Greywater Recycling Systems for Southwest Morocco

An Interactive Qualifying Project Supplementary report submitted to Association Dar Si Hmad for Development, Education and Culture, and Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science.

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Introduction

This document presents our findings and analysis of three greywater recycling systems and their implementation in the Aït Baâmrane region of southwest Morocco. Supporting this, we provide a recommendation on the optimal recycling system we found based on technical, regional, and cultural considerations. Drawing on our research and findings, we raise further areas of investigation for Dar Si Hmad in employing greywater recycling initiatives.

The Context and Need for Greywater Management

Throughout the rural areas of Morocco, there is a widespread lack of available clean water sources. The Amazigh villages surrounding the Anti-Atlas Mountains have a steadily declining water supply and poor access to the few sources that exist. Standing just a few kilometers outside of the city of Sidi Ifni are seven villages that are located at the base of these mountains. The demand for water is putting strain on not only the people, but the land around them. This region, located in close proximity to the Sahara Desert, shares many characteristics with the desert including an arid climate and a lack of bountiful water cycles. Per capita available water resources in all of Morocco are an estimated 700 m^3 per year for a population of 32.5 million. Annual per capita water availability is expected to drop to less than 400 m^3 by the year 2020 (The World Bank, 2009).

Allocation of water in Morocco is heavily geared towards agricultural applications. Current irrigation practices are inefficient, which has led various water sources to be heavily strained. Agricultural irrigation is allocated 83% of withdrawn water, leaving the rest for municipal, tourism, and industrial uses (The World Bank, 2009). Even with so much of Morocco’s water consumption used by agricultural irrigation practices, only 15% of the total agricultural land is irrigated. This leaves a majority of agricultural lands to have a heavy dependence on rainfall (USAID). This lack of efficient crop irrigation in Morocco leads to mass quantities of water being wasted; evaporation from the top soil causes the farmers to use a significant amount of extra water to produce prosperous cash crops. Efficient irrigation processes have poor adoption rates, causing a large portion of water used in agricultural irrigation to be lost due to evaporation. Additional water is needed to properly grow crops in these regions, leading to dwindling water supplies in rivers and groundwater sources. Residents of rural Morocco depend on agricultural practices for their livelihoods and survival. With the already harsh environment becoming increasingly challenging to live in, many residents of rural villages decided to move away from the rural villages in an effort to obtain basic needs for survival.

In May 2015, Association Dar Si Hmad for Development, Education and Culture, launched a solution to the problem of drought in southwestern Morocco. After a decade of research Association Dar Si Hmad constructed and implemented an array of fog harvesting nets at the summit of Mt. Boutmezguida, which is located in the Anti-Atlas Mountains. The Fog Water Collection System supported those living in the Aït Baâmran region by providing them with potable water piped directly into their homes. This non-governmental organization has installed fog nets that span 600 square meters and 8 kilometers of pipelines (Dodson, 2014). The expected increase in water use resulting from the addition of the fog net supply leaves room for a more relaxed water management practices, and waste water. With the implementation of fog nets that support and sustain the villages, the Association Dar Si Hmad aims to not only increase water availability, but to utilize this newly available water without waste. They aim to close the water loop.

The water that is being used in the village on a daily basis has a one-time use lifespan, meaning that water is being discarded rapidly, when it could be reused for other purposes. Nearly 3% of total water usage in Morocco is treated and reused; this water recycling is in cities that have the facilities to treat the wastewater. Reuse of water in rural areas is important because there is no sewage system for the water to funnel down and be introduced to a water treatment facility to handle it; once the water is thrown out it becomes useless to the environment that desperately needs it.

Greywater Management Techniques

Reed Bed Filtration

Reed bed filtration use an arrangement of reeds with dividers inside the bed to section off water flow, making the greywater weave back and forth across the planted reeds that remove contaminants from the greywater. A mulch pre-filter to remove all the solid matter before it reaches the system to make the cleaning easier. The primary method of filtration in reed bed systems are from microorganisms developing on the roots of reeds, breaking down organic components and making conditions difficult for bacteria and viruses to survive. Excess nutrients within the greywater such as nitrogen are removed by the roots of the reeds.

