

Development of Drainage and water supply systems to reduce water consumption in Residential Buildings in Egypt

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Abstract

The issue of water is gaining Egypt's attention in recent times, especially after the start of the Ethiopian Dam and Egypt's entry into the era of water poverty, where water is considered one of the most important natural and environmental resources. Moreover, the constant pursuit of increasing development rates, Wherever the residential building sector acquires a large proportion of water consumption between different activities. The research aims to rationalize water consumption in residential buildings by developing water supply and drainage systems responsible for distributing water within various units and spaces. Consequently, the research focuses on water treatment and the integration of water reuse techniques within residential buildings. The research studies a repeated porotype of economy housing in new cities in Egypt. The study surveyed number of users of the same levels to get the water consumption rates per unit. The research finds that water consumption can be reduced by 30.4% in residential units by modifying water supply and drainage systems design Which is reflected in the cost savings. In addition, the cost of proposed system can be returned within 2.5 years comparing to the savings cost.

Keywords:

Water Conservation, Drainage Treatment, Water Reuse, Drainage Systems, Residential Buildings, Sustainable Building.

1. Introduction

Water is one of the most important natural and environmental resources and essential for all development activities, especially urban development. However, Egypt has many natural water sources, such as the Nile River and a groundwater reservoir in the Eastern and Western Desert [1]. However, Egypt's per capita annual water consumption is 536 m³ per annum for 2018, lower than the global per capita average of 1,000 m³ annually.

Egypt's per capita share is expected to decrease to 330 m³ by 2050 [2]. With Egypt exposed to many of the challenges caused by the construction of the Ethiopian Renaissance Dam and the consequent possible reduction of Egypt's water share. Water is a top priority and concern in all development sectors, and the importance of maintaining existing water resources, where the residential building sector accounts for a large proportion of water consumption among various urban activities. The residential sectors for the largest share of water consumption for urban communities and buildings, as the consumption of urban sector buildings, is more than the total tourism and industrial sectors and facilities in the rural center, where they account for 1,437 million cubic meters of water as in figure 1 [3].

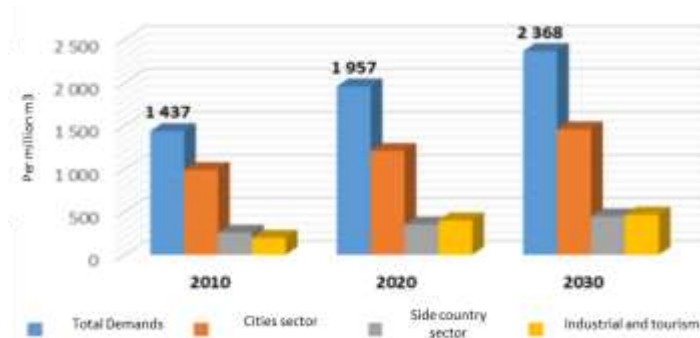


Figure 1 Development of water consumption distribution of sectors in Egypt [4]

Water consumption in units and residential complexes varies on drinking water, bathrooms, kitchens within buildings, irrigation, and site. Coordination work beyond residential complexes requires a review of the use of water inside residential buildings. The reasons for increasing consumption and a review of the design of water systems within residential complexes to reduce waste and maximize the utilization of water resources, thus achieving the objectives of water conservation, Reuse, and initial on-site treatment [5].

Water sustainability in residential buildings faces many challenges and constraints: the lack of awareness of users of the importance of water preservation and the lack of water overuse [6]. Furthermore, reducing water loss caused by low-efficiency appliances, plumbing connections and sewage systems, waste of rainwater, which is a source of alternative water, and directing it to sewage systems that have difficulty in being able to discharge rainwater and surface water from streets and rooftops [7].

The problem lies in the poor efficiency of the plumbing devices, the absence of an integrated system to reduce water consumption and rainwater collection, and the inadequateness of traditional drainage and nutrition systems for the idea of reusing water in residential units and complexes. Research hypothesizes that developing water and drainage systems in residential buildings will affect water consumption and plumbing performance strategies that reduce water consumption in residential buildings.

The research explains water sustainability techniques applied in residential buildings, discusses water consumption rates per capita, compares them with discharge rates in drainage devices, and concludes the relationship between

consumption and plumbing design requirements. Justify the traditional plumbing design to reach development mechanisms that increase network efficiency. Study models of economy housing projects in the government sectors and draw strengths and weaknesses to propose a model for developing the plumbing design to reduce the water consumption in residential buildings.

