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Reuse of Greywater and its Role in the Sustainability of Water Resources – A Study in Saudi Arabia

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Abstract— *Reuse of greywater has become one of the proposed solutions worldwide to support water resources; that are subject to depletion in desert areas such as Saudi Arabia, where rainfall is scarce, suffering growing water demand for municipal and agricultural purposes, and the sustainability of groundwater resources on the other. In Saudi Arabia greywater represents nearly 55-74% of the water consumed in the buildings; so this study aimed to answer the following question: According to ministerial order No. 228 of 29 August 1426 AH, which stipulates that greywater should be reused and that two wastewater recycling systems should be implemented in the development of specifications and plans for the construction of new installations in the sectors concerned; Are there any indicators which prove the implementation of this ministerial decision? What is the evidence for this application? The reuse of treated greywater depends on the natural, chemical, and physical characteristics of the amount of biological consumption of oxygen (BOD5), total suspended solids (TSS), and the chemical oxygen demand (COD). The study concluded that some of the general natural characteristics of water are similar in value to those of high-income and low-income countries. The results show a continuous increase in water consumed through the study period within the urban and agricultural sectors, of Saudi Arabia into global support for the conservation of natural resources.*

I. INTRODUCTION

Daily demand for freshwater in the civil, industrial, agricultural, and other sectors increases yearly. This demand corresponds to many factors such as the annual growth of the world's population, on the one hand, and to the disparity in their living standards, on the other [1]. These are the key variables that explain the annual increase in the amount of clean water consumed worldwide. On-demand for clean water: More than three billion people are expected to live by 2025 under the current 0.8 billion water stress threshold conditions [2]. They also pointed out that globally, the total volume of directly exploitable freshwater is only 1/100 of 3% of complete freshwater resources, which is well below the total human demand (Ibid). Of course, the percentage of greywater discharged from the residential sector varies at the regional level. The reason for this discrepancy depends on the primary use of water in the dwellings and the efficiency of the service of such water [3]. The reuse of treated water is mentioned in many kinds of literature and was advised by many global environmental agencies, including the United States Environmental Protection Agency EPA [4], to gain the ecological dimension of the sustainable development goals. Reusing greywater has recently become an essential strategic solution to secure water scarcity in Saudi Arabia's agricultural and industrial sectors [5]. Alternative water management strategies have been set up in dry territories because of the absence of freshwater [6]. This consecutive demand for fresh was associated with some geographical locations such as Saudi Arabia, Scarcity of supply of such water for different geographical reasons, Extremism in prevailing climatic conditions and its impact on the scarcity and occasional scarcity of rainfall, as in the desert regions, or one of the reasons for this scarcity may be poor consumption or mismanagement of available water resources. No doubt: It was accompanied by increased water consumption in various areas, an Increase in the amount of water used, and discharge to the public sewerage network [7]. Greywater was defined as water used by the State to meet the continuing demand for it for various civilian purposes, for example, in the residential sector for multiple purposes including bathing, washing clothes, kitchen, etc. [8]. There is also a similar definition of greywater: "Greywater is defined as a domestic wastewater that is uncontaminated by direct contact with human excreta [9]. Greywater was defined as water used for washing machines, baths, kitchen laundry, and laundry [10],[11], and greywater is any household wastewater produced except for sewage or black water [12]. "Reuse of treated greywater has become a demand, especially in those countries with natural and economic challenges in accessing safe water." The proportion of greywater discharged from the residential sector is up to 75% [13]. In Jordan, it is between 50 and 80% of the sewage for the residential sector ([14]. Since there is a rise in water use, the amount of wastewater discharged into public sewage systems is expected to increase. Thus, at the outset, it must be considered that greywater is one of the main sections of wastewater [15]. Some believe that greywater discharged from the residential sector, such as bathing water, and without purification, can be used for certain uses, such as irrigating crops in comparison to black water [16]. Of course, As the demand for water increases in various sectors in any of them, so does the amount of greywater. The relationship between the amount of demand for clean water and the amount of used water discharged is an evolutionary one. What's bad is that the increase in the amount of greywater that will undoubtedly flow into the public sewage system if it's not treated before, so that it becomes reusable in the sectors that consume it. Globally, it's estimated that 50-80% of sewage comes from greywater (Aljayyosi, op.cit.) explained that a case study was presented on the reuse of greywater in Jordan to shed some light on its role in sustainable water management. To operationalize this concept, water is seen as an economic commodity and a limited resource that should be evaluated and managed rationally. Notwithstanding the importance of the reuse of greywater in alleviating the demand for freshwater sources and protecting them from depletion; this is not without the technical and economic challenges that societies in low-income countries will face. Statistical data shows that the percentage of wastewater from the residential sector treated safely varied globally between developing and developed countries; and between countries with higher and lower incomes in 2020 (figure 1). Many countries were green color, which means a high percentage of safely treated wastewater flows from households. The darkest green color means > 90% as in the United States, France, Japan, Sewed, Finland, and other countries with high economies. Otherwise, the rest of the countries which appeared in a disparity of light green color, including Saudi Arabia, Algeria, Norway, Spain, Australia, New Zealand, Turkey, and other countries with the same rates of treatment are under 90% and up by 25%. The important notice matter wasn't in the groups of countries with other colors; but in the rest of the countries that appeared in grey color as no data, and the more dangerous thing of the countries which not yet begun the reuse of greywater, and both of that two groups classified of low economy and poor countries.

