Waste water system treatment assessment in the main house of Sunseed Desert Technology

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April 2012

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1 Introduction

Undoubtedly, an appropriate management of the grey water in Sunseed Desert Technology is a great opportunity for carrying out the clear vision of this project: *Sunseed Desert Technology aims to develop, demonstrate and communicate accessible, low-tech methods of living sustainably in a semi arid environment.*

It's an opportunity for developing an efficient and low-tech solution for the treatment of the waste water. At same time, we open the system for future improvements and researching projects: hydroponic crops with grey water; irrigation with grey water; new treatment system components, ...

It's an opportunity for demonstrating that the adopted solution works, finding a low-tech system for monitoring how the potentially hazardous parameters evolve through the system (suspended solids, pH, salinity, pathogens, …).

And finally, it's an opportunity for communicating that grey water, instead of to be a problem, is a useful resource for a sustainable living model in a semi arid environment.

2 Characteristics of the greywater[1] and Sunseed greywater parameters at main house

Greywater definition

Greywater is wastewater from baths, showers, hand basins, washing machines and dishwashers, laundries and kitchen sinks. Specific greywater sources have specific characteristics as summarised below:

Kitchen	Kitchen greywater contains food residues, high amounts of oil and fat, including dishwashing detergents. In addition, it occasionally contains drain cleaners and bleach. Kitchen greywater is high in nutrients and suspended solids. Dishwasher greywater may be very alkaline (due to builders), show high suspended solids and salt concentrations.
Bathroom	Bathroom greywater is regarded as the least contaminated greywater source within a household. It contains soaps, shampoos, toothpaste, and other body care products. Bathroom greywater also contains shaving waste, skin, hair, body-fats, lint, and traces of urine and faeces. Greywater originating from shower and bath may thus be contaminated with pathogenic microorganisms.
Laundry	Laundry greywater contains high concentrations of chemicals from soap powders (such as sodium, phosphorous, surfactants, nitrogen) as well as bleaches, suspended solids and possibly oils, paints, solvents, and non-biodegradable fibres from clothing. Laundry greywater can contain high amounts of pathogens when nappies are washed.

In addition, actually another source of the Sunseed greywater is the urine toilets. Fresh urine is keeping during the irrigation days by the Organic Gardening department for its used in the gardens. The rest of the days, the waste water coming from the urinals is discharged into the grease trap.

Associated risks to the greywater

If greywater is discharged in sewers and flows into aquatic systems, it will lead to oxygen depletion, increased turbidity, eutrophication as well as microbial and chemical contamination of the aquatic systems.

If greywater is discharged onto streets or open ground, water-borne diseases can be increased, due to mosquito breeding in stagnant water.

If greywater is reused inappropiately, the contained pathogens, salts, solid particles, fat, oil, and chemicals may potentially have a negative effect on human health, soil and groundwater quality.

- Pathogen ingestion through consumption of raw vegetables, inadequately irrigated with untreated greywater, is an important disease transmission route.
- Inadequate reuse of greywater can also have detrimental effects on soil. Suspended solids, colloids and excessive discharge of surfactants can clog soil pores and change the hydro-chemical characteristics of soils.
- Use of saline and sodium-rich greywater for irrigation over a long period can cause complete and irreversible salinization and deterioration of the topsoil, especially in arid

1 The technical information of this chapter is extracted from *Greywater Managment in Low and Middle-Income Countries*, Sandec Report No. 14/06. Compiled by Antoine Morel and Stefan Diener. Permission is granted for reproduction of these material, in whole or part, for education, scientific or development related purposes except those involving commercial sale, provided that full citation of the source is given.

regions with high evaporation rates.

Physical and chemical characteristics affecting greywater and its treatment

The hazardousness and acceptable limits of these parameters are going to be in function of the end use that Sunseed will do with its greywater after treatment. For example, if Sunseed discharges the treated greywater in the Aguas river, the load of nutrients like nitrogen, phosphorous or potassium must to be acceptable low, otherwise it will be a serious eutrophization problem of the river ecosystem. Nevertheless, if Sunseed uses the treated greywater for irrigation, preferentially the load of nutrients should keep as higher as possible.

As we commented in the introduction of this document, from our understanding, greywater is a resource, not a problem. Therefore, the greywater treatment system is going to be focused on waste water reuses like hydroponic crops system, garden irrigation or soil fertilization rather than discharging into surface and ground water flows. Consequently, the next parameters are going to be analyse taking account the growing plant needs and the soil properties consequences when infiltration.

