# Water Management in Existing Residential Building in Egypt (Grey-Water System)

Mohamed Abdel-All Ibrahim, Ali Fouad Bakr, Abdel-Aziz Farouk Abdel-Aziz

**Abstract** —Throughout history much of the world has witnessed ever-greater demands for reliable, high-quality and inexpensive water supplies for domestic consumption, agriculture and industry. In recent decades there have also been increasing demands for hydrological regimes that support healthy and diverse ecosystems, provide for water-based recreational activities, reduce if not prevent floods and droughts, and in some cases, provide for the production of hydropower and ensure water levels adequate for ship navigation. Water managers are challenged to meet these multiple and often conflicting demands. At the same time, public stakeholder interest groups have shown an increasing desire to take part in the water resources development and management decision making process. Added to all these management challenges are the uncertainties of natural water supplies and demands due to changes in our climate, changes in people's standards of living, changes in watershed land uses and changes in technology.

Egypt is approaching the point where water demands are exceeding supplies. This situation will necessitate improved decision making for water resources planning. Integrated management represents a unique approach, incorporating both temporal and spatial variations of the problem. To achieve an integrated procedure, efforts are being made to resolve numerous issues ranging from loss of agricultural lands to farmer involvement in the decision-making process. The first part of this paper describes the water resources and the water scarcity in Egypt. The second part describes the application of integrated management to water planning, water quality and the irrigation improvement program. Grey water is one of the promising solutions for reducing the water consumption in the residential sector and agriculture in Egypt. The paper case study applied the grey water system in the Wardan railway training centre throughout using the underground water in the staff housing unit for house and irrigation.

**Index Terms**— Integrated water management, Water scarcity, Domestic consumption, Irrigation, Grey water, Water quality.

## 1. INTRODUCTION

As per a recent study, by the year 2020 water shortage will be a serious worldwide problem. Our water resources will not be sufficient anymore. So an environmental approach is not only a good thing, it is necessary if we want our children to have water when they grow up. Of all the water in the world, only 3% is fresh. Less than a third of 1% of this is available to humans. The rest is frozen in glaciers or polar ice caps, or is deep within the earth, beyond our reach. To put it another way, if 100 liters represents the world's water, little more than half a tablespoon of it is fresh water available for our use. However, fresh water is essential to our existence, it allows us to produce food, manufacture goods and sustain our health. In fact, about 70% of our body is comprised of water. Global water consumption has risen almost tenfold since 1900, and many parts of the world are now reaching the limits of their supply. World population is expected to increase by 45% in the next thirty years, while freshwater runoff is expected to increase by 10%. [6]

### 1.1Problem Statement

One third of the world's population is already facing problems due to both water shortage and poor drinking water quality. Effects include massive outbreaks of disease, malnourishment and crop failure.

Furthermore, excessive use of water has seen the degradation of the environment costing the world much more of money. UNESCO has predicted that by 2020 water shortage will be a serious worldwide problem.

Egypt is approaching the point where water demands are exceeding supplies. Fig. 1 shows the approximate daily water use per person in Egypt 2010.


- *Prof. Dr. Mohamed Abdel-All Ibrahim, Architectural Department, Faculty of Engineering, Alexandria University, Egypt, E-mail: abdelallmai@yahoo.com*
- *Prof. Dr. Ali Fouad Bakr, Architectural Department, Faculty of Engineering, Alexandria University, Egypt, E-mail:ali.bakr.9883@facebook.com*
- *Architect: Abdel-Aziz Farouk Abdel-Aziz Mohamed, PhD Student at, Architectural Department, Faculty of Engineering, Alexandria University, Egypt, E-mail: abdelazizfarouk2001@yahoo.com*

ISSN 2229-5518

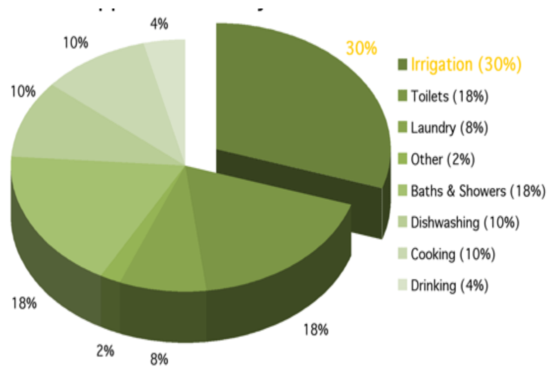


Fig 1. Approximate daily water use per person [13]

## 1.2 Research Aim

- To reduce the consumption of potable water in the home, and encourage the recycling of used water (grey water) for external water used.

