Innovation in Water Distribution and Recirculation Systems in a Sustainable Social Housing Model[*]

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ABSTRACT

Currently, there is a high systematic inequality regarding access to water, both between and within countries. In some, there is a wasteful picture and others show high water stress. This research developed an innovative response with the design of water supply, distribution, and recirculation systems (WSDR) in a sustainable social housing model (SSH) proposed by the researchers, based on a technological assessment which considers principles of spatial, environmental and economic efficiency in aqueduct cost and public service production for builders, user comfort, resource use optimization and its supply sources. In order to achieve this, the water resource of Bogota was diagnosed and technological options for saving water in new residential buildings were proposed; their viability was evaluated and their dimensions were estimated. Among the results, it was possible to project the saving of 110.03L/day or 40 % consumption of each residential unit (UH) proposed in the SSH model and 522,200L/month in the tasks of washing and irrigation of common areas; This would result in water savings of 2,210,000 m^3/month in the urban expansion area of Bogota, equivalent to 1,361.54 Ha.

Keywords: accessibility to water resources; water saving; sustainable construction; water recirculation systems; appropriate technologies; social housing**.**

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Innovación en los sistemas de abastecimiento, distribución y recirculación de agua en un modelo de Vivienda de Interés Social Sostenible

RESUMEN

En la actualidad, existe una alta inequidad sistemática de acceso al agua entre y dentro de los países, en algunos, existe un panorama de desperdicio y otros presentan alto estrés hídrico. Esta investigación desarrolló una respuesta innovadora en un diseño de los sistemas de abastecimiento, distribución y recirculación de agua (SADRA) en un modelo de vivienda de interés social sostenible (VISS) propuesto por los investigadores, a partir de la evaluación tecnológica (ET) teniendo en cuenta principios de eficiencia espacial, ambiental y económica en el costo del servicio público de acueducto y de producción para los constructores, confort del usuario, optimización del uso del recurso y sus fuentes de abastecimiento. Para lograrlo, se diagnosticó la disponibilidad del recurso hídrico pluvial de Bogotá; se plantearon las opciones tecnológicas para el ahorro de agua en edificaciones residenciales nuevas; se evaluó su viabilidad y se estimaron sus dimensiones. Dentro de lo obtenido, se logró proyectar el ahorro de 110,03L/día o el 40 % del consumo de cada unidad habitacional (UH) propuesta en el modelo de VISS y de 522.200L/mes en las labores de lavado y riego de zonas comunes; se encontró que, de implementar este modelo en la construcción de vivienda, se llegaría a un ahorro de agua de 2.210.000 m^3/mes en el área de expansión urbana de Bogotá equivalente a 1361.54 Ha.

Palabras clave: accesibilidad al recurso hídrico, ahorro de agua, construcción sostenible, sistemas de recirculación de agua, tecnologías apropiadas, vivienda de interés social.

INTRODUCTION

Along with the growth of human settlements, came the need to develop increasingly specialized systems for transporting, distributing and purifying water (aqueducts ranging back to 7,000 years ago in Jericho, water purification taking place in Scotland and Paris [1]). Parallel to these technological developments that have followed the advancement of civilizations, an environmental crisis has emerged due to the excessive human consumption of water resource, which exceeds the burden capacity of ecosystems.

In consequence, technological changes have been categorized in different paradigms: from the economy-focused standpoint where the exploitation of resources depended on the needs of economic growth, up to those paradigms related to environmental management, such as border frontier economy, deep ecology, eco-development and sustainable development [2]. The latter, on one hand, due to the absence of use value of the water resource in the total economic value, which contributes to the fact that countries such as United States, Canada, Belgium, Turkey and Mexico will get to an elevated level of water consumption of 1,207, 884, 883, 747 and 704 m^3/habitant/year, respectively [3], and high levels of urban waste: Montreal 33 % and Mexico City 44 % [4]. Colombia has aqueduct losses between 25 to 30 % [5] and Bogota has a waste of 6.0 m^3/s, projected to 10.2 m^3/s for 2025 [6].

Such losses confirm the need of a Technological Assessment (TA) of WSDR in terms of their efficiency, considering the substitution of *in situ* water at a level of home units (HU). Therefore, the contribution of this article in regards to the innovation of WSDR in social welfare homes (SWH), although considers economic adjustments in construction costs as well as the social behavior of water care derived from environmental awareness, it corresponds to the technical contribution in the implementation of technologies geared towards sustainable management in buildings.