The Sunseed water consumption is very variable along the weeks and months because the number of residents is too. The village shares the water coming from the ram-pump and there is a time schedule about its use. Sunseed main house has a 1000 litres deposit tank that receives water from 8h to 12h (Monday to Friday) and from 12h to 22h on Saturday. Therefore, there is a theoretical weekly water consumption limitation of 6000 litres, incremented with the quantity consumed during the water reception time.

For our calculus, we will assume a constant weekly consume of 6000 litres in the course of the year. Likewise, we will assume a weekly greywater load of 6000 litres.

Temperature

Greywater temperature is often higher than that of the water supply. For biological treatment processes, aerobic and anaerobic digestion occurs within a range of 15–50 ºC, with an optimal range of 25– 35 ºC (Crites and Tchobanoglous, 1998).

On the other hand, higher temperatures can cause increased bacterial growth and decreased $CaCO_3$ solubility, causing precipitation in storage tanks or piping systems.

Suspended solids (SS)

These particles and colloids cause turbidity in the water and may result in physical clogging of pipes, pumps and filters.

Non-biodegradable fibres from clothing (polyester, nylon, polyethylene), powdered detergents and soaps, as well as colloids are the main reasons for physical clogging.

PH and alkalinity

The pH indicates whether a liquid is acidic or basic. For easier treatment and to avoid negative impacts on soil and plants when reused, greywater should show a pH in the range of 6.5–8.4 (FAO, 1985; USEPA, 2004). Greywater with high pH values alone are not problematic when applied as irrigation water, but the combination of high pH and high alkalinity, a measure of the water’s ability to neutralise acidity, is of particular concern. Greywater alkalinity (indicated as $CaCO_3$ concentrations) is usually within a range of 20–340 mg/l (Ledin et al., 2001), with highest levels observed in laundry and kitchen greywater.

Salinity

Greywater contains also salts (negatively charged ions (e.g. Cl^-, $NO3^-$) and positively charged ions (e.g. Ca^{+2}, Na^+)), indicated as electrical conductivity (EC).

Salinity of greywater is normally not problematic, but can become a hazard when greywater is reused for irrigation. High EC of irrigation water can considerably reduce yield potential. This problem can be overcome by choosing more salt-tolerant plants. Grattan (2002) advices that irrigation with saline greywater exceeding 1300 µS/cm requires special precautions. FAO (2007) considers that water classified for irrigation should present conductivity below 2000 µS/cm.

The main origin of salts in the Sunseed greywater comes from the source water itself. The water from the *acequia* contents a high concentration of ions with an average electroconductivity of 3661 µS/cm found by Calaforra and Pulido (1986) in the ground water around Los Molinos aquifer. Expecting the confirmation of this data with the first water analysis we will do, we can assume that as much *acequia* water we use, as much we impoverish the soil. Therefore, the flooding irrigation system in gardens, Arboretum, nursery and dry-lands is advised against, whereas the saving water measures as located irrigation, mulching, etc. or rain water catchment and store measures are even more strongly recommended now.

In addition to the initial load of the source water, the salinity of the greywater mainly increases with the use of sodium chloride (common salt) in the food elaboration practices. A coarse estimation indicates that Sunseed buys about 2 kg of common salt every week. We can suppose that this value is incremented in 1 kg because of the salt contained in the manufactured food products like cheese, cookies, preserves, etc. Therefore, usually 3 kg of common salt are added per week in the greywater. As we assume an average water consumption of 6000 litres per week, it means approximately a 500 ppm charge of sodium chloride that increases the salinity in 250 µS/cm. This coarse estimated result doesn't suppose a significant incrementation of the original electroconductivity data, consequently for the moment we will focus our attention in the other sources of salts of the Sunseed greywater system.

The main part of soaps and detergents on the market are salt-based, specially the powder detergents. Sunseed consumes Detergentes Solyeco S. L. U. cleaning products, an enterprise with a compromise with the environment. Despite they don't detail the chemical components of their products, they announce low rates of salts in the composition. Consequently, we can assume that Sunseed minimised the greywater salinity due to soaps and detergents and this salinity is not being substantially increased. Anyway, this hypothesis must to be corroborated with future electroconductivity tests.

We can conclude that the salinity of the Sunseed greywater is high, with probable values above 4000 µS/cm, basically due to the water source quality, and probably it will raise along the treatment system because of evaporation process. Therefore, salinity is going to be a key parameter to be controlled in the treatment system and in the final irrigation and soil infiltration reuse methods.