## 1.3 Research Objectives

- Introduce a model for a family house that depends mainly on grey water system to run the appliances and human activities.

- Encourage owners and operators of existing buildings to implement sustainable practices and reduce the environmental impacts of their buildings especially in water consumption

## 1-4 Research Methodology

The methodology of this research adapted the following methods to reach its aim and objectives:

- Define the water resources and water scarcity in Egypt (water crisis in Egypt)

- Review the different experience in environmental practices of water management in the residential and irrigation sectors

- Study the environmental benefits of the grey water systems as well as the cost saving.

- Apply the grey water system in a case study in Egypt & analyse the costs of its applications

- *Prof. Dr. Mohamed Abdel-All Ibrahim, Architectural Department, Faculty of Engineering, Alexandria University, Egypt, E-mail: abdelallmai@yahoo.com*
- *Prof. Dr. Ali Fouad Bakr, Architectural Department, Faculty of Engineering, Alexandria University, Egypt, E-mail:ali.bakr.9883@facebook.com*
- *Architect: Abdel-Aziz Farouk Abdel-Aziz Mohamed, PhD Student at, Architectural Department, Faculty of Engineering, Alexandria University, Egypt, E-mail: abdelazizfarouk2001@yahoo.com*

## 2 Water Systems Principles

### 2.1 Water Supply

- Rainfall: It is insufficient to sustain planting.
- Surface water: It is the main traditional source of water; it is abstracted from rivers, or lakes.
- Ground water: It is abstracted from wells using simple suction pumps.
- Grey water: Which is reused water particularly treated sewage effluent (TSE).

### 2.2 Irrigation Systems

- Surface (flood irrigation):
  It has the lowest water use efficiency because a substantial proportion of the applied water is lost in evaporation, this can cause problems of water logging and salinity build-up if sub soil drainage is poor.
- Sub-surface irrigation:
  Underground trickle is extremely efficient in terms of water use. The major drawback of sub-surface systems is that they cannot utilize saline water.
- Sprinklers:
  It is more efficient than surface systems. Although evaporation losses are still a major factor, percolation losses are considerably reduced.
- Trickle irrigation:
  It is extremely efficient in terms of water use. It has been estimated that a trickle system will use 66% of the amount of water that a sprinkler system will use and only 40% of the water required by a surface irrigation system as shown in fig. 2. [3]

Trickle is the most suitable system for use with TSE.

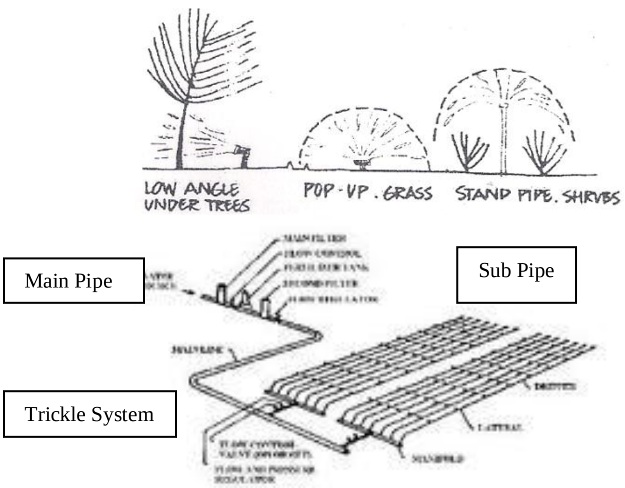


Fig. 2. Sprinkler and trickle irrigation systems [3]