2. Water sustainability strategies in residential buildings

Achieving sustainability in buildings requires a commitment to achieve water efficiency standards during the life cycle of the building, starting with the stage of design, implementation, operation, and maintenance of the building's life cycle, through several axes, the most important of which is reducing consumption, reducing waste, employing recycling methods, reusing, and employing alternatives to achieve the required objectives, the used strategy was highlighted as in figure 2, which can be explained as follows [7,8]:

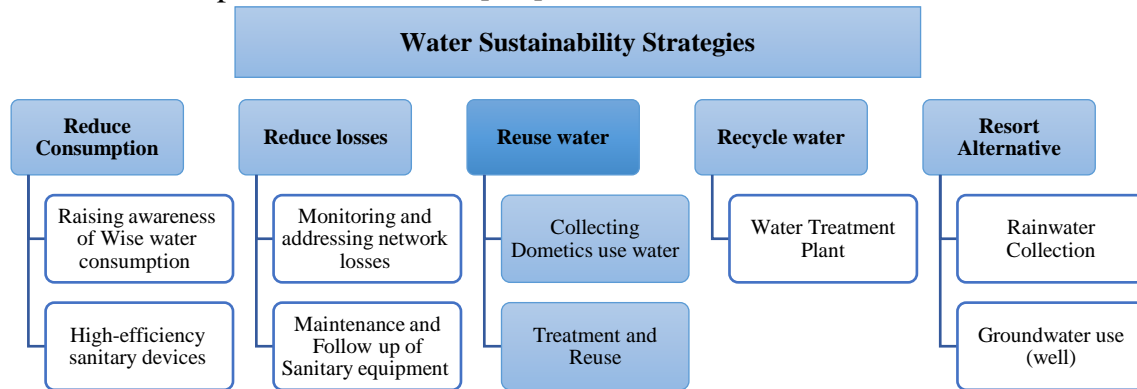


Figure 2. Water sustainability strategies, adopted [7-9]

2.1 Reduce Water

The concept of reducing consumption refers to reducing the amount of water consumed in buildings, which first begins with changing the culture of users, influencing the pattern of consumption within buildings, and raising awareness of the importance of water conservation as a vital source through awareness campaigns in different media [9]. Secondly, reducing the reliance on potable water for construction and construction and the site coordination elements' excellent design prioritizes plants' use from the local environment.

2.2 Reduce Losses

Reducing water loss involves monitoring and treating losses in buildings' health systems and devices and reducing losses. The use of innovative water-efficient appliances contributes to water conservation [10], such as touch infrared and other modern technologies as in Figure 3.

2.3 Reuse Water

Grey Water is defined as collecting water from showers, hand-washing basins, and automatic washing machines that can be treated and filtered in biological filters for Reuse in garden irrigation or sometimes even in package boxes [11]. And a model of the method of utilizing greywater in building as Figure 4.

2.4 Recycle Water

The concept of water recycling refers to processing water collected for Reuse, such as in grey and rainwater, or the complete treatment of "Black Water" resulting from toilets, urinals, kitchen sinks, and dishwashers highly concentrated organic pollutants [12]. Integrated water treatment plants that purify, treat, and sterilize that water and make it reusable can also be integrated into residential units in the toilet's ejection box, or out of buildings, in site coordination [13].

2.5 Resort Alternatives

Alternative water sources come from outside the public water system, which may come from, for example, rainwater, groundwater, or well water collection. Rainwater that falls on buildings can be collected and stored in water tanks for treatment and Reuse [14]. Egypt's cities, especially the northern coasts, have great rainfall chances in appropriate quantities that make them a source of access to clean water and less precipitation in Cairo and new cities. However, the chances of seasonal rains in winter and autumn remain and can be collected from rooftops and stored with ground reservoirs and purified for Reuse [3].



Figure 3. Examples of Water Efficient Sanitary equipment [15]

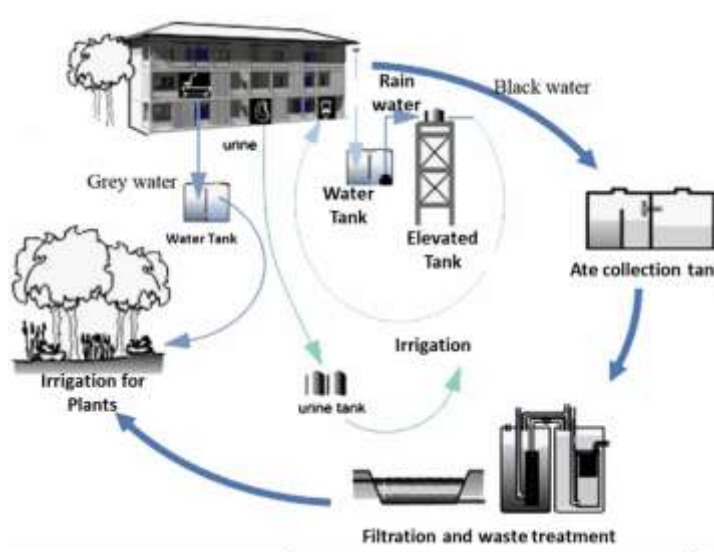


Figure 4. Water recycling and re-use methods in buildings, adopted [16]