During the TA, there was also consideration for inequality in water resource access, given that although 2,200 million people do not have access to drinking water [7] they do not present a high level of water related stress (Colombia is highly vulnerable given that 80 % of urban settlements draw their supply from only one water source with low regulation [8]), the remaining population has high variability in their individual mental model and often their consumption habits are irrational and complex to regulate. Because of such reasons, this research sought through efficient WSDR technological proposals to overcome such cultural complexity and to contribute to Sustainable Development Goal (SDG) 6, in the availability (supply), quality, and access to water [9].

In the TA, there was, likewise, an evaluation of the increase of housing need (in Colombia there is a deficit of 5.6 % [10]), which is tackled in Colombia through SWH, which correspond to low income homes [11]. SWH are coupled to horizontal property dynamics, with an increase in HU which generally measure 35-50 m^2 [12]. Applying saving measures is important, given that the inefficient use of water also depends on current building designs (constructed environment is responsible for 20 % of world drinking water use [13]), because of this reason, sustainable construction defined the TA in this study, given that it is a response implemented in large cities such as Bogota, which seek for efficient water use and the reduction of negative environmental impacts [14], since it relates with the pillars of the triple base line, namely, lifecycle analysis and cost analysis, balance of needs [15], and Sustainable Development Goals (SDG), specifically SDG 11 and SDG 12.

Currently, between the different water saving techniques used in residential buildings, there is an acknowledged use of devices or saving accessories, home monitoring, rainwater reuse and water reuse [16], most of which have been used in rural areas, given the availability of space and low investment needed. The trend in water saving in large cities such as Bogota, is the reuse of washing machine water for various activities (67 % surveyed) [17], which is a low efficiency labor, given there is little time available for this and reduces comfort by adding more tasks to home management.

Given the above, the SSWH model, along with the new WSDR design for water saving, proposes offering the user in the building the capacity of using drinking water for pertinent activities and generating less production cost for the constructor. This is done through the use of water saving technologies which are directly integrated to the building, which cause a greater benefit since it allows people to achieve a lower payment for their public service bills. This model was proposed with 30 residential buildings measuring 262.34 m^2 and 5 floors each, 4 HU per floor measuring 51.11 m^2 and 60.06 m^2, obtaining a residential unit of 600 HU, in addition to 1,433 m^2 distributed between offices, commercial shops, event meeting halls, and common areas (OCEA).

1. MATERIALS AND METHODS

This Project was developed under the concept of applied research, where the generation of knowledge with direct application to society was sought. The methodological development comprised four stages:

Stage 1. Diagnostics

A bibliographical review was conducted in relationship to water resource, and it was done under RAS guidelines [18] in order to answer questions described in Table 1.

Table 1. Water related questions for the diagnosis stage of WSDR design

Question	Description	Purpose
What types of water are acknowledged?	Types of water within the national normative	Recognizing the pertinence of appropriate energies
Does water safety exist?	Quantity of water available, aqueduct service coverage	Pertinence of types of technology
What is it used for?	Activities that require the resource at home, in percentages	Specific quantities of water saving

Source: own elaboration.

Stage 2. Proposals for technology options

After obtaining the resource's description, water re-circulation technology options were analyzed, as well as the use of devices for saving and reusing rainwater. The principles considered for this purpose were the following: saving, optimal use conditions, easy to implement at home and simplicity for their maintenance.

Stage 3. Feasibility of technologies

Technologies found to be categorized in the section above were assessed for the TA to develop socially desirable and useful technical applications, being water saving and efficient use the object of analysis. Secondary information sources and experts (architects) in a focus group with experience in technology design for housing were consulted. The evaluation of alternative supply sources was systematized according to their feasibility through the use of a matrix, considering the following: the concept (development of the technological idea), technologic capacity (applicability of technology and its availability), political-social motivation (capacity of the population for implementing this technology) and the level of water saving.

Stage 4. Technology design and test within a digital model

For this design, three fundamental aspects were considered:

Identification of supply sources

During the TA, the premise of replacing a fraction of aqueduct sourced water for *in situ* water sources was established to replace the use of drinking water in HU and common areas. Bogota precipitation conditions were identified through the use of IDEAM and FOPAE data [19], such information was input into the software ArcGis®, in order to produce the model of isohyets and to locate the SSWH model in function of available rainwater sufficiency quantity.