### 2.3 Grey Water Systems

- Gray water is water that is mildly soiled from washing, bathing or showering, as opposed to "black water", which is water flushed from toilets as shown in fig. 3.
- Water from kitchen sinks, dishwashers, and washing machines also counts as black water due to its high level of combination from detergents, grease and organic matter. Grey water cannot be simply collected and reused; it must first be filtered and treated. There will be a risk of disease and plumbing blockages, after treatment, it can be used for garden irrigation or toilets flushing. Systems to recycle grey water have become increasingly prominent in recent years. [13]

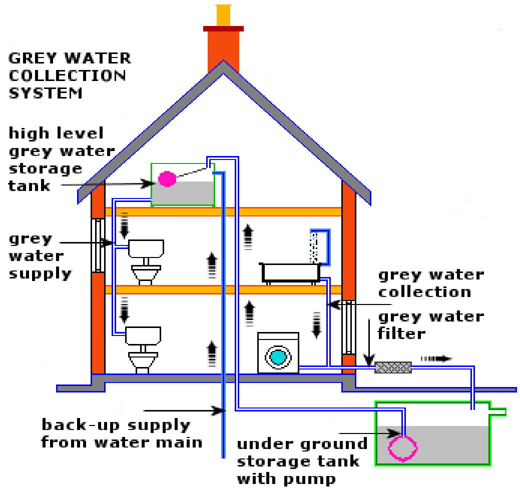


Fig. 3. Grey water systems [12]

grey water is first coarsely filtered through crushed stone or gravel, then run through reed beds to be biologically purified by microorganisms feeding among the roots of the plants. [14]

### What is gray water?

- Any water that has been used in the home, except water from toilets, is called grey water. Dish, shower, sink, and laundry water comprise 50-80% of residential "waste"

ISSN 2229-5518

water. This may be reused for other purposes, especially landscape irrigation.

### Why use gray water?

- It's a waste to irrigate with great quantities of drinking water when plants thrive on used water containing small bits of compost. Unlike a lot of ecological stopgap measures, grey water reuse is a part of the fundamental solution to many ecological problems and will probably remain essentially unchanged in the distant future.

### The benefits of grey water recycling include:

· Lower fresh water use
· Less strain on failing septic tank or treatment plant
· Grey water treatment in topsoil is highly effective
· Ability to build in areas unsuitable for conventional treatment
· Less energy and chemical use
· Groundwater recharge
· Plant growth
· Reclamation of otherwise wasted nutrients

### Saving cost

Grey water systems can help you save 35% to 40% on your annual water bill, and while saving money, you will also help save the environment and provide a better future for our children and their children to come. With this amount of savings, your Grey water Recycling System pays for itself. [11]

### 2.4 Composting Toilets

One dynamic way of cutting water consumption is to install a composting toilet- a waterless system that breaks down human waste matter into organic compost.
A shaft directly to a large scaled container in a basement or lower level connects the toilet. Air circulates through the container to break down the waste matter and an exhaust vent extracts smell and emits them above the roof as shown in fig. 4. There may also be a shaft for adding organic waste from the kitchen and another opening for adding garden waste. Large containers only need to be emptied every couple of years. [15]

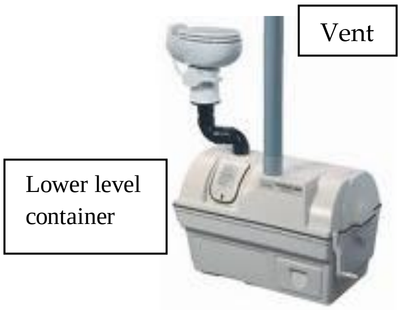


Fig. 4. Composting toilets (Wilhide, 2003)

## 3. Water Management in Egypt

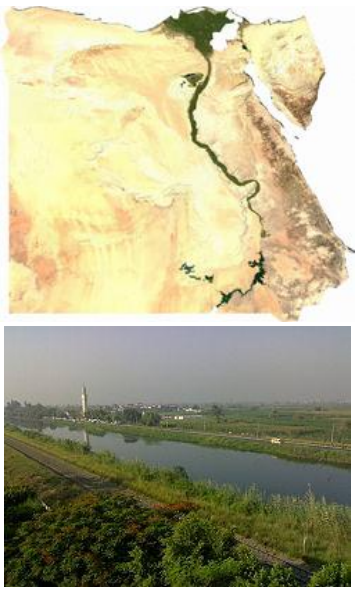

Fig. 5. Green irrigated land along the Nile amidst the desert [11]