3. Water supply and drainage (plumbing) systems in residential buildings

The Egyptian code and the building regulations used in the design of drainage and feeding networks in residential buildings require a set of criteria, the most important of which are:

3.1 Drainage Systems in Residential Buildings

There are many drainage systems used in the design of internal drainage systems for residential buildings, each with a code for defining the strategy and its requirements, and the drainage systems that comply with Egyptian building requirements are summarized as follows, figure 5:

A. One-stack System

This system relies on the assembly of all devices used in the consumption of water and discharge on only one (ascending) column and requires the use of a ventilation stack for all single devices as follows [17,19,20]:

B. Two-stacks System

In this system, the drainage load is employed by two columns, one for drainage and the other for work with one or two columns for ventilation. It is the most common system, especially in residential complexes, in figure 5 and illustrated as follows:

- Waste Stack (WS): Used to drain laundry tubs, kitchen sinks, floor siphons, bathroom sinks, showers, washing machines, and the like. It is usually 3 inches in diameter in residential buildings.
- Solid Stack (SS): Used to drain toilets, urinals, and the like, usually 4 inches in diameter in residential buildings. Sometimes another ventilation shaft is used to ventilate appliances on the drainage shaft in this system. It is the most common system, especially in residential buildings

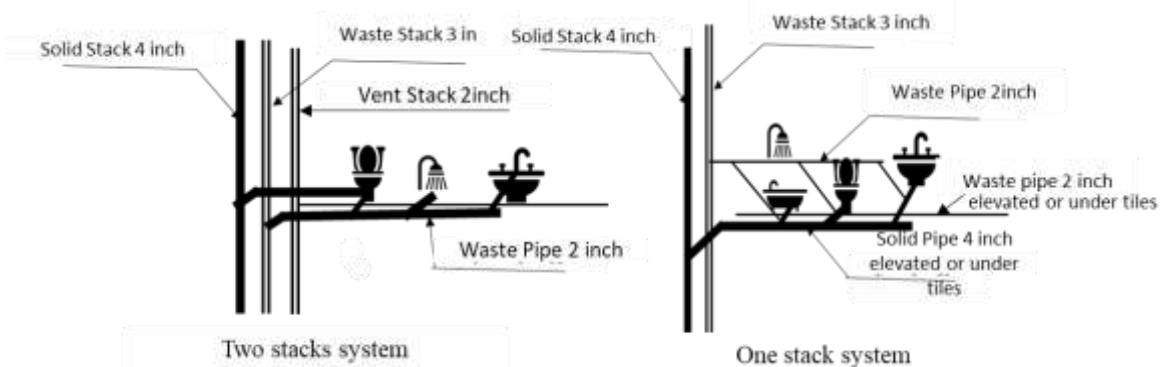


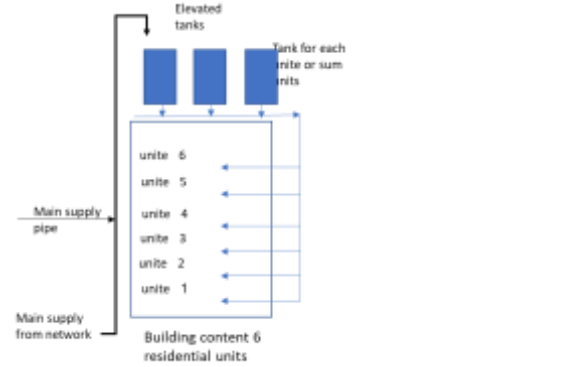
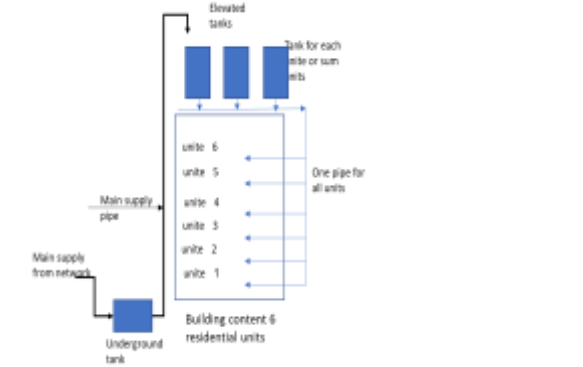
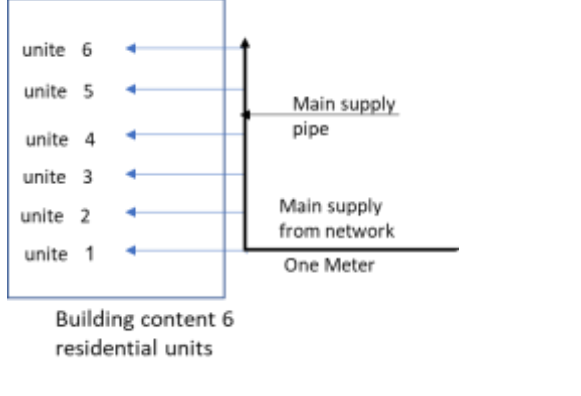
