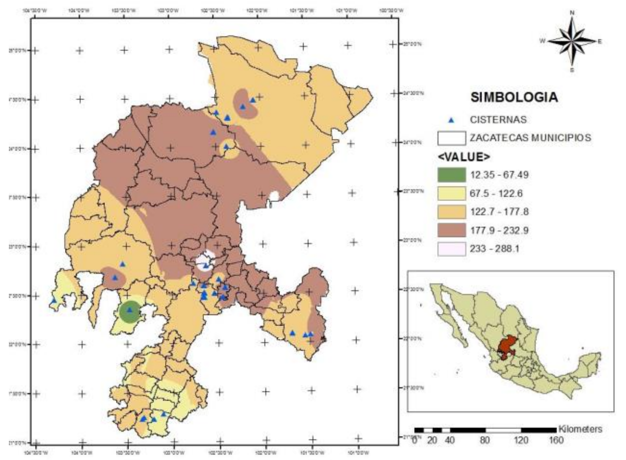

Figure 6 Electric conductivity spatial variability

The nitrates analysis shows concentrations between 0.6 – 5.4 mg/l which are acceptable according to the norm NOM-127-SSA1-1994 (DOF, 2022) and OMS with a maximum value of 10 mg/l, obtaining in this research a mean value of 2.6 mg/l, these could be probably due the organic sediments form animals in the regions that were similar to Young Lee et. al., (2012) in south corea.

Values of 2.8 and 2.4 mg/l have been found for metal and concrete roofs, respectively. In other sense, Al-Salaymeh et al., (2011) reports values between 1.5-7.0 mg/l according to values measured in Palestina in previous research works. Abaynew et al. (2022) and Mendez et al., (2011) indicate that the nitrates concentration of the first season rain is significantly larger than in previous rains, they reported that nitrates come from organic sediments in the capitation area. Gikas et al. (2012), also found similar results previously discussed. In this research, the animals stay too close to the tanks where the water was measured justifying the presence of nitrates (Figure 7).

ISSN 2414-4932

Figure 7 Storage tank type

High iron concentrations were found (0.0491 mg/l) with high values were obtained when iron sheets in roof were installed or also because of the high concentrations in concrete, none of the results indicate upper values compared with the maximum stablished in the norm NOM-127-SSA1-1994 (DOF, 2022).

Mean lead concentration was 0.0043 mg/l, just the 15 % showed presence of lead in low quantities. Zinc was found in a rank of (0.0024 – 0.7054 mg/l) with a mean value of 0.0914 mg/l with acceptable values according to the norm. The 51% of the samples indicate the presence of this metal. Mendez et al. (2011) showed that in iron roofs is common also found zinc. Physical, chemical and biological characterization in laboratory. The physical, chemical and biological parameters were analyzed in the reservoirs showed in Figure 4 and the results are shown in Table 1 and the results were compared with two official norms.

Parameter	Rank	Average	NOM-127-SSA1-1994 (2000)	WHO (2020)
Color (Pt-Co)	1 - 95	28.208	20	20
Cloudiness (UTN)	0 -15	3.15	5	5
Total Solids suspended (mg/l)	0 - 25	3.7	500	500
Alcalinity (mg/l)	9 - 253	97.98	-	250
Total hardness (mg/l)	10 - 210	100.72	500	500
Chloride(mg/l)	2.75 – 16.79	8.43	250	250
Nitrate (mg/l)	0.6 - 5.4	2.6	10	10
Sulphate (mg/l)	0 - 69	8.93	400	250
Total coliform	absence - presence	74 % presence	absence	absence
E-coli	absence - presence	58% presence	absence	absence

Table 1 Water comparison between standards of NOM-127 (2000) and WHO (2020)

Acknowledgments

This research received no external funding. Financiamiento.

Conclusions

The reservoir tanks built in the Zacatecas state are a sustainable alternative in order to storage high quality water and according to the precipitation data these could satisfy the water demand that lives in this arid region.

The tanks capacity is up to the collection area of each house, the rainfall and the water demand. These parameters could vary in volume of water, making necessary the simulation and the variables analysis will determinate the water supply during the year.

Water variables measured were suitable and recommended for human consumption, nevertheless the biological variables require much more careful and analysis. Chlorinating the water in the filtering phase could be a suitable alternative without compromise the quality avoiding illness such as typhoid and cholera.

The water color overpass the maximum values reported in NOM-127-SSA1-1994 that generally is due the organic matter, this problem could be solved by filtering the water.
The metals concentration of Fe, Pb y Zn were obtained as low, not representing a risk for health in humans.

Physical, chemical and biological variables measured in water tanks shows the same rank that in geomembranes, showing that these technologies implemented by the academic group CA-177 from the Autonomus University of Zacatecas is a low-cost alternative that could be implemented in low-cost housing.

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ISSN 2414-4932