The management of water supply and sanitation is practiced since at least 5000 years ago in Egypt. At that time, it was a challenge how to make use of flash floods. Like today, agriculture was the major water-consuming sector and therefore ancient Egyptians focused mostly on irrigation. Ancient Egyptians had only one season in which they cultivated the lands, which were enough since the population was much, lower than today. [11]

### 3.1 Recent development

The current problems and scenarios for the future are putting Egypt in a situation to review its water policy. In order to meet new challenges which refer to water scarcity, infrastructural needs, environment, socio-economic developments and water allocation, new solutions concerning conservation and protection and thus new policies are needed. For those reasons, the National Water Resources Plan has been established. The whole idea is based on an integrated water resources management approach. The plan has three major steps:

Cooperation with Nile basin riparian countries and the development of new water resources

Increasing the water use efficiency and making better use of the existing water resources.

Protection of water quality and environment

Recent developments in Egypt are also concerned with private participation processes. Furthermore, Egypt is engaged in several mega projects like Toshka, North Sinai and South Valley. [11]

### 3.2 Current Water Resources

Egypt depends for 97% of its water supply on the Nile. Rainfall is minimal at 18 mm per year, occurring mainly during autumn and wintertime. The 1959 Nile waters treaty between Egypt and Sudan allocates 55.5 billion cubic meter of water per year to Egypt that as shown in table 1, without specifying any allocation for upstream; riparian is besides Sudan (18.5 billion cubic meters per year). There is no water sharing agreement among all ten riparian countries of the Nile. However, the riparian countries cooperate through the Nile Basin Initiative. [11]

TABLE 1

Water Resources in Egypt (Billion)

| Source | 2002/ 2003 | 2003/ 2004 | 2004/ 2005 | 2005/ 2006 | 2006/ 2007 | 2007/ 2008 | 2009 |
|---|---|---|---|---|---|---|---|
| Nile | 55.5 | 55.5 | 55.5 | 55.5 | 55.5 | 55.5 | 55.5 |
| Ground Water | 5 | 5 | 5.5 | 5.9 | 6.2 | 6.6 | 6.6 |
| Treated waste Agricultural | 4.4 | 4.8 | 5.1 | 5.3 | 5.9 | 6.7 | 7.8 |
| Municipal Treated waste | 0.7 | 0.8 | 0.9 | 1.1 | 1.3 | 1.55 | 1.8 |
| Floods & Rain | 1 | 1.1 | 1.1 | 1.1 | 1.3 | 1.3 | 1.3 |
| Water Sea desalination | 0 | 0 | o | 0.06 | 0.06 | 0.06 | 0.06 |
| Total | 66.6 | 67.2 | 68.1 | 68.96 | 70.26 | 71.71 | 73.06 |

*Source:[4]*

Egypt has four main groundwater aquifers: the Nile Aquifer, the Nubian Sandstone

Aquifer, the Moghra Aquifer between the West of the Nile Delta and the Qattara Depression, and coastal aquifers on the North western coast. The Nile Aquifer, the Moghra Aquifer and the Coastal Aquifer are renewable. The Nubian Sandstone Aquifer is non-renewable. (Ministry water Resources and irrigation, Egypt 2009)

### 3.3 Water Scarcity

Egypt's water resources based on current agreements range from a total of 66.6 billion cubic meters in 2002/2003 to 73.06 billion cubic meters in 2008/2009 (as

ISSN 2229-5518

shown in table 5.4) these amounts are distributed between agricultural use (from 57.8 to 60.5 billion m3 /year), to domestic, industrial and other uses as shown in table 2.