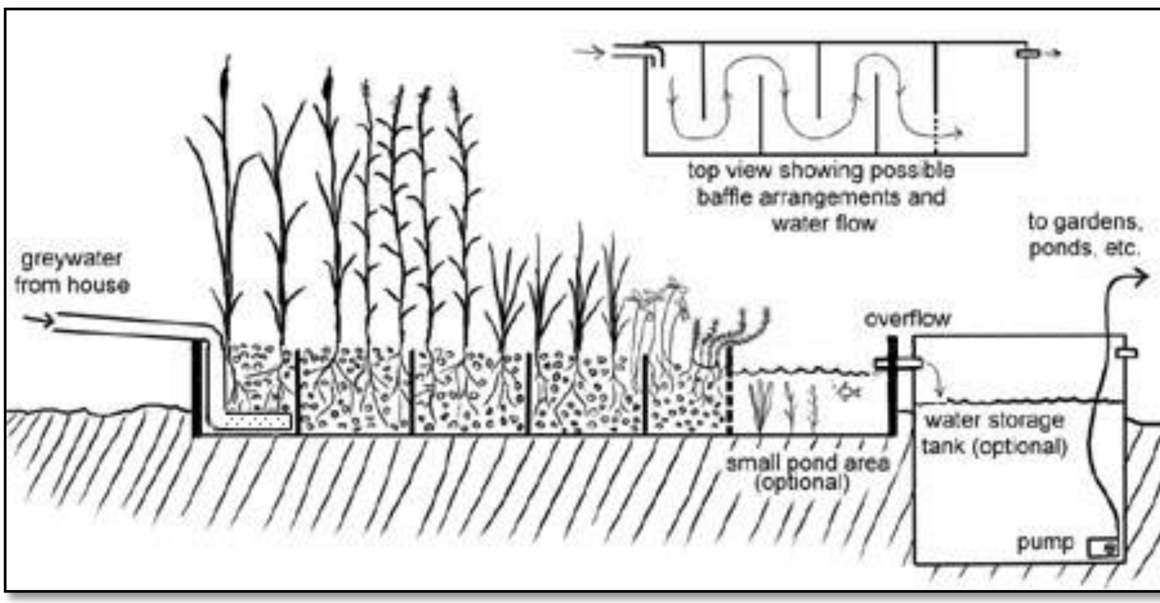

Figure 1: Reed Bed Filtration System (Bradley, 2012)

Materials

- Wetland Reeds (Refer to Table 1 in additional information for list of common wetland plants in Morocco)
- Gravel
- Plastic Liner
- Dividers
- Piping

Optional Materials

- Mulch - as a pre-filter
- Planter Box - for above ground

Strengths	Weaknesses
Can use indigenous plants to filter out pollutants	Water loss to evaporation
Can be used to remove harmful contaminants that would otherwise require special filters	Must have a constant supply of water
Reeds can rejuvenate	Must tend to plants
	Industrial chemicals would kill reeds

Placement Options

Reed beds need to be placed outdoors within a water tight system. If situated within the ground, the plot should have a plastic liner to enclose the system, preventing water from seeping into the ground. Otherwise the system can be positioned above ground with a suitable planter box.

Maintenance

Due to the presence of plants in the system, which require water and nutrients, upkeep is required quieter times of the year where passive household greywater generation is not enough to sustain the reeds.

Optimal Conditions

For households that already have greywater drains installed, adding a reed bed filtration system to the outflow of the drains would be ideal, providing that the surrounding land is suitable. Reed bed filtration units need to have an active water flow for sustainable operation. One large household may not produce enough greywater regularly to effectively maintain a reed bed system. Reed bed filtration could be effectively implemented through a village wide effort, being fed with greywater flows from multiple households. This effort would require land for the system installation, piping connecting participating households to the system, as well as an effective community garden. A village-wide effort may produce enough greywater and a controlled flow of water upstream prevents a system overflow of water when water usage is high during holidays or celebrations.