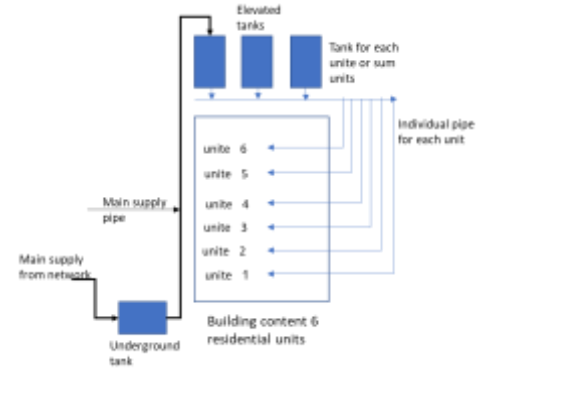
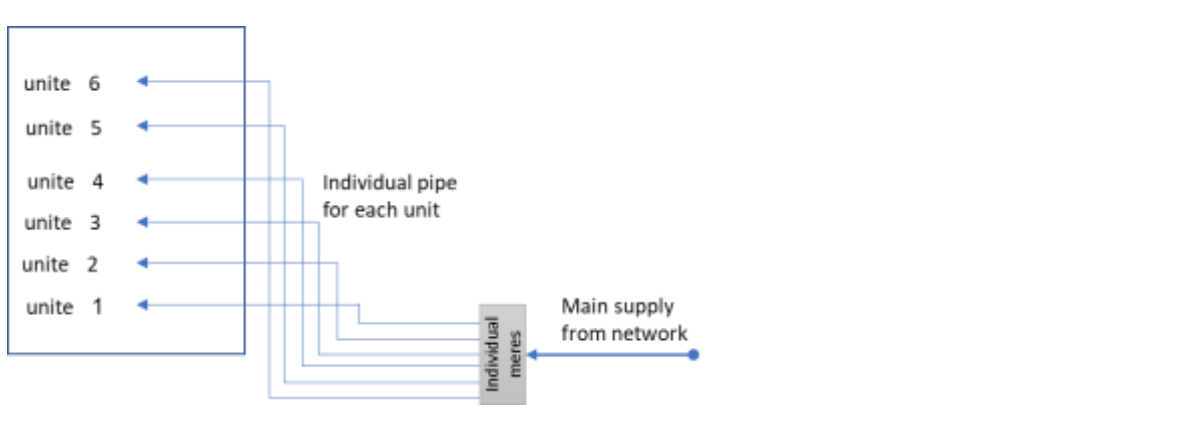
Figure 5. Common Drainage systems in Egypt, adopted [18]

3.2 Water supply systems in residential buildings

water supply systems provide water with appropriate pressures. They must be equipped with the proper design for water-supply pipes and the needs of the required tanks and tanks to increase water pressure in the building's internal water system to reach the required heights at the appropriate pressure [19].

Water supply systems vary within residential buildings according to the amount of consumption, the number of housing units, heights of buildings, and the internal network that should be safe and non-toxic materials. The choice of highly efficient materials is not affected by the quality and components of the water passing by them [20].

Table 1: Types of water supply systems used in residential buildings, adopted [18-20]

<p>A-Elevated Tanks with Direct supply</p>	<p>B-Elevated tanks for daily store and underground tank</p>
	
<p>C-Direct supply without tanks</p>	<p>D-Elevated tanks and underground tank with direct supply from individual stacks</p>
	
<p>E-Direct supply without tanks but separate supply for units (battery) without tanks</p>	
	

3.3 Water consumption rate in residential buildings

Average water consumption in residential buildings in new cities ranges from 100-400 liters/person/day [19]. While the distribution of water consumption within residential units varies depending on the family activity and the number of individuals using different water and sanitary devices. The figures and consumption from various resources rely on the culture and methodology of the analysis test. The research can divide each device's consumption or feature using water as average