Artifacts or technologic devices

Regarding technological designs for used water re-circulation, activities that generate used waters at home were identified, as well as the quantities used *per capita* for the design in each HU and per apartment tower. Table 2 shows considered aspects:

Table 2. Design parameters of technological devices for wastewater recirculation

Device	Distribution network	Treatment system	Tank	Electric pump
Design parameters	• Water quantity for recirculation • Building information modeling (BIM): distribution, length of pipelines. • Optimal network (pipeline) location proposal.	• Type of treatment and device. • Properties of the treatment system. • Filtering time. • Dimensions.	• Location. • Dimensions.	• Flow rate. • Power. • Evaluation of the brand. • Power source.

Source: own elaboration.

In *SCRR*- system for collecting rainwater in roofs, there was consideration for the average annual precipitation of Bogota D.C., the area of collection of each tower of apartments and OCEA for using in washing and cleaning of common areas (Table 3):

Table 3. Design parameters of technological artifacts in the SCRR

Device	Roof	Tank	Interceptor
Design parameters	• Captation dimensions. • Materials. • Runoff. • Capacity.	• Dimensions and capacity. • Tank location.	• Amount of water for the device. • Operation.

Source: own elaboration.

Supply and distribution network design

The placement of the appropriate proposed technologies was simulated, considering national regulations, and through Building Information Modeling (BIM) of the amounts of pipelines and accessories of WSDR technologies inside ArchiCAD® software. Emphasis was made in not affecting the construction structure nor available space for the user; design was made for a HU, in order to be replicated in 600 HU in the SSWH model (see introduction). There was consideration for the activity and the quality of water necessary in order to conduct it correctly with water reuse and this way, avoiding lack of supply in homes.

2. RESULTS

In correspondence to methodological stages, the following was developed:

Stage 1. Diagnostics

Considering the guidelines presented by national regulations [20-23], officially defined types of water in Colombia are the following (Table 4):

Table 4. Water resource types

Water Types	Definition
Raw Water	Superficial or underground water in natural state; has not been subjected to any treatment process.
Rain Water	Precipitation rainfall water
Drinking Water	Water which, given it gathers organoleptic, physical chemical and microbiological requirements established in Decree 1575 of 2007 or the current one, it may be consumed by humans with no adverse health effects.
Domestic residual water	Liquid wasted from domestic activity in homes, building or institutions.
Water with excretions	Liquid wastes generated in the toilet
Used Waters	Waste Waters from the sink, bathtub, shower, dishwasher and other artifacts that do not discharge fecal matters.

Source: Modified RAS [18].

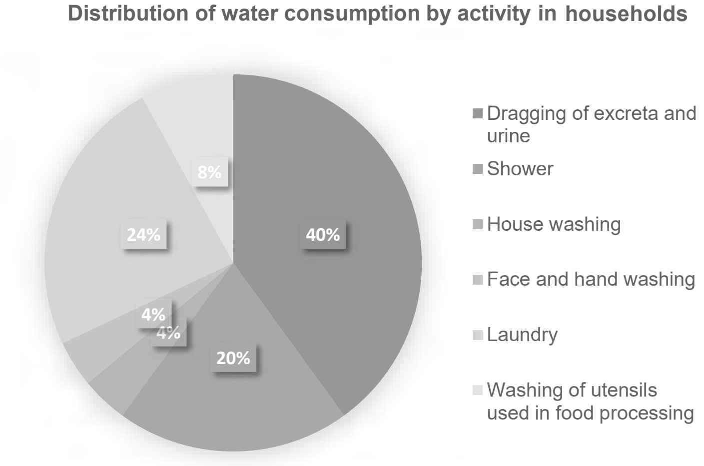
Regarding water availability, Bogota insures an aqueduct coverage of 99.5 % of its populations through different reservoir systems [23]: 75 % of its water is sourced from Chingaza System; 22 % from the Tibitoc System and 3 % remaining from Tunjuelo river basin [24]. Despite such coverage and streams, the effects of climate change in water security are clear, and in in turn, there is an estimation for an increase in water consumption of 37.6 % from 2015 to 2035; Bogota currently consumes 223.2 million m^3/s in 2020 [25], the greatest portion consumed in residential areas (71 %).

