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Study of the Reuse of Greywater in the Irrigation of the Home Garden in Rural Areas

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Abstract: Greywater is an important water resource at the household level. It includes water from household operations such as cooking, washing, cleaning and other household processes. The reuse of greywater is one of the most promising ways of conserving water because it has an important role in increasing plant productivity at the garden level. It is an important option for increasing the efficiency of water use at the household level in rural Iraq as well as treating water scarcity. Many homes in Iraq are drained of wastewater through cesspits, especially in the countryside and urban areas, leading to groundwater and surface pollution. A greywater treatment compact plant has been designed and implemented at the household level and used to irrigate the home gardens because we have seen a benefit that can be achieved for the family, especially, the community at large. This project, through the implementation of a greywater treatment unit in the rural areas of Al Diwaniyah governorate has sought to develop the treatment technology and exit the local community in rural areas to encourage their reuse. The aim of this study is to highlight the rationalization of the uses of water resources through the use of greywater. It aims to deepen the knowledge and transfer of the relevant expertise in this field and to define the interested parties in this field and to build their capacities in the greywater issue and how they can be separated of the use of greywater in Iraq. The greywater treatment unit in the village of Khairi in Al Diwaniyah Province consists of a septic tank, up-flow anaerobic filter, a multi-layer aerobic filter amd a storage tank. To ensure the quality of treated greywater used in irrigation, a periodic water monitoring program was implemented before entering and after treatment. The percentage of removal of suspended solids reached 94% and the nitrogen removal rate was 85 %. This results are encouraging and excellent. The results of the test and analysis that the plant has a high processing efficiency of up to 97% for BOD and conform to the specifications of water used for irrigation.

Key words: Greywater, BOD, rural area, aerobic filter, anaerobic filter, separated, capacities

INTRODUCTION

Iraq suffers from water scarcity in recent years and the problem is exacerbated by increasing population. The per capita water supply will shrink annually if new water sources are not provided. This in turn prompts decision-makers and technicians to seek unconventional water sources including reclaimed and gray wastewater for irrigation in environmentally safe ways. Since, the problems of the agricultural sector are a difficult task for the decision makers in Iraq under the current water shortage conditions of the low share of the agricultural sector of water and increased demand for water to other sectors, it became necessary to use all available water resources, including low-quality water sources to address these challenges.

Greywater is an important water resource at the household level. It includes water from household operations such as cooking, washing, cleaning and other household processes. Greywater does not include water from the use of bathrooms which include waste and is called sewage (black water). Greywater accounts for about 50-80% of all household water consumed, so, greywater is an important resource at home (Nolde, 2000).

The reuse of greywater is one of the most promising ways of conserving water because it has an important role in increasing plant productivity at the garden level. It is an important option to increase the efficiency of water use at the household level in rural Iraq and is also an option for rural communities to be used to grow crops of high economic value.

Interest in greywater as a source of unconventional water has been increasing in many countries of the world and some Arab countries. In Iraq, citizens in different areas of the Middle Euphrates are aware of the importance and necessity of saving water consumption and the reuse of greywater amd some are taking steps to improve the efficiency of household water use. Most rural households own an area of land around the house that is used for agriculture, livestock or poultry to provide part of the family's food needs. Women play a key role in exploiting these areas by growing vegetables, medicinal plants, legumes, fruit trees, poultry and sheep. Drinking water is often used to irrigate the garden, leading to increased water consumption, especially in the Summer and Autumn months, thus, increasing the cost of water consumption and the high cost of living for the family, forcing many of them to use greywater without treatment to irrigate the garden.