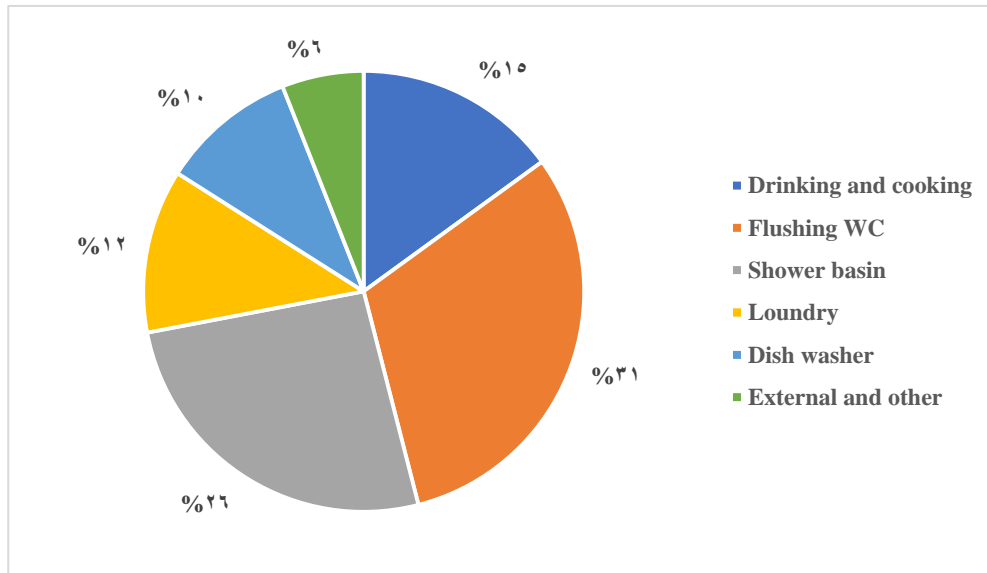


Figure 6. Water consumption rates for appliances in residential units, adopted [21] [21-22].

4. Survey of water consumption in residential buildings

The research has an online survey for the government economy residential users, and the representative sample have some features: the apartment areas vary from 100 to 200 m², with an average of 160 m². Number of rooms percentage is (2 rooms 5% - 3 rooms 78% - more than 3 rooms 17%). number of bathrooms in apartments (1 bathroom 13% - 2 bathrooms 74% -more than 2 is 13%). the number of users varies from 3 to 8 person with an average of 5 users per apartment. Having a washing machine is 100% while having a dishwasher is only 45%.

Water national companies divide the value for water consumers according to the monthly consumption segments (Low consumption from 0-20 cubic meters, Average 21-30 cubic meters, High 31-40 cubic meters, and Very high over 40 cubic meters). (Source of the water company)

The survey results show the increase in the cost of monthly water consumption during the summer, and 60% of users join the very high consumption segment, whose cost exceeds 200 pounds per month and gradually decreases during the months of spring, autumn, and winter as in Figure 7.

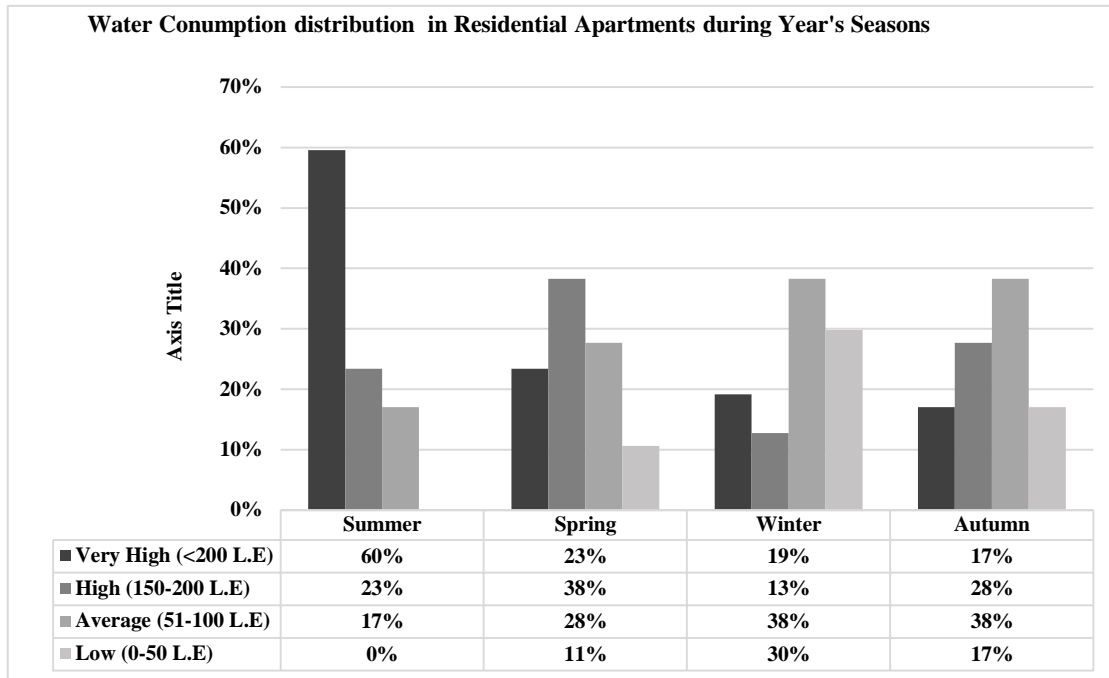


Figure 7. Water Consumption distribution in Residential Apartments during Year's Seasons

The questionnaire result also shows that the very high and high section represents (a cost of more than 150 EGP per month bill), which expresses the categories of consuming water quantities higher than 30 cubic meters per month. It represents 83% of users during summer and decreases to 61% in spring, then 45% in autumn, and 32% during the winter months.