Sodium adsorption ratio (SAR)

While EC determines all soluble salts in greywater, the sodium hazard is defined separetely due to its specific detrimental effects on the soil's physical properties in the event of greywater infiltration or reuse in irrigation.

The sodium hazard is indicated as sodium adsorption ratio (SAR), which quantifies the proportion of sodium (Na+) to calcium (Ca++) and magnesium (Mg++). The unit of measure is miliequivalents per litre (mEq/L) and the formula:

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

Sodium is of special concern when applied to loamy soils poor in calcite or calcium/magnesium. High SAR may result in the degradation of well-structured soils (dispersion of soil clay minerals), thus limiting aeration and water permeability.

European and North American countries recommend irrigation water with SAR < 15 for sensitive plants (FAO, 1985).

Due to the high rate of gypsum ions (therefore Ca^{+2} and SO_4^-) in the *acequia* water, low values for SAR are expected. Calaforra and Pulido (1986) found and average concentration of 31,8 mEq/L of calcium, 7,4mEq/L of magnesium and 6,2mEq/L of sodium in the ground water around Los Molinos aquifer. After formula application, we obtain a SAR = 1,4 at source water level.

Using the coarse result about the food elaboration sodium chloride consumption of the previous chapter, we can conclude that the generated greywater increases in 500 ppm the quantity of common salt or equivalently 500mg of NaCl per litre of water. The atomic mass of Na^+ is 22,9 uma and CL^- is 35,453 uma, then the greywater is increased in 196,22 mg of Na^+ per litre or 8,51 mEq/L. Renewing the calculus, SAR = 3,32, substantially increased but without significant any problem in posterior use in irrigation.

Despite not to have quantified data about the sodium increase with the cleaning products Sunseed uses, we can assume that the SAR values are going to keep in save levels. Therefore, sodicity of greywater is not going to be a key parameter to be controlled along the waste water treatment system.

The biological and chemical oxygen demand (BOD, COD)

They are parameters to measure the organic pollution in water. COD describes the amount of oxygen required to oxidize all organic matter found in greywater. BOD describes biological oxidation through bacteria within a certain time span (normally 5 days (BOD_5)).

Discharging greywater with high BOD and COD concentrations into surface water results in oxygen depletion, which is then no longer available for aquatic life.

Where water consumption is relatively low, BOD and COD concentrations are high.

The COD/BOD ratio is a good indicator of greywater biodegradability. A COD/BOD ratio below 2–2.5 indicates easily degradable waste water.

The Sunseed main sources of BOD and COD in the greywater comes from the rests of food and from the cleaning products. The first ones are obviously 100% biodegradable and the second ones are about 95% as Solyeco company announces. Therefore, the COD/BOD ratio will keep approximately in 1 and is not going to be a key parameter to be controlled.

Nevertheless, due to the Sunseed water reduction policy, we can suppose that the BOD concentration in the greywater is going to be initially high. Consequently, we should ensure the appropriate oxygen supply when the components of the treatment system requires it.

Nutrients (nitrogen, phosphorous and potassium)

They are important parameters given their fertilizing value for plants, their relevance for natural treatment processes and their potential negative impact on the aquatic environment.

Levels of nitrogen in greywater are relatively low (urine being the main nitrogen contributor to domestic wastewater).

In countries where phosphorous-containing detergents have not been banned, dishwashing and laundry detergents are the main sources of phosphorous in greywater.

As we have already commented, Sunseed would like recycle these nutrients for increasing the crop production and fertilising soils. Therefore, the load of nutrients should keep as higher as possible trough the system whereas is not reused.

Microbial characteristics of greywater

Greywater may pose a health risk given its contamination with pathogens, such as viruses, bacteria, protozoa, and intestinal parasites, originate from excreta of infected persons. They can end up in greywater through hand washing after toilet use, washing of babies and children after defecation, diaper changes or diaper washing. Some pathogens may also enter the greywater system through washing of vegetables and raw meat, however, pathogens of faecal origin pose the main health risks (Ledin et al., 2001).

Since greywater may contain high loads of easily degradable organic compounds, re-growth of enteric bacteria, such as the faecal indicators, are favoured in greywater systems (Ottoson and Stenstrom, 2003; WHO, 2005).

Sunseed must to award special attention to this parameter due to the hazard for the health of the community residents and visitors. Even more if the greywater is reused for growing food or the people managing greywater can be in contact with.