Additional Information and Building Guides:

Table 1: Indigenous Wetland Reeds

Wetland plants in Morocco	Description
Frankenia laevis	Pink flowered herb
Arundo donax	Very tall grass used as shelter belt and along river margins
Phragmites altissima	Reedmace
Juncus acutus Pointed	Sedge
Phoenix dactylifera	Along river edge
Tamarix gallica	Pink flowered shrub

(Upson, 2012)

Appropedia.org – Subsurface flow constructed wetland for greywater

Foodforest.com.au – Designing a reed bed

Sand Filtration

Sand filtration systems function by passing contaminated water through three layers of sand. The top-most layer of sand contains an active bio-layer that naturally forms after roughly ten days of consistent use. The system uses a barrel as an enclosure, commonly made with either plastic or concrete. Within the container are three layers; fine sand, course sand, and gravel. The sand for this system is layered in a way where the fine sand is the top layer, coarse the middle, and gravel the bottom. It is also important that the outflow tubing be positioned exiting the bottom of the unit and extends upward to be parallel to the top of the fine sand, so it keeps the active bio layer wet and does not drain the system of all of its water. The active bio-layer, made up of various microbes, functions to fight pathogens and contaminants within the water and has to stay moist to avoid dying out.

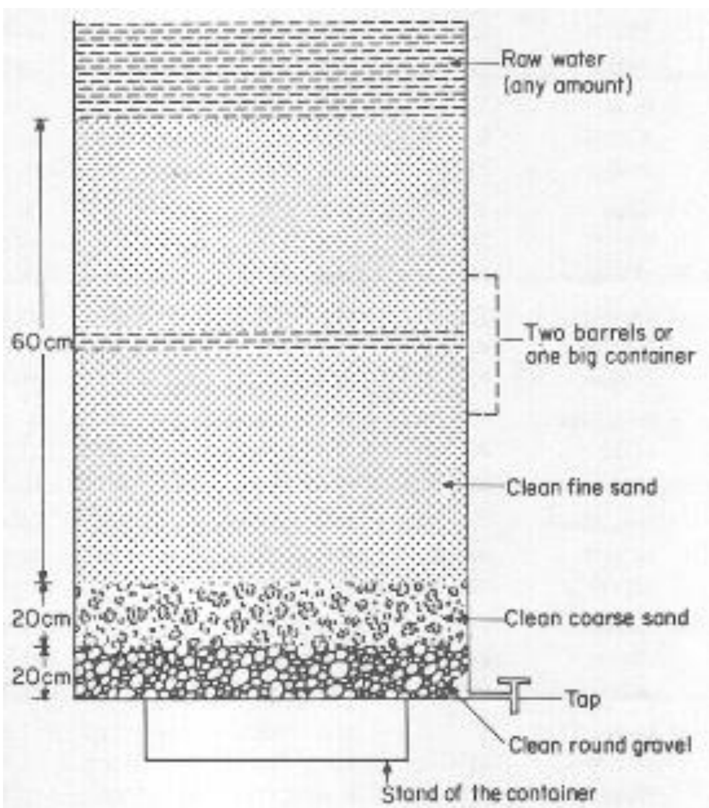

Figure 2: Diagram of a Sand Filtration System. (Dodson, 2014)

Materials

- Gravel
- Coarse Sand
- Fine Sand
- Sealable tank or barrel
- Drip plate
- Piping

Strengths	Weaknesses
Low costs to build	Large task to clean
Minimal regular maintenance	Susceptible to damage from chemicals
Versatile placement options	

Placement Options

Sand Filtration systems can be located above or in-ground. These systems are a barrel that may be placed anywhere as long as the space is available and the input and output of the system are located near the top of the system.

Maintenance

To clean the solar distillation unit, flush the basin with clean water to remove any possible buildup within the unit. Drain the water through the disposal valve instead of leaving the unit to process the liquids.

Optimal Conditions

Sand filtration units are adaptable and easy to implement system. This filtration unit can be varied to fit in almost any application. Since the unit can be placed above and below ground while being fully closed in both applications it can be located inside or outside of homes, only requiring enough space to fit the size filtration unit that has been constructed. Also because this system has the most attractive price-point it would be the best unit to implement to low income families.