The average amounts of water consumed monthly in residential apartments were calculated on an annual basis, which shows that 30% of users consume more than 40 cubic meters per month, that 26% of users consume between 31-40 m³/M, while that 30% of users consume. Moreover, between 21-30 m³/M and 14% of users consume less than 20 m³/M, as in Figure 8.

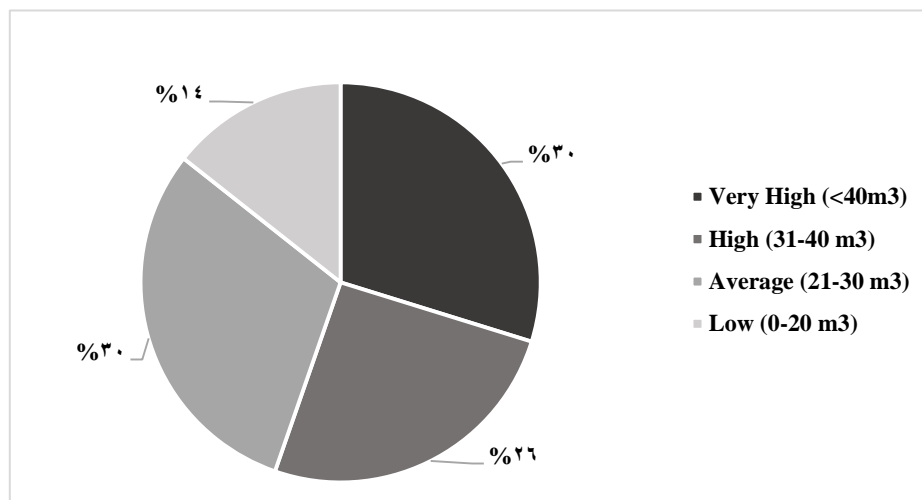


Figure 8. Distributions of residential apartments water consumption Monthly

5. Typical economy residential complex in Egypt (Case study)

In line with Egypt's strategy to achieve vision 2030, the Ministry of Housing is constructing and providing thousands of housing units through two categories: Economy and Social. These housing categories are the most targeted in the new cities, so the research studies one of the typical projects in The City of Shorouk [23].

The building code refers to the average per capita consumption of 100 to 400, which is a varying percentage between the low level of housing to luxury housing, so the research conducted a random questionnaire addressed to residents or users of the Dar Misr project to determine the housing level and average consumption of water.

Table 2. Sample of Government housing project

Project Name	Dar Misr		
Project Location	Repeated in many locations (New Cairo, Sadat city, 10th of Ramadan, 6th of October, Obour city) as the first phase and the project will be repeated in the future with the same model in all-new government strategy		
Owner	Egypt Government		
Consultant	Engineering department, military force.		
Project description	Modular buildings consist of six floors, and each floor consists of 4 apartments with two types per floor as following:		
		Type A	Type B
Information		A	B
Area		130	140
Number of bedrooms		2	3
Number of bathrooms		2	3
Number of Kitchens		1	1
Water supply system			
Type	Direct system (batteries)		
Number of sanitary devices	Type	Type A	Type B
	hand washtubs	2	3
	toilets	2	3
	bathtub	1	2
	Dishwasher	1	1
	clothes washing machine	1	1
	kitchen sink	1	1
	water heater	1	1
Drainage system			
Type	Two pipes (stacks), one for Solid stack and one for waste stack		
Water treatment	Not Applicable on site		