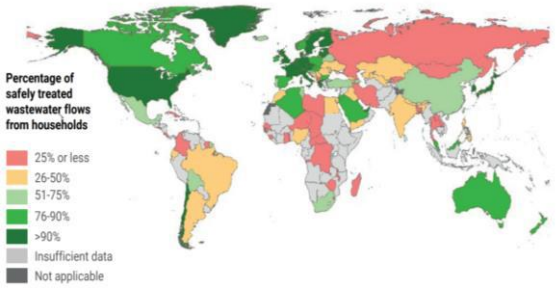

Fig.1: Estimated proportions wastewater safely treated (2020), Source: [17].

Using treated greywater is expected to reduce the demand for freshwater use within residential, governmental, and service sectors. If specific treatment policies are implemented, the greywater will be recycled to meet the increasing demand. When deciding to treat greywater for reuse, it should be known that this water differs in terms of whether it is a high load or low load, as shown in (Figure 2); Water discharged from hand-washing and fast bathing basins is classified as "light water," while water discharged from the kitchen basin and dishwasher is "heavy water." In Saudi Arabia the greywater removed from the washbasins in mosques is the purest compared to the previous greywater sources. It, therefore, requires only simple and economically inexpensive purification (General Administration of Sanitation, op.cit.)

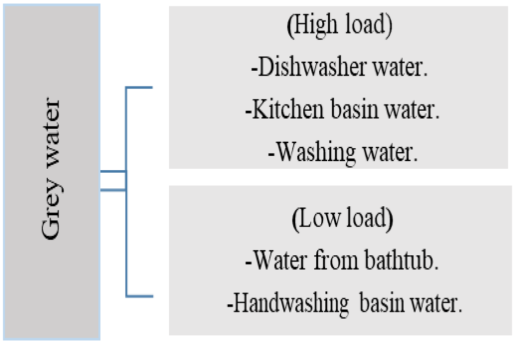

Fig.2: Classification of greywater by payload.

Source: this diagram was designed by the researcher.

Although the process of greywater reuse includes several natural, economic, and social benefits in the sense that it would achieve the globally recognized triad of sustainable development; the success of this operation depends on the type of pollutants that may be present in such water, according to sources (Allen, op.cit). BOD5 is the acronym for Biochemical Oxygen Demand and is widely used for cxin biological wastewater treatment. It is known as a standardized unit for measuring organic water pollution. Through BOD5, the mass of molecular oxygen consumed by micro-organisms in five days in one Liter of water at 20ºC in the dark [18].