Oil and grease (O&G)

As soon as greywater cools down, grease and fat congeal and can cause mats on the surface of settling tanks, on the interior of pipes and other surfaces.

Surfactants and other household chemicals

Surfactants, the main components of household cleaning products, also called surface-active agents, are organic chemicals altering the properties of water. They consist of a hydrophilic head and a hydrophobic tail. By lowering the surface tension of water, they allow the cleaning solution to wet a surface (e.g. clothes, dishes etc) more rapidly.

While most studies indicate full biodegradation of common surfactants in aerobic environments, other studies indicate a potential accumulation of surfactants in greywater irrigated soil, leading to a reduction in capillary rise and build-up of hydrophobic soils.

Linear alkylbenzenesulfonate (LAS) is the most widespread anionic surfactant used. LAS is quite rapidly degraded aerobically, but only very slowly or not at all under anaerobic conditions.

As we have already commented, Sunseed uses the line of household and soap products of Detergentes Solyeco S. L. U. These products have around a 15% of anionic surface-active produced from natural products like coconut oil or palm oil, with a biodegradability around 15 days. The concentration of no ionic surface-active of these products is around 5%, with a top concentration of

15% in the grease remover product that is scarcely used. From the historic Solyeco bills, we can assume a yearly Sunseed consume around 250 kilograms of cleaning products, equivalently 5 kg per week. It represents a concentration of 833mg/l of cleaning products in the Sunseed greywater, with 124,95 mg/l of anionic surfactants (15% assumed) and 41,65 mg/l of no ionic surfactants (5% assumed). The daily surfactants load in greywater suppose around 107,14 g and 35,71 g respectively. As surfactants can clog soil pores, we should control this parameter if we use the greywater for infiltration into the soil.

During greywater irrigation, toxicity problems may occur if boron ions (similarly to sodium ions) are taken up by plants and accumulate to concentrations high enough to cause crop damage or reduced yield. Although boron is an essential micronutrient for plants, excessive amounts are toxic. The recommended maximum value for irrigation water amounts to 1.0 mg/l for sensitive crops such as lemon, onion or bean (FAO, 1985).

Although Solyeco doesn't explicit, it seems it doesn't use sodium perborate and other boron molecules. Therefore, as long as Sunseed continues carry on the non-chemical policy, the boron ions shouldn't be a problematic parameter in the greywater.

Bleach, disinfectants and solvents are further substances of concern in greywater. Inhibition of the biological process by bleach begins at concentrations as low as 1.4 ml/l, with quite a substantial inhibition occurring at 3 ml/l.

Due to the non-chemical policy, Sunseed doesn't use this kind of substances.

Heavy metals

The heavy metals use to be inorganic species of large atomic weight, usually chromium (Cr^{3+}), lead (Pb^{2+}), mercury (Hg^{2+}), zinc (Zn^{2+}), cadmium (Cd^{2+}), and barium (Ba^{2+}).

Due to the Sunseed non-chemical policy, the greywater should be free from this kind of substances.

Summary

Parameters	**Special considerations**
Temperature	No special considerations
Suspended solids (SS)	No special considerations
Total dissolved solids (TDS)	No special considerations
pH	No special considerations
Salinity or Electrical Conductivity	Probable values above 4000 µS/cm
Sodium Adsorption Ratio (SAR)	Save values expected (below 5)
BOD and COD	High concentrations expected
COD / BOD ratio	Save values expected (around 1)
Plants nutrients	Keep as higher as possible
Pathogens (virus, feacal coilforms, Salmonella, ...)	To award special attention
Oil and Grease	No special considerations
Surfactants	Anionic surfactants: 107,14 g per day with a concentration of 124,95 mg/l. No ionic surfactants: 35,71 g, with 41,65 mg/l.
Boron	Save values expected
Bleach, disinfectants, solvents	Save values expected
Heavy metals	Save values expected

3 Theoretical Sunseed WWS and current situation

We can decompose a greywater management system in five different parts: source control, pipe system, primary treatment, secondary treatment and end uses.

Source control

Source control measures are necessary to reduce use and discharge of problematic substances, such as oil and grease, large particles or chemicals. Inside these measures, we can include the Sunseed non-chemical policy and the minimisation of the water usage. Nevertheless, there are some improvements we could develop at the source control stage.