Previous studies by Guozhong (2010), Pinto and Maheshwari (2010), Abudi (2017), Jabornig (2014), Mahatyanta and Razif (2016), Chaabane *et al*., (2017), Al-Ismaili *et al*. (2017), Khatiwada *et al*. (2017), Chen *et al*. (2017), Moges *et al*. (2017), Shoults and Ashbolt (2017) and Rengaraj and Nirmaladevi (2017) have shown that the reuse of greywater is good in irrigation, increasing plant growth and production and that there is acceptance and adoption by local communities for use in the irrigation of the home garden. In the field of greywater treatment, many researchers have worked to develop the best ways to obtain the highest efficiency in the treatment of greywater at acceptable costs by the community.

The belief that all wastewater from homes is similar is incorrect. There is a big difference between greywater and black water from the point of view of environmental protection and reuse and how to treat this water in terms of treatment. Greywater contains a nitrogen element that is much less concentrated than black water and does not contain bacteria and viruses contained in black water. The natural organic content in these waters decomposes very quickly compared to black water which needs advanced processing methods. If it is planned to be reused well, it can be used to irrigate trees and green spaces without gravity (WHO, 2005).

After studying many projects and researches in the field of reuse of greywater in different countries of the world and the lack of research and similar projects in Iraq, there is a need to develop greywater treatment technologies and out to the community in rural areas to stimulate the reuse of greywater. This research sought to be realized as part of the activities of the agricultural resource management project implemented by the Ministries of Agriculture, Irrigation and Education in the areas of the Middle Euphrates and Southern Iraq.

In this study, a house was chosen in the village of Khairi in Al-Diwaniyah governorate. The greywater network is isolated from the sewage network and the family has 8 persons. The house area with the garden is about 600 m^2. The greywater treatment plant was implemented in the garden of the house. The biogeochemical, chemical and physiological characteristics of the greywater were examined before and after the treatment and its quantities. The greywater treatment and reuse plant consists of 4 basins (septic tank, sedimentation and upflow filter anaerobic gravity, multi-layer aerobic filter and storage tank). The rationale for this research is the scarcity of available water resources and the need for additional water for irrigation at the household level in rural areas of Iraq. The need to develop more efficient and cost-effective techniques for the treatment of greywater and its use in domestic irrigation and the need to exploit greywater as a water source to increase the productivity of the garden home and provide an additional source of income for poor families in the target areas. The objectives of this research is to stimulate the reuse of greywater in rural areas. In the province of Al-Diwaniyah as an alternative water source and raise the productivity of the home garden to increase the income of the community by designing and implementing a greywater reuse plant consisting of cheap construction materials available in local markets and easy to use, implementation and maintenance.

MATERIALS AND METHODS

Gray wastewater in the Iraqi countryside: Most of the population in rural areas of Iraq is not connected to sewage networks where these people get rid of wastewater through cesspits. These cesspits cause pollution of ground and surface water as a result of the leakage of wastewater from cesspits into this water (Anonymous, 2003).

After a period of lengthening or shortening, these pits become unable to discharge all the wastewater through the soil surrounding the cesspit. The groundwater level is high in the sedimentary plain in Iraq. This results in a problem no less difficult than the pollution problem. It is a major health problem where these water is often dumped in agricultural land near the village. The introduction of water in agricultural land and near population centers is also a major health problem for the population in these communities (Al-Jayyousi, 2003).

In order to minimize this problem, a rural wastewater treatment program has been developed which is the reuse of gray waste water (resulting from the laundries, kitchen, washing machine and bathroom) after treatment for irrigation of domestic gardens.

For this purpose, treatment plants have been designed and implemented after they have been separated from black wastewater. The use of treated gray wastewater is acceptable in terms of health and culture (Sabbah *et al*., 2004).

The main objective of this study is to obtain local expertise in the field of wastewater treatment and reuse in agriculture by designing a small-scale purification plant for a rural house. This idea will be developed and made available to specialists and interested in solving the problem of rural sanitation from the risk of pollution and disposal of the process of perfusion and water scarcity and thus, reduce costs and maintain public health and the design of the home purification plant for the treatment of gray wastewater.