In a country such as Saudi Arabia, which is within the arid tropical desert climate region, the attendant scarcity and sudden rainfall on its territory, which, although covering a land area of approximately 2 million km^2, is devoid of permanent inland water bodies, such as lakes, rivers, and waterfalls. Otherwise, temporary waterways, such as the stream of valleys, appear after the winter rains in all areas of the Kingdom of Saudi Arabia and after the summer rains fall exclusively on the mountain's lands of the southwest of the Kingdom of Saudi Arabia.

II. STUDY AREA

Saudi Arabia lies between 16° and 32° north of the equator (Figure 3). As a result of the astronomical nature of this site, extreme climatic characteristics prevail throughout the year. The study area has no permanent water bodies, such as lakes or rivers. Apart from this, there are hundreds of dry valleys in which water flows at varying intervals immediately after the rains fall. Meeting the increasing water demand depends on several traditional sources, namely deep and surface groundwater, and salt-water desalination plants, located directly to the Red Sea and Arabian Gulf. The decision-makers valued the importance of preserving groundwater, therefore, issued ministerial order No. 228 of 29 August 1426AH. Under the terms of the Act on the Reuse of Greywater, two water-recycling systems must be implemented in the formulation of specifications and plans for the construction of new installations in the sectors [19], as well as the promulgation of several programs and initiatives dealing with freshwater consumption regulations; however, with the successive annual increase in the population of the Kingdom of Saudi Arabia, which reached 32,175,224 people in 2022 [20]. Hence, the increased demand for water for the agricultural sector, which meets the requirements of producing various plant and animal foods, increases the amount of greywater discharged from farming and other sectors.

Fig.3: Map of the study area

Source: the researcher.

III. METHODOLOGY

Statistical data of freshwater consumption in the municipal, industrial, and agricultural sectors, other data on the source of that freshwater, as well as data on the amount of wastewater, and the amount of what was treated during the study period 2009-2020 in the Kingdom of Saudi Arabia; that issued in the statistical yearbook, and the annual reports of the Ministry of Environment, Water, and Agriculture. Information was also collected from the statistical yearbook of the General Authority for Statistics. Graphs were drawn that showed the nature of freshwater consumption within the urban and agricultural sectors and the change in the amount of treated water reused during the study period.

IV. ANALYSIS AND DISCUSSION

Tracking freshwater demand in any population area proves to be subject to constant change. The quantity of freshwater demand in the Kingdom of Saudi Arabia changed during the study period 2010-2020, as this demand increased from 17447 million m^3 in 2010 to 25992 million m^3 in 2018. In 2019, the consumption decreased significantly to 15393 million m^3, but it increased slightly to 15979 million m^3 in 2020 Table (1). It noted that just as there was a variation in the amount of water demand during the study period, the data in the same Table also shows a disparity in the amount of water consumption within the three municipal, industrial, and agricultural sectors. Water consumption within the municipal sector, as well as the industrial sector, has been characterized by continuous increases. Data in Table (1) shows that the volume of water consumption within the municipal sector increased from 2.2 million m^3 in 2010 to 3.6 million m^3 in 2020. This leading sector includes all sub-sectors, mainly residential, health, educational, and services. This increase reflects the impact of key variables within these sectors. The growth in population size and the consequent diverse water requirements play primarily within the residential sector, which includes drinking, cooking, bathing, washing clothes and kitchen utensils, as well as other uses such as garden irrigation and yard washing. The percentage of water demand in the urban sector reached 23% in 2020. Although water consumption in the industrial sector was characterized by a continuous increase during the years of study from 753 million m^3 to 1680 million m^3, this amount represented only 10% of the total amount of water demand in the Kingdom of Saudi Arabia in 2020. Finally, the water demand reached the highest in the agricultural sector, becoming the dominant sector in the total water demand during the study period by 82.5% in 2010 and 66.7% in 2020. The percentage of this dominance over the total amount of water consumption during the study period was 82.5% in 2010 and 81.5% in 2018 (Table 1). The decline in the amount of water demand in the agricultural sector (Figure 4) and (Figure 5) reflects the efforts of the Ministry of Environment, Water and Resources to adopt the water demand management approach and not meet it to keep pace with the global trend in this important matter [21]. By applying this policy, Saudi Arabia engages the global a crucial role in sustaining its rare water resource.