The Sunseed non-chemical policy is not 100% accomplished. For example, during the 3 months closing, we have used high amounts of non-ecological paint as well as solvents for the interior of the houses, doors, windows, banisters, etc. Actually, we are still using and buying these products for the renewing of the Sunseed information signs.

The kitchen greywater uses to contain high quantity of oils and large particles that could be easily reduced with some simple previous measures to the washing up.

Pipe system

The pipe system is needed to collect and transfer the greywater for the treatment and reuse. Clogging is a potential risk that must be considered. Pipes must be laid straight with a gradient of 5mm per meter (Winbland and Simpson-Hébert, 2004).

The current Sunseed pipe system uses to clog periodically. Special remark must to be done for the *tubo del pis* or pee pipe, that it has an own cleaning song and the substance inside has an own name, the *chis*. From my understanding, there are two different factors producing these blocks.

There are large particles raising the pipe system because the sink filters and other traps are not thin enough or sometimes non-existent. The accumulation of these particles in combination with the elbows, connectors and other components of the pipe system produces some of the referred clogs. We should make an assessment of the gradient, straightness and connections of the pipe system and try to avoid the unnecessary ones (i.e. the big bend in Diego 3 from the grease trap to the vertical bed).

The second factor is related to the great quantity of gypsum dissolute in our water supply and, consequently, in our waste water. In some cases (like in the *tubo del pis*), there is a remaining waste water inside the pipes because of the insufficient gradient of the line and the low flush of waste water. The elevate summer temperature and when direct isolation the heat absorption of the black pipes produces a high waste water evaporation ratio and consequently a high gypsum precipitation ratio inside the pipe, becoming a clogging in some of the cases.

In the other hand, the Sunseed pipe system crosses the acequia under the main house, while the acequia flows to the next houses and the river. Actually, some of the pipes are leaking and there is a potential risk of water contamination.

Primary treatment

The primary treatment uses mechanical methods, such as filtration, sedimentation and flotation for reducing levels of coarse solids, suspended solids, oil and grease and part of the organic matter.

These kind of methods include the little filters of the sinks and the drain screens or the grease traps and septic tanks.

There is an 1 square centimeter grid covering the exit of the old shower block with a non covered part. This filter is too rude. Also, the big discharges of water overflow the grid and reach the uncovered part.

There is a 1 square milimeter grid at the exit of the kitchen sinks must to be changed. It has a broken part that doesn't filter appropiately. Besides, sometimes the area of the grid surface is not sufficient, when the whasing up responsible forget to clean it, it's get block and the discharged water with its suspended solid reaches the drain and flows to the grease trap.

The waste water coming from the new shower block and the water coming from the drainage system outside this shower flows through a 10 centimeters of diameter pipe till an uncovered small chest placed in the front of the main house. A second pipe of 3,2 centimeters of diameter connects the chest to the grease trap. There is a little filter in the income of the second pipe that uses to be blocked and the greywater overflows out of the small chest. The small chest enterely should be protected from undiserable objects like leaves, dust, etc. In addition, actually there is a part of water remaining in the bottom where mosquitos can develop.

The little grease trap outside the kitchen is ineffective because is underdimensioned and because of the high amount of water dumped at same time. It has a capacity of few litres that doesn't rise the required volume and hydraulic retention time of the grease trap principles (Morel and Diener recommend a HRT = 15–30 minutes and a minimum volume of 200–300 litres). In addition, the great water downloads produce a great turbulence effect that impulses the floating fats and the settled solids to the outcome.

The big grease trap placed in Diego 1 garden is well dimensioned in terms of hydraulic retention time. Nevertheless, the placement is not ideal. In one hand, it's located in a rented land, with the potential problem of a contract rescission. The second weak point is related to the high isolation time. With a higher temperature inside the grease trap, there is a higher concentration of dissolute solids passing trough the next treatment step. Likewise, there is less proportion of scum created by the grease.

Secondary treatment

The main objective of secondary treatment is the removal of organic matter and reduction of pathogen and nutrient loads.

In the original design of Sunseed greywater system, the secondary treatment began with two vertical flow filters (VFF) with a serial distribution. The VFF principles are three: physical filtering of solids in its porous material; microbiological aerobic degradation of the organic matter and nutrients in the filter media; chemical adsorption of pollutants. Greywater must to be well shared in the surface of the VFF in order to use all the filtering volume and must to be correctly oxygenated for a proper aerobic digestion.