This study, focused in the residential water consumption of SWH, which cost can be subsidized by the populations belonging to socio economic levels 2 and 3, possesses a per capita drinking water use of 21.8 m^3/year and 25.1 m^3/year, respectively [25]. The latter was considered as a point of reference for this study.

The distribution of water resource in households is depicted in Figure 1:

According to Figure 1, 40 % of water in households is used in toilets, activity, which given it does not require drinking water, represents a waste in the quality of water supplied by Bogota’s aqueduct company Empresa de Acueducto y Alcantarillado de Bogotá (EAAB), situation which is present in all supply systems of conventional households which have only one supply source given these do not have separate pipelines according to use pertinence.

Figure 1. Distribution of water consumption by activity



Source: Modified from Blanco *et al.* [26].

Stage 2. Technology options

Three options were proposed in order to reduce water consumption at homes in which the aqueduct is the only source of supply. These options were based on the following: implementation from its design, easy to use and maintain for families (not specialized), low environmental impact, alternative water sources and their applicability. Options were:

Reuse of used waters

Allows for the reuse of slightly contaminated residual waters under safe sanitary conditions according regulations, for the reuse of this resource [27] in domestic activities that do not require the use of drinking water; the choice was made to carry out physical treatments to it in order not to incur in high costs during the process. It was established that the re-circulation of used waters in HU (not using the water used for washing kitchen utensils, given its high grease content and food remnants, which would increase costs [27]), this water is redirected for use directly in toilets for disposing of urine and excretions [26].

System for collecting rain water in roofs (SCRR)

SCRR was taken into consideration given the wide areas available in roofs in the SSWH (30 apartment towers). The alternative consisted in a typical SSWH design model, through storage in containers located in each apartment towers and OCEA, being an alternate source of supply for irrigation and cleaning common areas.

More effective technologic devices

There was also consideration for using more effective technologic devices inside households in order to reduce water consumption. Specifically, toilets with systems that use less water in their discharge, currently from 6 to 3L.

Stage 3. Feasibility of technologies

The TA process was carried out with the alternatives proposed in stage 2, with the criteria shown in the section of materials and methods, as can be observed in Table 5:

Table 5. Assessment of water resource technological alternatives

Elements	Concept	Technological Capacity	Political-social motivation	Level of savings (%)
Wastewater reuse	X	X	X	40
Rooftop rainwater harvesting system (SCRR)	X	X	X	20
Technological devices for improved efficiency	X	-	-	10

Source: own elaboration.

The table above shows the best alternatives for water consumption reduction. These are the following: reuse of served waters and the system for collecting rainwater in roofs (SCRR) in the development of a SSWH.

Stage 4. Design

The dimensions expressed below seek to illustrate the diversification of WSDR, reason for which it is worth to clarify that these quantities, although being representative, are variable in regard to the design of each building; what this study seeks to guide the constructor, architect or engineer with is to replicate simple treatments and avoid overcosts.

Re-circulation of used waters

Devices are broken down and depicted in dimensions for this case study below:

Distribution network: hydraulic pipelines

Proposed from the building's design to avoid manual processes, which aims for the comfort of the housing user. To establish the dimensions of pipelines, participation percentages of activities that generate useful used waters were considered for the re-circulation system (see Table 6).

Table 6. Activities that generate wastewater in the household and their share in total consumption

Activity	Consumption supplied by the system				Consumption supplied by the system
	Laundry - washing machine	Shower	Washing of the house	Face and hand washing	Dragging of urine and excrement
Percentage of total load (%)	24	20	4	4	40
TOTAL	52				40

Source: Adapted from [26].

Calculations for establishing dimensions in the system are displayed in Table 7.

Table 7. Regular water consumption, feed water and water supplied by the WSDR recirculation system

Consumption		System power consumption				Consumption supplied by the system
Type of consumption	Total	Laundry - washing machine	Shower	Washing of the house	Face and hand washing	Dragging of urine and excrement
Annual per capita (m^3/hab/year)	25.10	6.02	5.02	1.00	1.00	10.04
Daily per capita (L/hab/day)	68.77	16.50	13.75	2.75	2.75	27.51
Daily by HU (L/HU/day)*	275.07	66.02	55.01	11.00	11.00	110.03
Daily per apartment tower (L/tower/day)**	5,501.37	1,320.33	1,100.27	220.05	220.05	2,200.55
Total design (m^3/tower/day)	5.50	2.86				2.20

* Taking into account an average of 4 persons per housing unit.