Table 1: Amount of freshwater consumption 2010-2020 (million m^3/year)

	2010	2012	2014	2016	2018	2020
Municipal	2284	2527	2874	3130	3428	3629
Industrial	573	843	930	1015	1400	1680
Agricultural (non-renewable water)	14410	17514	19612	19789	19000	10670
Total	17267	20884	23416	23934	23828	15979
% For consumption of the agricultural sector	83.4	83.8	83.7	82.6	79.7	66.7

Source**:** Ministry of Environment, Water and Agriculture (2020). Statistical Yearbook: 1441-1442 AH.

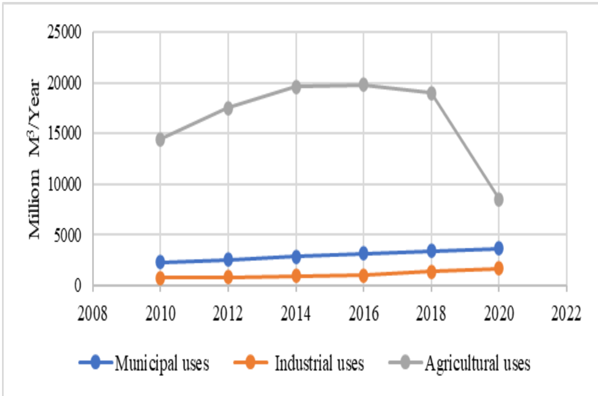

Fig.4 Sectoral distribution of freshwater consumed in

Source: prepared by the researcher.

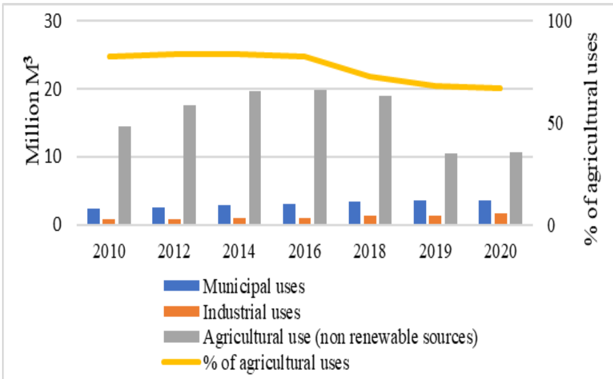

Fig.5: Amount of freshwater consumption in all sectors from 2010 to 2020 (million m^3/year). Source: prepared by the researcher.

Conventional and non-conventional sources have played essential roles in meeting the growing annual demand for water in the municipal, agricultural, and industrial sectors. Data collected from the General Authority for Statistics showed that the non-renewable groundwater sector is the primary source of the freshwater demand, as it plays an important role compared to other sources in terms of the amount of water it provides to meet the increasing domestic demand for fresh water from various sectors during the study period (Figure 6).

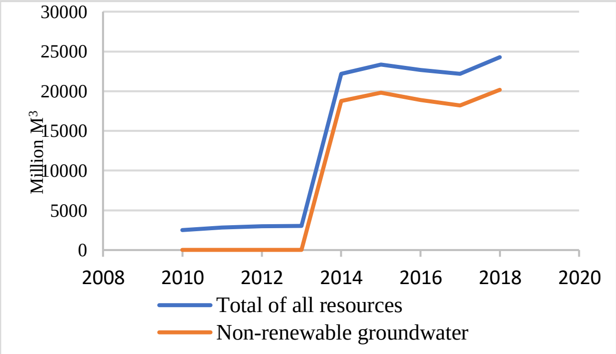

Fig.6: The predominance of non-renewable groundwater over total. Source: The researcher.