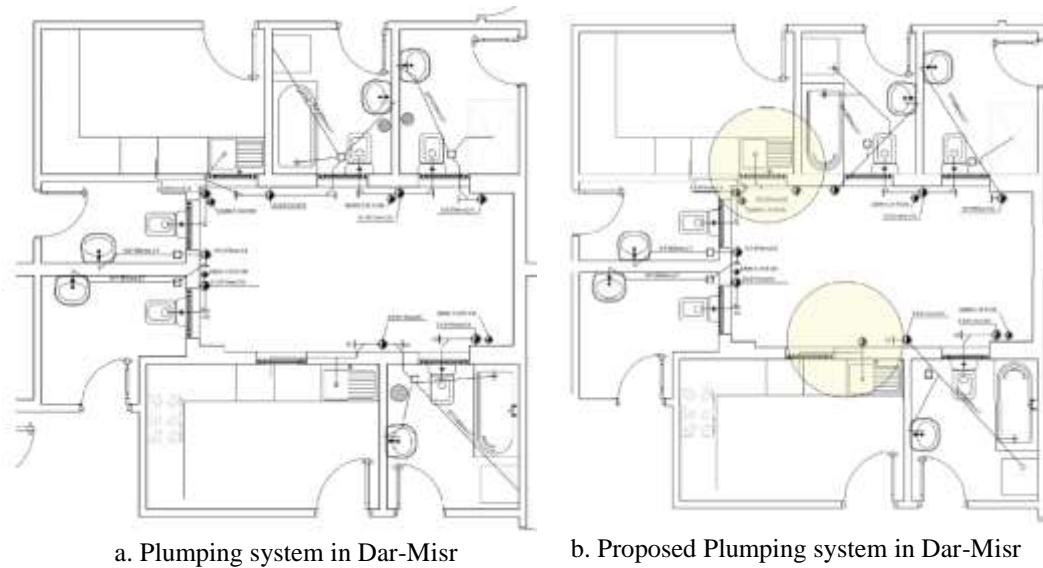


Figure 9. Distributions of residential apartments water consumption Monthly

5.1 analysis of plumbing system

The used drainage system is the traditional way contents of two pipes with ventilation stack, the typical floors have been collected in the ground floor level and separately of the ground floor drainage in figure 9a as follow:

- a) **The ground floor drainage system:** It is assembled directly to inspection rooms where both the solid stack and the waste stack collected from different drainage types have been observed. The composition of the collected water contains organic elements, acids, and chemical elements such as soap.
- b) **The drainage system of typical floors:** The drainage exits are assembled according to the established procedure. As noted, all the wastewater from the bathtub, washing basin hands, and ground siphon to the drainage pipe. The wastewater is separated from the discharge of the output from the toilet.
- c) **Water supply system:** The supplying system is related to table1 as direct supply without tanks (battery system).

6. Proposed model of a plumbing system

The case study analysis shows that residential units designed for an average of five users, and according to Egypt's codes, every person consumes from 250 to 300 liter daily. Besides, the amount of wastewater without oils is 38% of water consumed, nearly equal to the volume required to fill toilet flush appliances in residential units [24]. The proposed modification is to separate the drainage stack for the greywater without kitchen devices besides the existing two pipes system. Describe as in figure 9b,10.

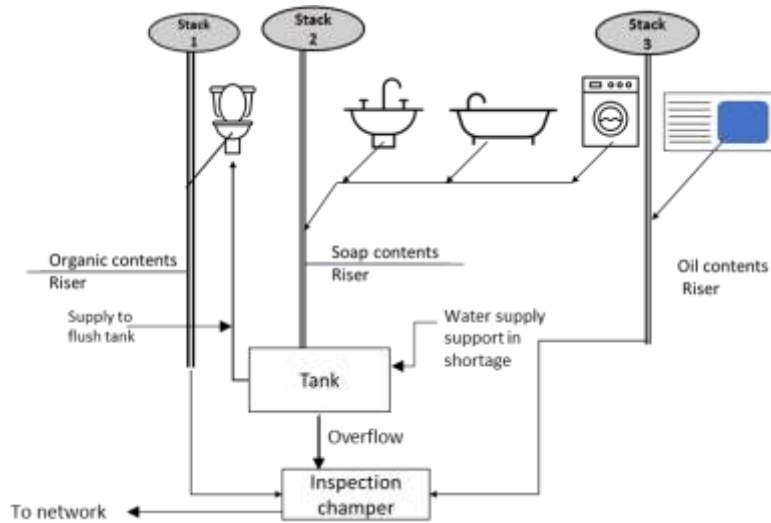


Figure 10. Proposed modification of Plumbing system for Residential building

The proposed system decreases the total amount of water consumption in residential units where it collects greywater in an underground tank and reuses it again in toilets' flush tanks. According to the average amount of water consumed in residential' appliances, the Consumption calculation in table 3 shows that the average saving percentage is 30.4%.