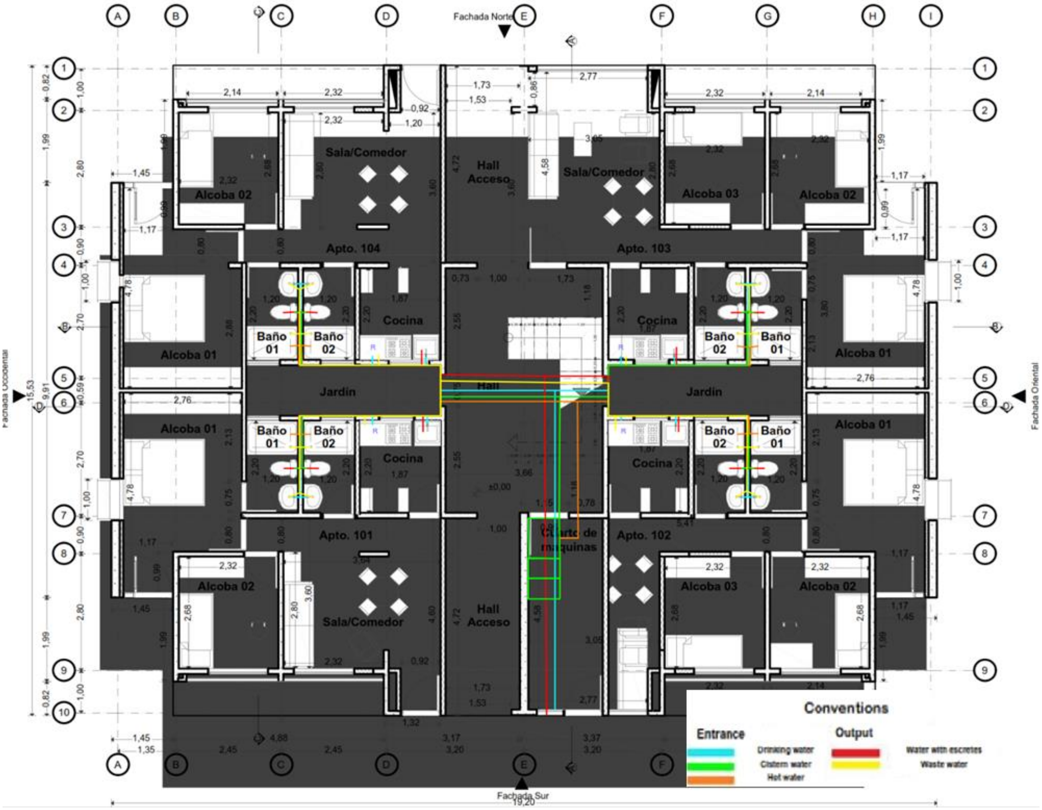
** Considering that the design has 20 dwelling units per tower.

Source: own elaboration.

According to the results shown in the Table above, out of the 25.1 m^3/hab/year (see 'Results', 'stage 1') of total consumption, the design volume output of 143.03 L/HU/day or 2.86 m^3/tower/day of generated used waters is considerable. Therefore, considering the quantity of re-circulated water will be used for the discharging of urine and excretions, the quantity of water to be supplied is of 2.20 m^3/tower/day.

In order to determine network distribution, a BIM process was carried out for the proposed SSWH model in ArchiCAD®, for the distribution, length and location of WSDR pipelines, seeking for the lowest use of additional materials in order to avoid cost increases for constructors. It is worth to highlight that through this design, a high efficiency is achieved in the spatial distribution of pipelines, given the joint proposal with architect Mauricio Sanchez, of using a "duct" for the location of an assortment of pipelines in structure walls, with facilitated access that enables their control and maintenance. This design is shown in Figure 2, where input systems can be observed, cistern water pipeline (green), which corresponds to re-circulation of treated water coming from used waters (yellow) and the output to water sewage with excretions (red pipeline).

Figure 2. Plan view of SSWH piping on one floor of the WSDR model



Source: own elaboration.

Used water treatment system

Water sourced from used waters is conducted for its treatment in the system located in the foundations of each apartment towers, corresponding to a primary physical quick filtering system with sand; the porous system withholds solids and achieves the quick elimination of large suspended particles (from 0.5 and 1.5 mm in diameter with sand and gravel, of 35 and 130 mm), with a filtering speed between 4,000 to 12,000 L/h/m^2, for which a filtering time of 1 hour is estimated [28], this quickly responds for the flushing of excretions in toilets of all housing units.