Due to the scarcity of rainfall at times and the limited amount of rain at other times due to the nature of the prevailing climate, which is the direct source that feeds surface and deep groundwater, and due to the continuously increasing demand for freshwater, the attention of decision-makers has once again focused on the reuse of greywater. Every increase in clean water consumption will be offset by an increase in the amount of greywater discharged into sewage channels, so the greywater reuse initiative has been activated.

Data in (Table 2) show that government decisions have played a crucial role in dealing with wastewater in a more beneficial way that ensures the sustainability of groundwater resources. What is noticeable about these data are two things: the growth of the quantities of that treated water, and finally, the % reused water quantity of the total processed fluid through the years from 2018 to 2020. There are many advantages of reusing greywater; one represented 55-74% of the water used in building. It is also easy to deal with the low pollution from organic matter, nitrogen, germs, and microbes during purification stages (Ministry of Environment Water and Agriculture, op. cit). The process of reusing treated water for living requirements depends on crucial things, the first of which is acceptance from members of society. Otherwise, the reuse of greywater is such a sensitive thing. The reuse of treated greywater depends on the natural, chemical, and biological characteristics of the amount of physical consumption of oxygen (BOD5), total suspended solids (TSS), and the chemical oxygen demand (COD). The study concluded that only some of the general natural characteristics of water in Saudi Arabia are similar in value to those of high-income and low-income countries (Table 3). The importance of greywater reuse in groundwater sustainability in the Kingdom of Saudi Arabia requires new analytical studies to fill in the gaps in some parameters of the characteristics mentioned in this table.

Table 2: quantities of treated wastewater

	Quantity of treated wastewater (M^3 /year)	**Average amount of treated wastewater (M^3 /day)**	**Average amount of water reused (M^3 /day)**	**% of reused water quantity of the total processed fluid**
2018	1665059190	4561806	862140	18.11
2019	1801873551	4936640	852307	17.26
2020	1868573838	5105431	929252	18.20

Source: Preparation by the researcher based on the Ministry of Agriculture, Water and Environment, Statistical Yearbook from 2018 to 2020

Table 3: Physicochemical characteristic of greywater s in low- and high-income countries

Parameter	**Low-income countries [a]**	**High-income countries [a]**	**Saudi Arabia [b]**
pH	6.7	7.17	-
Turbidity (NTU)	35.2	41.35	-
TSS (mg/L)	285.8	48.0	-
TDS (mg/L)	337.5	171.0	-
BOD5 (mg/L)	206.0	80.6	-
COD (mg/L)	819.5	204.8	-
TOC (mg/L)	-	-	-
Oil and grease (mg/L)	7.0	-	-
Nitrate (mg/L)	49.3	3.9	-

Source: Preparation by the researcher.

[a] Peprah, Acheampong and deVries, 2018.

[b] Ministry of Water and Electricity, General Department of Sanitation. Greywater Reuse Guide. Second edition, (1429h).

V. CONCLUSION

Reusing greywater is play an important role in sustaining water resources in the arid areas. The ability of using treated greywater depend on the Physicochemical characteristic BOD5, TOD, SST. Grow in freshwater consumption in dry areas will lead to an increase in continuous demand, and hence surface pressure and deep groundwater sources. Find other sources to support traditional water sources in these areas and adopt them as permanent sources to meet water demand, such as seawater desalination or reuse of greywater and wastewater after treatment. It is necessary to conduct applied analytical studies to reveal the values of the parameters of the natural characteristics of greywater in the study area to decide on its suitability for reuse, and to make the outputs of these research available for comparison with the results of international studies.

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