Dealing with gray wastewater: The gray wastewater treatment at the site, especially near the accommodation, allows access to this water in limited agriculture. But this requires separation of gray waste water from black wastewater to contain a large amount of bacteria and pathogenic viruses. Full wastewater treatment (gray+black) requires a larger plant that needs more land than may be available in small gardens.

All the water used in the house except for toilet water is called gray waste water and is produced from the kitchen, washing machine, bathroom and laundries. This water contains fat, food residue, soap, hair, skin cells amd other dirt that reach the sewer pipe irregularly (Anonymous, 2000).

Although, gray wastewater is considered to be less polluting than black wastewater, recent studies have shown that it contains significant quantities of organic and chemical pollutants which requires adequate treatment of this water before reuse in agriculture. So, as to maintain public health and soil conservation from ruin. The statistics presented in this study showed that the amount of gray wastewater produced daily in the Iraqi countryside with a water network of 150-160 L per person. This figure varies from house to house and depends on the standard of living and the customs used in the use of water. For example, a house with a self-contained washing machine produces more gray waste water than a house that uses a hand-held washing machine. This amount is significantly reduced when the house gets its water needs from a tap outside the house or from a river. The amount used in the same house varies from day to day and from season to season.

Greywater quality: Water from the kitchen contains parts of food residues, fats, oils, dust, soap, cleaning powders. Water from the bathroom contains toothpaste, shaving residue, soap and shampoo. The water from the washing machine contains oils from the secretion of the body, dust, washing powders, detergents and other dirt.

The likelihood of disease transmission from gray wastewater increases if a household member has an infectious disease but mixing with the patient poses a greater risk of transmission of the disease to healthy people than the risk of transmission by dealing with gray wastewater. Child waste that is often disposed of to laundries or pigeons contributes to the leakage of harmful bacteria into gray wastewater.

In all cases, gray waste water is cleaner than black waste water considering all pollutants except fats and oils. Black wastewater contains many bacteria (harmful and harmless), chlorine, phosphorus and nitrogen as soluble compounds that are difficult to treat in simple ways but some require complex techniques (Sperling *et al*., 2005). Currently there are limited standards available for greywater quality when used for garden irrigation. In this study, the Iraqi National Standards and criteria set by the Regulation 25 of 1967 for treated greywater were adopted to assess the quality of treated water used in garden irrigation as shown in Table 1.

Table 1: The Iraqi national standards and criteria water quality suitable for domestic water recycling

Variables	Values
Sewage temperature	
Minimum (T)	15°C (Winter)
Maximum (T)	30°C (Summer)
Treated effluent characteristics	
Biochemical Oxygen Demand (BOD_5)	20 mg/L
Chemical Oxygen Demand (COD)	90 mg/L
Total Suspended Solids (TSS)	60 mg/L
Total Nitrogen (TN)	10 mg/L
pH	7

Table 2: Percentage of the most important pollutants as a weight in both grey and black wastewater

Type of pollutant	Gray wastewater (%)	Black wastewater (%)
BOD, COD	50	500
NO_X	15	850
P_X	35	650
Feacal coliforms	00	100

Table 2 shows the proportions of the most important pollutants as a weight in both gray and black wastewater (Mahatyanta and Razif, 2016).

Greywater is used to irrigate plants in the garden and send black wastewater to the cesspit. The use of gray wastewater in the garden without treatment encourages the proliferation of harmful bacteria such as amoeba and mosquito breeding amd also cause pollutants and fats in these waters to close openings in the soil leading to the death of plants (FAO., 2007).

Greywater sampling: Greywater samples for raw and treated grey water were collected on a monthly basis beginning in late January 2017 and ending in December 2017. Samples were labeled using waterproof markers and noted in hard-cover, bound field books. Samples were transported to the Al-Diwaniyah Environment Directorate Laboratories on ice in isolated containers. The parameters measured for the samples at the study site and in the laboratory included temperature, pH, total Biochemical Oxygen Demand (BOD), total Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), color, odor, total Nitrogen (TN), *E. coli*/100 mL bacteria and total coliform/100 mL bacteria. The analysis was carried out according to the standard method for examination of water and wastewater (APHA., 2005).