Additional Information and Building Guides:

OasisDesign.net – Slow Sand Filtration

REUK.co.uk – Sand Filters for Greywater

Solar Distillation Unit

A solar distillation unit operates by evaporating the water at a lower temperature than the contaminants in the water would evaporate at, then condensing the water and capturing it. Typical solar distillation systems are a box or tray with a sloped piece of glass on top. The tray is colored black to absorb the most heat from the suns radiation. The water is pumped into the tray where it will sit and heat up as the sun's energy bypasses the clear glass and heats the tray. The water then evaporates and the resulting water vapor collects on the glass above it. After the water has condensed on the glass it beads up and rolls down the slope, where it drips into a small semi-circular tube where it is collected and ready for use.

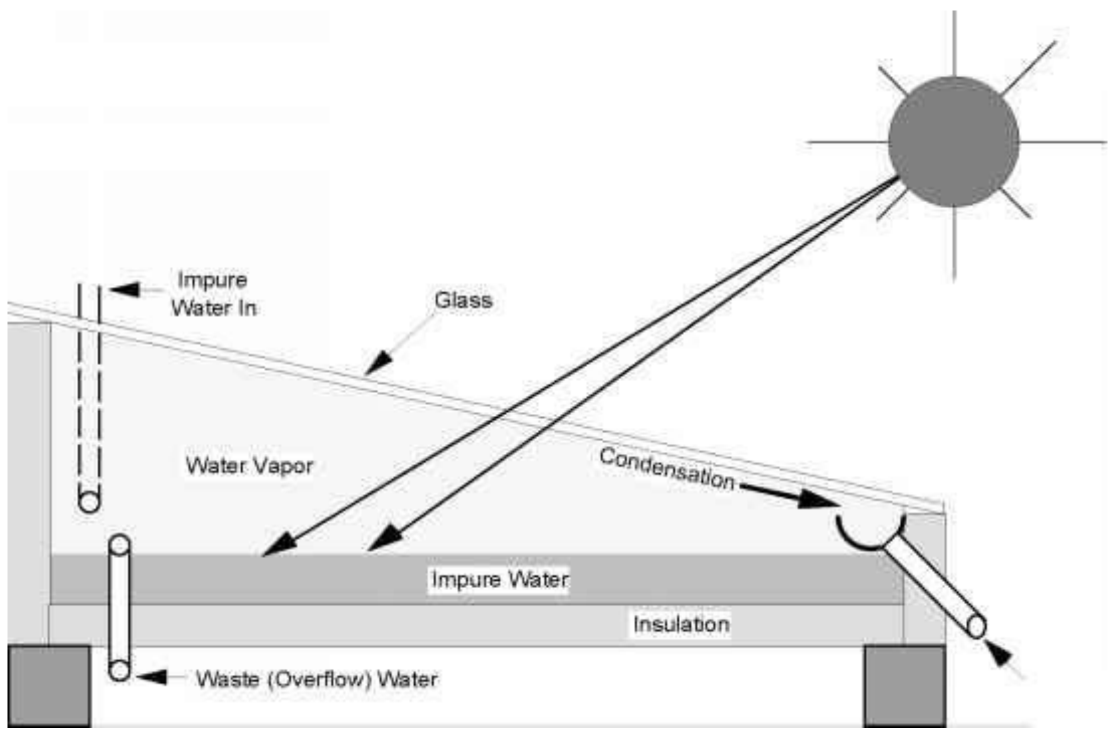

Figure 3: Solar Distillation Unit (McCracken, 2015)

Materials

- Glass Pane
- Black Trough
- Piping
- Gutter tubing
- Waterproofing bonding agent
- Frame for the still to sit on

Strengths	**Weaknesses**
Produces potable water	Produces chemical brine
Simple maintenance	Slow processing time
Works effectively in sunny environments	Requires large surface area
	Needs to be monitored during operation

Placement Options

Solar stills need to be placed in an outdoor location with high exposure to sunlight. This unit needs to be placed in a location that is preferably out of the path of any shadows. Depending on the desired output flow of distilled water, the units can vary in size. Large solar distillation units can take lots of space, limiting potential placement sites.