TABLE 2
WATER CONSUMPTION IN EGYPT (BILLION METERS CUBE/YEAR)

| Sector | 2002/2003 | 2003/2004 | 2004/2005 | 2005/2006 | 2006/2007 | 2007/2008 | 2009 |
|---|---|---|---|---|---|---|---|
| **Agriculture** | 57.8 | 58.5 | 58.5 | 59 | 59.3 | 60 | 60.5 |
| **Evaporation losses** | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 |
| **Domestic uses** | 5.4 | 5.7 | 6.05 | 6.5 | 7.5 | 8.2 | 9 |
| **Industry** | 1.1 | 1.1 | 1.15 | 1.15 | 1.15 | 1.2 | 1.25 |
| **River Navigation** | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 |
| **Total** | 66.6 | 67.2 | 68.1 | 68.95 | 70.25 | 71.70 | 73.05 |

*Source: [4]*

### 3.4 Water Use

Egypt is using around 95 % of the available water, which is very critical. Around 86 % of water is used for irrigation, 8 % for domestic purposes and another 6 % by industry as shown in fig. 6 [8]

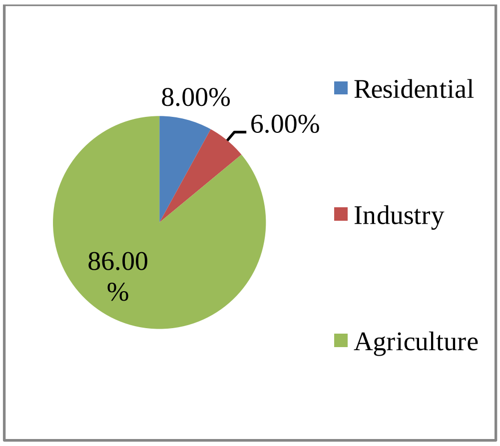


Fig. 6. Water use allocation in Egypt [8]

The individual annual share of current and expected available water has decreased from 2604 m3/year in 1947 to 860 m3/year in 2003 and expected to come down to 582 m3/year with increasing population table (3). Egypt has been facing scarcity of water (share of less than 1000 m3/year) since 1996 [2].

TABLE 3
AVERAGE INDIVIDUAL'S SHARE OF WATER (PAST, PRESENT AND FUTURE) UNIT = M3

| Year | Average Individual's share of water ($m^3$/year) | Change in Individual's share (%) compared to 1947 |
|---|---|---|
| **1947** | 2604 (water plentiful) | - |
| **1960** | 1893 | -27.3% |
| **1970** | 1713 (sufficiency water) | -34.2% |
| **1986** | 1138 | -56.2% |
| **1996** | 936 (water scarcity) | -64.1% |
| **2003** | 860 | -67% |
| **2025 (expected)** | 582 (poverty water) | -77.6% |

*Source: [4]*

Water consumption in the house in Egypt is shown in the fig. 6


Fig. 7. Water consumption in the house [7]

## 1.

## 2. 4. Case Study: Renovation of Railways Training Institute, Wardan, North Cairo, Egypt

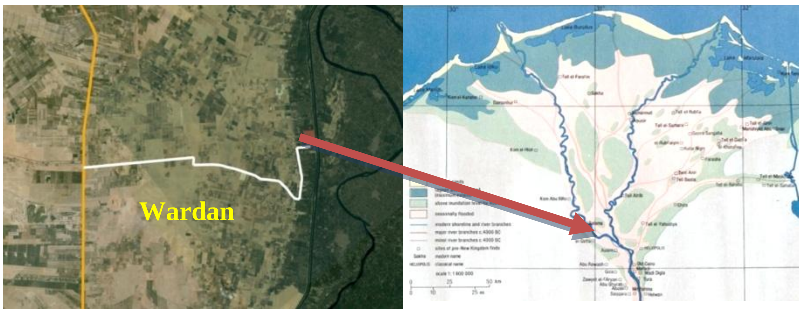


Fig. 8. Wardan institute, North Cairo, Egypt (Google Maps, 2010)

### Location

Wardan Training Institute is located at kilo 58 Cairo/Alexandria desert road, North Cairo, Egypt. It is located at latitude 30o 22'N, and longitude 30o 27'E, and it is 50 kilometres north-west Cairo as shown in fig. 8.