For this case, a filter of 3 m^3 was chosen (given the 2.86 m^3/tower/day generated), with a cement structure, filtering bed of 0.8m in height, 2.76 m in length and 1.4 m wide, buried type, with a maintenance room for changing bed whenever it fulfills its useful life (around one month and a half). After treatment, water is stored in a tank.

Tank

The tank, as well as the treatment system, will be located in the structure's foundations, in an underground level, avoiding the loss of useful occupation area for users of the building. As observed in Table 7. There is an excess between water that feeds the system and the consumption it seeks to supply of 0.66 m^3/tower/day, in other words, 23 % of water that must be stored. In this TA it was considered that in order to supply possible re-circulated water use increases, be it due to excessive use caused by illness, visitors, among others, it is necessary to use a cistern type tank, of 3,000 L.

Electric pump

A H(S)I MOVITEC brand electric pump was chosen, which according to the TA, has a flow output of 26.3 m^3/h, with a power of 7.5 kW, powered by electric energy in order to avoid the use of oil derived fuels.

System for collecting rainwater in roofs (SCRR)

We reiterate that water collected through this system will be used for activities of cleaning and irrigation common areas.

Roof

Average multiannual and monthly precipitation data was considered to determine the quantity of water storable in residential condo roofs in the SSWH model, which includes the area of apartment towers, the area of offices and event halls (see introduction), which add up to 9,303 m2. Water to be collected is observed in Table 8.

Table 8. Characterization of rainwater harvesting

Zone	Period	Area (m^2)	Rainwater (L/m^2)	Total Catchment (L)	Total net* catchment (L)
WSDR residential complex	Year	9,303.0	900	8,372,700.0	6,289,891.2
	Month		75	697,725.0	522,191.7
OCEA	Month	1,432.8	75	107,460.0	80,668.1
Each apartment tower	Month	262.3	75	19,675.5	14,720.9

* Considering runoff losses, evaporation, tank occupancy area and interceptor device losses.

Source: own elaboration, rainwater obtained from [19].

In this TA, an independent distribution system was established for each apartment tower and OCEA, with a monthly period, given the periodicity of use for cleaning and irrigation in common areas in each type of building, in addition to the regularity of rainfall.

The material proposed for collection in roofs was glass, with a runoff coefficient of 0.85 [29] which has losses of 15 %, in addition to estimated evaporation losses of 7.82 %, being 14,720.9 L the estimated approximate net quantity for use in apartment towers and 80,668.1 L in OCEA areas.

Interceptor

Regarding the SCRR, system cleaning is necessary due to the arrival of particles that come in periods of drought. This is done through a device known as interceptor or "device for discharging first waters", which impedes the contamination of water and the entry of undesirable material in the storage tank. The estimated volume of water required for washing the roof is 2 L/m^2 of roof. In other words, approximately 524.6 L for each apartment tower and 2,865.6 L for OCEA areas; posteriorly, these waters will be conducted to the sewage system.

Tank

The net amount of rainfall it can collect monthly (Table 8) is approximately 14.7 m3 for each tower of apartments and 80.6 m3 for OCEA areas. Because of this, additionally considering the periodicity of water used for monthly collected water, or the emptying of the tank for cleaning and irrigation of common areas, aspect that is established 3 times per month, requires the following in order to store the useful stream for cleaning and irrigation of common areas: One 5 m3 tank in each apartment towers and four 7 m^3 tanks distributed between OCEA areas. In Figure 3 a SCRR design is shown, evidencing pipelines, storage tanks and the storage useful area.

Figure 3. Operation of a rainwater harvesting system on roofs

Source: own elaboration.

With this study, it is acknowledged that through SCRR there is a saving of close to 522,200 L of drinking water per month.

Added together, the innovation of WSDR in SSWH residential condos, includes the following technologic alternatives or devices: (Table 9).