Maintenance

Operation of solar stills involves several steps. First, the greywater to be processed is poured into the bottom basin of the distillation unit. After some time has passed and the solar still has processed most of the greywater, the remaining greywater in the basin needs to be manually emptied and disposed separately. By routing a pipe from the disposal valve to nearby blackwater drainage, effort in operating the system can be reduced.

Optimal Conditions

Solar Distillation would be best implemented in a home with few people. Around two or three people's worth of greywater would be great for the capacity of this system. This family would have to be prepared to provide extra care for their recycling but would receive extra benefits from it in the form of potable water. This system would also be best suited for a home on the outskirts of a village or an isolated house, to minimize shadows that could interfere with the distilling process.

Additional Information and Building Guides:

Motherearthnews.com – How to Make a Solar Still

SolAqua.com – Solar Still Basics

i4at.org – Solar Water Distiller

Proposed Greywater System for the Dar Si Hmad House

Figure 4: Dar Si Hmad House in the Bled

Three greywater recycling options have been described above and considered as designs to be applied at the Dar Si Hmad house as seen in Figure 4. Our recommendation utilizes a sand filtration unit to be implemented at the site. The reason we make this recommendation is that this system will be the easiest to maintain during the intermittent time when no one occupies the house. Sand filtration does not require the constant influx of water that the reed beds require and in the future when the test house is inhabited, the greywater recycling unit will be able to handle the increased flow of water to be processed, unlike the solar distillation. The industrial cleaning products used in the house can be monitored and avoid bleach which will keep the bio-layer of the sand system safe. This is also a low cost option with the most accessible materials, which leads it to being the optimal test system to be observed and later used for a wide scale resource in the bled.

For ease of demonstrating the placement of the system we drafted up Computer Aided Design that we could mark up with a general overview of how the system should be placed, shown in Figure 5. The option for collecting the greywater for this system would be a sink basin mounted on the wall in the courtyard and for easier accessibility, piping the greywater directly to the sand filter. For this method to function through gravitational forces only, the collection basin would need to be positioned at a higher point relative to the top of the sand filter unit. This poses the issue of deciding the placement of the sand filter. The sand filter can be partially buried into the ground, allowing the collection basin to be lower. In turn, the exiting flow of the sand unit will also be lower.

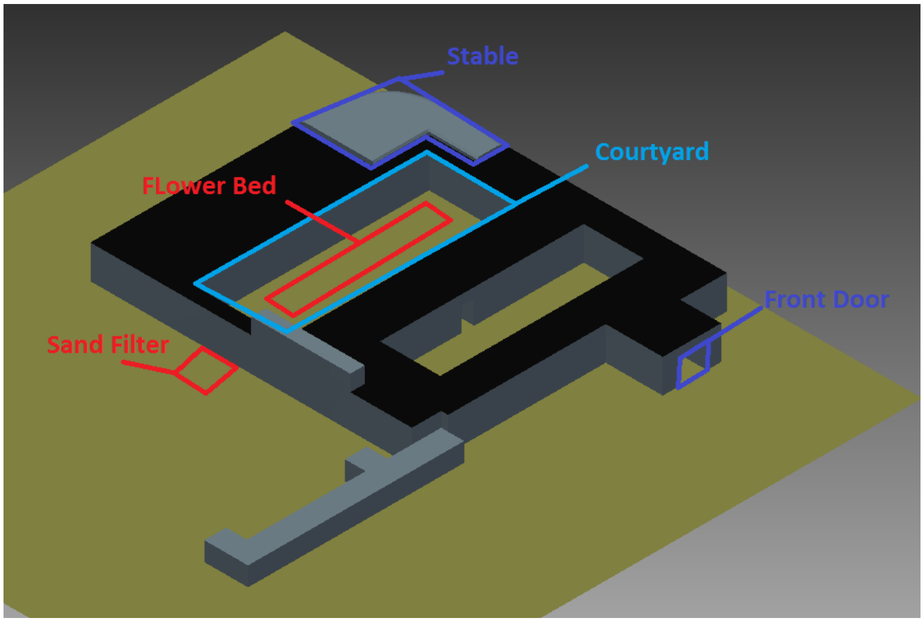

Figure 5: Computer Aided Design of Dar Si Hmad House

The end use is a garden in the middle of the courtyard because this helps with the aesthetic value of the house as well as impeding growth of the bushes that are growing there currently. With no evident use for the courtyard area, a garden would be an effective use of the space, due to the increased productivity of the land as well as straightforward process to implement. Not only would a garden be useful, but it could be also used as an educational demonstration for modern and efficient permaculture practices. When no one inhabits this building there can be shrubs or other indigenous plants, in place of decorative plants, that can survive without the system constantly running. Then when the building is being prepared for full-time occupants, switching to any other plant can be sustained in the climate with proper water management. In Table 2 is a list of plants we found to grow in the bled using sufficient watering practices.