Area: Wardan institute area is 150 acres with its 20 acres garden as shown in fig. 9.

Design: Architect: Ezat, H. Abougad, Alexandria, 1964 (Who was one of the pioneers of the Egyptian architectural in the 20th century.)

### Background

The railway industry is considered a special type of industry that requires a certain technical and cultural level of employees, which cannot be obtained from the usual schools or institutes or universities. So Wardan training center considered one of the promising and advanced training center in the middle-east.

Fig. 9. Wardan Campus & Staff Housing Zone [1]

### 4.1 Staff Housing Unit Description

Orientation: All villas are oriented to north, south and they with two stories as shown in the fig. 10.

Ground Floor: Entrance hall, living area, dining room, office room, kitchen, housekeeper room, toilet and terraces

First floor: Three bedrooms, bathrooms, upstairs sitting area, kitchen, toilet and terraces

Fig. 10. Proposed ground, first floor plan [9]

### 4.2.1 Water Management

#### Water Sources

Water sources at Wardan institute are from Nile River (Elbaheiry branch) and underground water from two wells.

#### Proposed Indoor Materials

- Remove all lead pipes, asbestos pipes, and water supply iron pipes from villa

- Using polypropylene pipes for water supply and polyethylene pipes for drainage system

- Water supply system is a poly polypropylene pipe.

- Sewage system is a polyethylene pipes

- In order to avoid the growth of legionella (fresh water bacteria), thermostats in water tanks should be set to 55 deg C and lipped fitted lids should be placed securely over water tank. Fig.11 shows the existing indoor materials in the case study unit and the proposed materials for the water system (water supply and drainage system).

Fig. 11. existing bathroom & Poly polypropylene pipes in water supply system in the villa bathrooms [8]

#### Proposed Water System (Grey water system)

- Reuse water coming from basin and shower for toilet flushing and storage it in the underground water tank, and reuse the grey water to irrigate the villa garden after filtration as shown in fig. 12.

- Collect rainwater from roof and storage it into underground water tank.

- Hot water from solar hot water system.

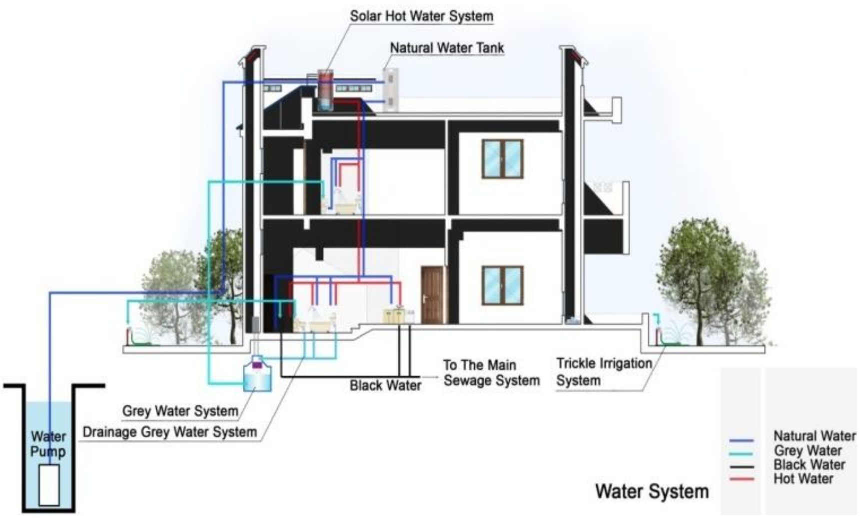


Fig. 12. Proposed grey water system in the Wardan staff housing unit cross section [8]

## Grey Water System Cost

Table 4 shows the comparing between the costs of grey water system in the wardan staff housing unit and the costs of the conventional method of water supply and consumption in the case study unit.