RESULTS AND DISCUSSION

The analysis of untreated greywater showed the high concentration of BOD and the increase in the number of fecal coliform bacteria which necessitates upgrading the treatment system used to obtain agricultural water quality for irrigating the garden without causing harm to public

Fig. 1: A proposal for the management of rural effluents at the household level

health or a component of the other environment. To evaluate the efficiency of processing and improving the quality of greywater, a treatment unit was implemented and periodic water samples were taken before and after treatment to obtain the best quality of greywater and to reduce the negative environmental effects in the long term. The treatment units are designed based on the environmental data of the site, the quality of the water discharged from the houses and the quality of the water required to exit the treatment system. The gray waste water treatment plant at the level of the designed house consists of the following sections:

- Septic tank
- Upflow anaerobic filter
- Multi-layer aerobic filter
- Storage tank

Table 3 and 4 shows the design criteria used in this research to design the greywater treatment unit at the household level.

Figure 1 shows the proposed management scheme of black and gray sewage in rural areas of Iraq and the reuse of greywater in the irrigation of gardens. Where the wastewater out of the house enters the sedimentation basin and fermentation by gravity, so that, the waste water is brought in close to the bottom. In this part of the plant the deposition of solids and the separation of fat by the special structure of the pipes which prevents fat from going into the next basins, this part of the bacteria reduces sulfur which is necessary to dismantle many chemicals such as washing powder, ice and shampoos (Fig. 2).

The water is transferred to the second basin which contains gravel of 3 cm^3 (20-40 mm) in size which grow bacteria that feed on organic matter and turn it into raw

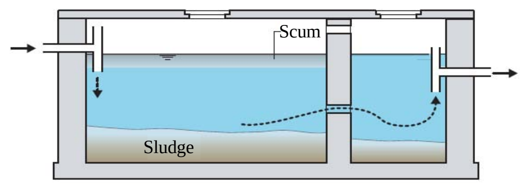

Fig. 2: Septic tank (Morel and Diener, 2006)

Table 3: Design criteria of sedimentation tank

Parameters	Ranges
Detention time (h)	1-2
Surface loading rate (l\h\m^2)	500-750
Depth of tank (m)	0.6-1.0
Length to width ratio	3:1-4:1

Table 4: Design criteria of roughing filter (Up flow-down flow)

Parameters	Ranges
No. of compartments	3-4
Media and size (mm)	Gravel (20-40)
	Gravel (5-20)
	Course sand (1-5)
	Fine sand (0.1-1)
Hydraulic loading (m^3/m^2-h)	0.1-0.3
Depth of media (m)	0.4-0.6
Capacity in opopulation equivalent (Person)	Up to 8
Rate of water supply (l/person/day)	150

materials, energy and gases including carbon dioxide and methane. The water naturally flows to the third basin which also contains 1 cm^3 (5-20 mm) gravel. The second basin, the only difference between the two basins is that the first basin contains spaces of a large size do not close by the sediments and bacterial blocks resulting from the high concentration of organic substances in this basin and this leads to the natural cleaning of the bacteria making their number is always limited. The second gravel is characterized by low organic matter and the surface that the bacteria can use is large, so, the spaces are not closed and there is a greater chance of getting rid of the rest of