Table 9. Technologies used in the SSWH

Alternative	Technologies to be used	System*	Materials	Value/ Quantity	Unit
Wastewater reuse	Hydraulic Piping	Hu	PVC	406,88	m
	Hydraulic Piping	OCEA	PVC	24,67	m
	Rapid sand filter	TA	Reinforced Concrete - Structural, Sand, Gravel	2,00	m^3
	Motor pump	TA	N/A	1	Unit
	Subway tank type cistern	TA	Plastic	3,00	m^3
SCRR	Cover	OCEA	Glass, wood, insulation, metal	114,00	m^2
	Cover	TA	Glass, wood, insulation, metal	262,30	m^2
	Interceptor	OCEA	PVC, Plastic	524,00	L
	Interceptor	TA	PVC, Plastic	2.865,60	L
	Tanks (4 in total)	OCEA	Plastic	7,00	m^3
	Tanks	TA	Reinforced Concrete – Structural	5,00	m^3

*HU: Housing units; TA: Tower apartments; OCEA: offices, commercial shops, event meeting halls and common areas.

Source: own elaboration.

3. DISCUSSION

Water saving in buildings has had great relevance given that ever since 2018, more than 55 % of the population is urban [30], which is correlated to an increase in demand of water resource, given more intensive consumption habits. In this regard, although individual conducts have been catalogued as the aspect that determines the consumption of this resource [31], however, countries such as Colombia, where the lowest socio-economic levels do not possess elevated levels of use (25.1 m^3/hom/year), the alternatives of this TA for the SSWH model of this study respond to the need of redesigning construction structures for the efficient use of water resource and its access.

It is evidenced that in countries with higher consumptions (see "introduction" section), are not those who are focused in innovating in water conservation, but rather, countries which are in risk of water stress, such as Greece, Saudi Arabia, Israel and Germany [32]; in the case of Colombia, 318 municipalities are in risk of water stress (49 % of hydrographic sub-areas are threatened) [33]. Despite this, none of these countries have focused in conducting a TA of WSDR in buildings. Because of this, technologies proposed for the SSWH model, SCRR and the system for re-circulation of water in the building, are aligned with the strategic categories of "water source replacement" and "consumption reduction" in a useful strategic framework for formulating saving schematics [34].

The implementation of these technologies corresponds to methods that facilitate management, maintenance and efficient use of water for building occupants [35], by avoiding manual tasks. Although this research was specific for SSWH, it seeks to be replicable for the integration of water saving measures in every new building.

The development of sustainable residential buildings has a high impact in terms of pollution reduction and resource savings. The dynamics of certification for evaluation and monitoring makes it possible to compare with equal references, since most of the water saving measures implement the technologies in the operation stage, with installed saving devices and consumption meters[16]Hunan was developed relatively late compared to other more industrialized regions of China. However, with the local government's attention and focus, Hunan has made enormous progress and caught up rapidly. Green residential buildings grow even faster than green public buildings. The overall floorage of residential buildings is about two times of public buildings among these Green Building Labelling (GBL, and not from the construction design stage with incorporated networks.

With this proposal, the aim is to improve residential type buildings in a counter position to the trend of evaluating sustainability measures in structures such as tall or commercial type buildings, which possess a high financial strength and are not the places of longer time occupation for the population, the way residential buildings are. Because of this, the environmental impact of the project proposed here is outlined when it is replicated in the space available for construction SWH, in other words, 7.17 % of Bogota [36], it is estimated to achieve a drinking water saving of close to 2,209,385,200 L/month.

4. CONCLUSIONS

- The current response to a growing urbanization has included densification and increase of the urban perimeter; in Colombia, this deficit has been sought to be covered with SWH, which are of great importance in Bogota, Colombia; before such response, this research focused in designing water consumption saving measures included in such types of housings, which are thought of from the building's design and which anticipate users' consumption habits; through this TA the most adequate measures were established: treatment and re-circulation of used waters for use in toilets and SCRR.

- Water saving in the SSWH model designed by the authors generates water savings of 110.03 L/day in each HU and of 66,018 L/day in a total of 600 UH. In other words, 40 % of consumption, which represents less costs in the aqueduct public service bill; additionally, there is an estimated saving of 522,200 L/month upon replacing water sourced from the aqueduct for rainfall water for the washing and irrigation of common areas. Implementing these water saving mechanisms in the urban expansion area of Bogota will allow water savings of close to 2,210,000.000 L/month.
- This innovative design obeys to the XXI century dynamic of vertical building growth, reason for which this water saving measure projections can be estimated for tall buildings, for their functional performance [37]. This is part of constant evolution, innovation, and optimal planning, with a multidisciplinary intervention according to the project's level of complexity, including disciplines such as environmental engineering, sanitary engineering, civil engineering, architecture, and systems engineering in monitoring.

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