TABLE 4

Comparing between the typical and proposed renovation budget (Water management)

| Items Work | Typical Renovation | Typical Budget | Proposed Renovation | Proposed Budget | Saving |
|---|---|---|---|---|---|
| Plumping Works | Wells, tanks, piping and plumping features. | 40,000 EGP | Piping and plumping features. | 20,000 EGP | -20,000 EGP |
| Underground Water | – | – | Submergible pump in the well and water tank | 10,000 EGP | +10,000 EGP |
| Grey-water System | – | – | Grey water filter, pump and underground tank | 5,000 EGP | +5,000 EGP |
| Total EGP | | 40,000 | | 35,000 | -5,000 |

*Source [6]*

The conclusion of this comparison explains that the proposed renovation budget of Wardan staff housing unit is lower than the existing renovation budget. In addition to the proposed renovation is eco friendly than the existing case. (Total cost saving is 12.5%)

Fig. 13 shows the Wardan staff housing unit perspective before and after proposed renovation project with the ecological features such as photovoltaic panels, solar hot water, water tank, grey water tank, filtering tank, trickle irrigation system and natural ventilation systems. [8]

Fig. 13. Wardan staff housing unit perspective (before & after renovation) [9]

## 3. 5. Conclusions

- Water saving should be managed efficiently to control the waste water throughout the grey water system in the buildings and irrigation.

- Grey water recycling system is a must for anyone who cares about the environment.

-Grey water system to reduce the water consumption

-Trickle system is the preferred irrigation system in the house gardens to saving the potable

-Water saving should be managed efficiently to control the waste throughout the grey water system in the buildings and irrigation.

-Grey water should be filtered before using in the irrigation systems

-Water management policies must recognize the need to shift from the "business as usual" supplying more to meet the demand, to the demand management approach that manipulates demand to match the supplies.

To apply the water management in Egypt should be made these procedures:

1. An assessment of the available water resources (current and potential) and the past, current and future water demands by all water user groups.

2. Allocating water, in quantity and quality, amongst the competing water using groups to ensure meeting the public interest as defined by the national socioeconomic objectives.

3. Establishing water efficiency targets for each water users group.

4. Identifying water efficiency performance indicators to monitor the performance of each water using group.

5. Establishing an incentive or disincentive system to enforce the demand management approach.

6. Designing and executing sustained water efficiency programs integrated within the operation of each water using group.

7. Monitoring the performance of the water efficiency programs of each user group and undertaking the necessary adjustments.

## 4.

## 5. REFERENCES

[1] Abou Gad, K. H. (2008). "Wardan Training Institute Project Documents", Projects Management Department, Architectural Consulting Firm, Alexandria, Egypt

[2] Abo Zaid (2008). Integrated Water Resources Management Plan, Ministry of Water Resources and Irrigation

[3] Ali, T. C. and Brown Jane (1977). "Landscape Design for the Middle East", RIBA, London

[4] Bishay, A. (2010). "Future Intermediate Sustainable Cities", a message to future generations". First International Conference Sustainability and the Future: BUE the British University in Egypt, 23-25 November 2010.

[5] Egyptian Railways, (2010). "Wardan Training Institute Renovation project's documents", Construction & Environmental Management, Egyptian Railways, Cairo, Egypt

[6] FAO (2009). Aqua stat: Country profile Egypt. Retrieved November 15, 2009

[7] Farouk, A. (2011). "An Ecological Residential Buildings in Egypt" Published MSc Thesis, Architectural & Environmental Design, Arab Academy for Science, Technology & Maritime Transport, Alexandria, Egypt

[8] Goueli, A. (2002). "The Future of Agriculture in Egypt", FEDA Earth Day 2002 Conference

[9] Low Energy House (2011). " Grey Water Systems in the Houses" http://www.lowenergyhouse.com/grey-watersystems.html. [Accessed in 10/6/2011]

[10] Ministry of Water Resources and Irrigation; Egypt (2009), Integrated Water Resources Management Plan, Retrieved on November 7, 2009

[11] Sydney and Loan Baggs (1996). "The healthy House", Thames and Hudson, London

[12] Wilhide, E. (2003). "ECO", Rizzoli, New York, USA

[13] (http://www.udcinc.org/approximate_daily_water_use.gif)