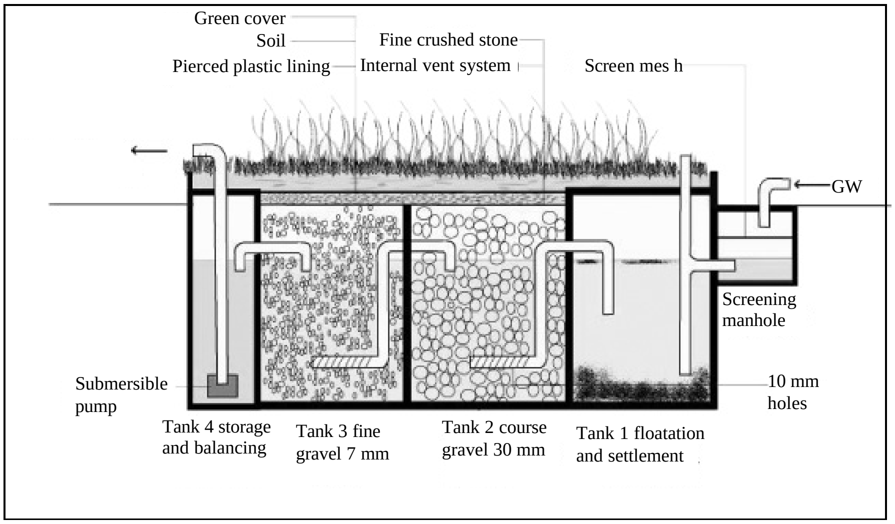

Fig. 3: The purification plant

the organic matter. Water is also naturally transferred to the fourth basin and is for assembly only. All this process is done in the absence of air (anaerobic) and therefore, the water collected in the fourth basin are free of dissolved air and contain suspended substances formed decomposing substances and bacteria.

The treated water is then transferred from the fourth basin by a pump to a three-layer air filter consisting of small gravel, a layer of coal and a sand layer. This water acquires some oxygen and also removes the suspended material that may close the irrigation system if it remains in the treated water. After this stage, the treated water can be treated with care by a suitable irrigation system to irrigate the tree plantations or the plants that are eaten and cooked (Fig. 3-5).

To ensure the quality of treated greywater used in irrigation, a periodic water monitoring program was implemented before entering the treatment unit and after treatment. Table 5 shows the results of biological analyzes of the most important criteria, where the concentration of BOD and COD in the water after treatment is noted in 97 and 93%, respectively.

The Iraqi standard for the use of greywater in irrigation determines the BOD concentration of 20 mg/L. Accordingly, the water discharged from the treatment unit is in compliance with the Iraqi standard and can be used for irrigation.

Table 5 shows that the concentration of chemically and biologically absorbed oxygen has been reduced in treated greywater compared with it after treatment. The greywater before treatment is very saturated with fecal coliform bacteria and total colon bacteria and the numbers of these bacteria decreased after treatment. Fecal

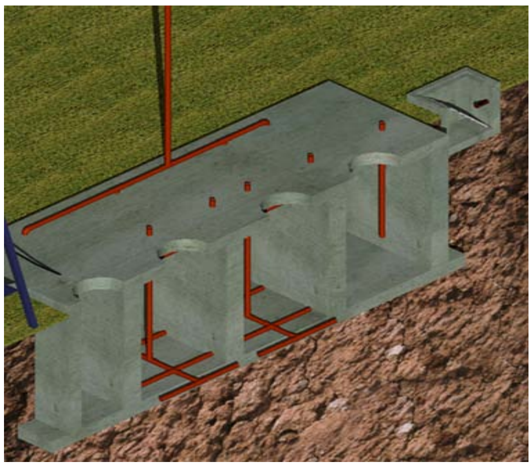

Fig. 4: Vertical section of the household purification plant showing the basins and placing the internal pipes in them

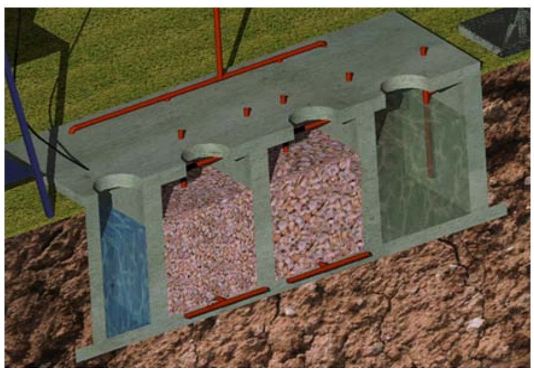

Fig. 5: Vertical section of the house purification plant shows the basins and the laying of gravels