This would help the system be used intermittently because if there are no plants to soak up the greywater in the system the water will be left to stagnate in the planter.

Table 2: List of Flora Discovered in the Bled

Fruit	Vegetable	Herb	Plant
Date	Carrot	Basil	Argan
Eggplant	Turnip	Parsley	Bamboo
Fig		Rosemary	Cactus
Lemon			Henna
Olive			
Orange			
Plum			
Pomegranate			
Tomato			
Watermelon			
Pumpkin			

Broader Implications and Future Considerations

Introducing a greywater recycling system into the bled enables every resident to preserve and extend the use out of their newly supplied resources. Any implementation of a greywater recycling system will come with expected maintenance each household will need to perform. Solar distillation, sand, and reed bed filtration all have their strengths and weaknesses but doing case studies of each recycling system in households who are open to introducing a new concept to their lives, will assist in the long run to determine which system works best in the bled.

The end-use applications for greywater can brighten their lives by having a garden for aesthetic appeal and the residents have the benefit of choosing to grow an edible, crafting, or decorative garden. Challenges in adding greywater recycling systems would be the locations of where each system will be placed. If there is not enough room on one family's property to implement the system appropriate for them then the groundwork in placing a system within a village brings the same problems faced in the fog water project. These issues are finding a property that the owners would accept placing necessary components for a community wide greywater recycling system on their land. These villages are clustered together as seen in Figure 6, and it could be hard to actually find a location to install a greywater recycling system without it infringing on multiple families plots of land.

Figure 6: A Tightly Packed Village in the Bled

Recycling greywater requires the community to be mindful of the chemicals that they have been introducing into the environment through their daily living. Educating the residents that greywater does not have to be carelessly discarded and can be filtered, treated, and used for more applications, as well in the long run saving some households money. Introducing greywater recycling to households will help close the water loop by maximizing the use of the excess water which is increasing daily.

Future research to be conducted is to test greywater produced at each household for the concentration of chemicals they contain. Specifically tests can be done looking primarily into the chemicals found in the products of Table 3. A thorough investigation of how the chemicals affect these three particular recycling systems would be required. Finding bio-friendly cleaning products available in southwestern Morocco and educating people to use them in substitution of major cleaning products found in this region would be a helpful endeavor.

Table 3: List of cleaning products used in the bled

Cleaning Materials Found in the Bled	Uses
Ace	Clothing, dishes, toilet
Babaria Cien	Body wash
Cadum	Personal hygiene
Care4Me Hand Wash Liquid (with aloe vera milk)	Hand soap
Essence of Musk	Toilet and remove odor (combined with water)
Exet	Bleach product
Force and Vitality Aux Oeufs	
Fraheur Shampoo	Personal hygiene
Hand Soap	
Javel Yaak	General cleaner
Magix	Dish detergent
Marvela	Liquid hand wash
O'kade soap	
Omo (laundry detergent)	Laundry Detergent
Oni	Dish detergent
Pine sol-like cleaner	
Taous	
Tide	Laundry Detergent
Top Bright	Shampoo
Traditional Bar Soap	

(Valcourt & Association Dar Si Hmad, 2015)

This recommendation leads into new opportunities for Dar Si Hmad to receive further input from the Aït Baâmrane people in what they would like to get out of a greywater recycling system. Informing the community that there are other means in maximizing their greywater is a step towards accepting recycling systems in their villages. It is inspiring to realize that the people of this region are open to new methods of improving their daily lives, and continual collaboration from the community will lead to an accelerated acceptance of greywater recycling.

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