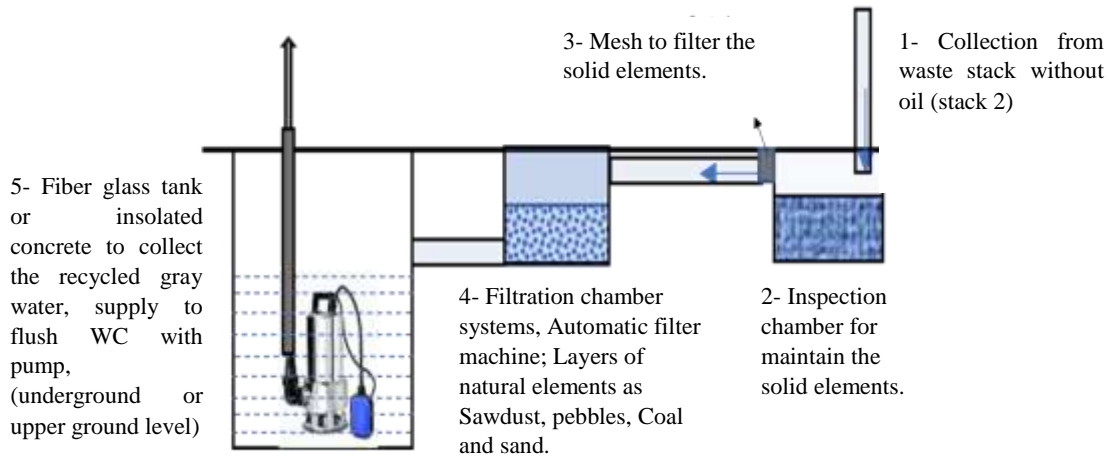


Figure 11. Diagram of proposed Greywater system for Residential building

The proposed systems' initial cost contains the modification of drainage and water supply system, the price of underground tanks, and finally, constructing and operating it. The proposed method has a high value of initial cost than the traditional system. It decreases the average monthly bills excluding the proposed system's initial cost, explained in table 4. And the calculation of cost analysis shown in table 5.

Table 3 Calculation of proposed system water consumption

Consumption study of one model of water where (average per capita consumption per day for residential buildings) = average number of beds in Egypt is 5 individuals = 5x 250 =1250 L per day

Device	Number of Units	Number of floors	Average of device consumption of the total water consumption	Average of number of persons	Average of person consumption per day	drainage volume L per unit	Total of drainage daily per building / m ³	Total of drainage monthly per building / m ³
*WF-WC flushing	4	6	31%	5	250	387.5	9.3	279
EO-External and others	4	6	6%	5	250	75	1.8	54
WS-Washing and Shower	4	6	26%	5	250	325	7.8	234
L-Laundry	4	6	12%	5	250	150	3.6	108
D-Drinking & cooking	4	6	15%	5	250	187.5	4.5	135
DW-Dishwashing machine	4	6	10 %	5	250	125	3.0	90
Total monthly consumption of building /m ³ (Sum. Of all above devices)								900
Total monthly consumption per Apartment /m ³ (Sum. Of all above devices)								37.5
Total for Greywater / m ³ (GW = WS+D)								342
Total Monthly drainage per building (with fat and oil contents) /m ³ (GW_f = D+DW)								225
Proposed of Reuse water m ³ / unit/month								14.25
The efficiency of reuse system = 80% (m ³), [3]								11.4
**Percentage of reduction in water consumption								30.4%

* WF = no. units * no. floors * percentage of device consumption* No. of persons * avg. of person consumption * 30 days (Equation repeated for all devices)

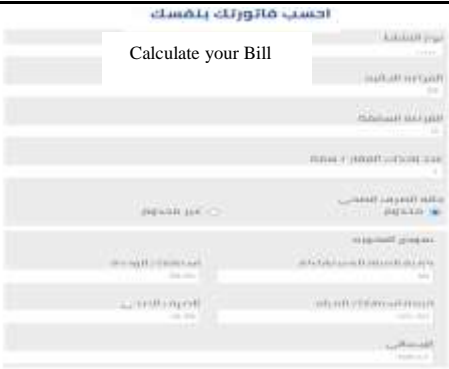
**Percentage of reduction in water consumption = Total monthly consumption per Apartment / The Volume of reuse system

Table 4 Cost calculation of proposed greywater system

No.	Item	Estimated Construction cost per building /EP	Cost of proposed system per apartment / EP
1	Concrete tank	10000	
2	PVC drainage pipes	30000	
3	PPR water supply pipes	36000	
4	Pump	5000	
*CGW- Total cost of greywater system		81000	3375

* Cost of greywater system equal sum. of items from 1 to 4, according to March 2021 prices in Egypt.

Table 5 Cost Reduction in water Consumption

Water monthly consumption of apartment /m ³	Consumption classes	Cost of monthly consumption / Egyptian Pound	
Before			
37.5 m ³	4	186 EP	
After			
26.1 m ³	3	71 EP	
DM-Difference of Monthly cost		115 EP	
Duration of moneyback = $CGW/DM = 3375/115 = 29.4$ Months			

* Price of water for residential use from HCWW water company online calculator in March 2021, [25]

Conclusion

A unified plumbing system is used for most of the residential buildings without developing the component and design of the drainage system and water supply that to be matching with the new project aims and sustainability strategies. To demonstrate that the research assessed one of the massing productivities projects as Dar Misr. The research found that the drainage system uses two pipes to systems collected in one way to the network without consideration of the onsite reuse system,

The research dependent on calculating the consumption rate of plumbing devices to validate those quantities of greywater without oils and fats are equal to the required volume of flush tanks. the contents of greywater affect filtration cost and process. The proposed system is to add a stand-alone stack and water supply flash tank stack to improve the greywater performance and filtration process.

the proposed system has direct benefits for users to reduce the average percentage of water consumption bills, decreasing the average amount of water consumption percentage by 30.4%. the initial cost can be returned in less than 3 years.

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