Table 5: Results of biological analyzes of water

Months (2017)/Parameters	Before treatment	After treatment
January		
BOD mg/L	278	11.7
COD mg/L	442	29
E. coli/MPN/100 mL	50	0.20% per mL
Total coliform/MPN/100 mL	129.4	0.30% per mL
Temperature	15°C	15°C
TSS	350 mg/L	5 mg/L
Color	Black	No color
Odor	Foul gas	Odourless
TN	30 mg/L	8.5 mg/L
pH	7.4	6.8
March		
BOD mg/L	276	6.5
COD mg/L	343	24.7
E. coli/MPN/100 mL	53	0.20% per mL
Total coliform/MPN/100 mL	123	0.30% per mL
Temperature	20°C	20°C
TSS	380 mg/L	11 mg/L
Color	Black	No color
Odor	Foul gas	Odourless
TN	46 mg/L	6.5 mg/L
pH	7.1	6.5
May		
BOD mg/L	320	10.9
COD mg/L	409	41.8
E. coli/MPN/100 mL	43	0.20% per mL
Total Coliform/MPN/100 mL	132	0.30% per mL
Temperature	22°C	22°C
TSS	350 mg/L	3 mg/L
Color	Black	No color
Odor	Foul gas	Odourless
TN	56 mg/L	8.5 mg/L
pH	7.5	6.9
July		
BOD mg/L	260	6.8
COD mg/L	378	23.5
E. coli/MPN/100 mL	48	0.20% per mL
Total coliform/MPN/100 mL	123	0.30% per mL
Temperature	28°C	25°C
TSS	256 mg/L	11 mg/L
Color	Black	No color
Odor	Foul gas	Odourless
TN	45 mg/L	7.3 mg/L
pH	6.7	7.0
September BOD mg/L		
254	7.8	
COD mg/L	343	24.8
E. coli/MPN/100 mL	46	0.20% per mL
Total coliform/MPN/100 mL	125	0.30% per mL
Temperature	20°C	22°C
TSS	400 mg/L	4 mg/L
Color	Black	No color
Odor	Foul gas	Odourless
TN	85 mg/L	12.5 mg/L
pH	7.1	6.7
NovemberBOD mg/L		
289	8.8	
COD mg/L	432	23
E. coli/MPN/100 mL	52	0.20% per mL
Total coliform/MPN/100 mL	128	0.30% per mL
Temperature	16°C	16°C
TSS	320 mg/L	5 mg/L
Color	Black	No color
Odor	Foul gas	Odourless
TN	56 mg/L	6.5 mg/L
pH	6.8	6.5

coliforms have ideal conditions for life: low temperature, high humidity, low solar brightness, up to 30 days in maximum water, 10 days in soil and 3 days on crop surface if suitable climatic conditions are not available in the project area. The water produced from the treatment unit is also colorless and odorless. The percentage of removal of suspended solids reached 94% and the nitrogen removal rate was 85 %. This results are encouraging and excellent.

CONCLUSION

From this study, we conclude the following: The current practice of collecting domestic wastewater in cesspits, siphoning and disposing of their contents by placing them in adjacent land will contaminate groundwater and pose a public health hazard.

There is a need to treat gray wastewater and use it in agriculture as a result of the acute shortage of fresh water available. Reuse of treated water will reduce the consumption of fresh water, especially, used in irrigation of the garden and eliminates the need for composting because of its efficiency in treated greywater. Water was produced with acceptable quality for irrigation purposes for household gardens.

IMPLICATIONS

The implementation and operation of the greywater treatment unit led to the withdrawal of wastewater from the septic tank or the cesspits as well as the lack of drainage of the soil and reduced the consumption of water used to irrigate the gardens. The use of grey treated wastewater to irrigate the garden can be accepted from a social and cultural point of view.

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