One of the VFF of the current waste water system was removed and not replaced (currently, it's decorating the arboretum area). The second one is remaining in the system, but with serious doubts about their well function. The water is not shared over the surface and probably is not well oxygenated. We don't have data about the last time that the filter matter was replaced, but both the porosity capacity for filtering and the surface of the filter media for hosting microorganisms must to be considerably reduced. From my understanding, the filter media must to have collapsed time ago, therefore I guess the greywater has found a direct channel through the VFF to the outcome and the water is not being treated.

Morel and Diener recommends to design the VFF with a hydraulic load rate of 5 – 10 cm/d, equivalently 50 – 100 litres/m^2d. Assuming an average consumption of 850 litres per day, we need a minimum horizontal surface of 8,5m^2 each VFF. The current VFF has a surface of 0,65m^2, therefore we can affirm that it's completely underdimensioned.

The set of five horizontal flow planted filters (HFPF) constitutes the next step on the secondary Sunseed greywater treatment. The filter material acts as in the VFF like a screen for solids and organic matter. The plants transform water and nutrients from the greywater in biomass at same time that transfer oxygen to the root zone and increase the available surface for microorganisms growth. The microorganisms remove the organic matter and the nutrients by aerobic, anaerobic and anoxic processes.

Sunseed selected the common reeds (*Phragmites australis*) as a specie to be planted in the HFPF, although some test with other species have been developed. The maintenance of the reed stock and nursery seems to be more annoying than expected. The reeds uses to die in the winter because of the cold and frost and must to be replanted; in summer, because of the high evapotranspiration rate, extra irrigation needs to be applied. In addition, the common reed roots produce punctures in the plastic of the beds than lose their impermeability with the consequent greywater infiltration into the soil. As well, the common reed nursery bed needs frequent flooding irrigation and weeding.

The current situation of the Sunseed HFPF is that the first and fifth reed beds are leaking, and a bypass has been done to the next ones, therefore there are just tree HFPF working. The total 15m^2 of the 3 HFPF work together accomplishes the design criteria suggested by Morel and Diener if we assume a functional water level of 20cm in the beds: a hydraulic load rate of 5 - 8 cm/d, it means, 750 – 1200 litres/d; and a hydraulic retention time of 3-7 days.

In addition to the situation of the reed beds, the nursery bed seems to have lost its impermeability and we cannot ensure the appropriate growing conditions for the young plants.

End uses

After treatment, water is used for irrigation or returned to nature through discharge to surface water, percolation to ground water or infiltration into soil.

The end use of the Sunseed greywater consists in the surface irrigation of a spiral soil bed planted with a variety of different species. Because of the existing leaks in the HFPFs, we don't have information about the hydraulic rate raising the spiral bed, neither about the theoretical quantity in the original design.

Summary of original design status and theoretical removal efficiency

	Elements	Status	BOD	TSS	TN	TP	O&G	LAS	FC
Source Control	Sunseed non-chemical policy	Non-ecological paint being used							
	Minimisation of water usage	Approppiate							
	Washing up methodology	Better food rests elimination before washing up							
Pipe System	Straightness	Bends and elbows							
	Gradient	Insufficient							
	Acequia crossing	Leaking							
Primary treatment	Old shower block filter	Too rude							
	Kitchen filter	To improve							
	New shower block filter	Blockages, uncovered, water remaining							
	Little grease trap	Underdimensioned							
	Grease trap	Excessive temperature	20%	20%	10%	10%	70%	20%	
Secondary treatment	VFF 1	Missing	85%	75%	35%	0%		90%	1-2 log
	VFF 2	Underdimensioned, no water spread, doubts about filtering and oxygenation	85%	75%	35%	0%		90%	1-2 log
	HFPF 1	Leaking	85%	90%	25%	40%		90%	2-3 log
	HFPF 2	Working properly, but high maintenance and vulnerability	85%	90%	25%	40%		90%	2-3 log
	HFPF 3	Working properly, but high maintenance and vulnerability	85%	90%	25%	40%		90%	2-3 log
	HFPF 4	Working properly, but high maintenance and vulnerability	85%	90%	25%	40%		90%	2-3 log
	HFPF 5	Leaking	85%	90%	25%	40%		90%	2-3 log
	Reeds nursery	Leaking							
End use	Spiral bed	No data							

Current design and expected removal efficiency

The next picture show the elements still working from the original design and the theoretical expected removal efficiency.

	Elements	BOD	TSS	TN	TP	O&G	LAS	FC
Primary treatment	Filters							
	Grease trap	20%	20%	10%	10%	70%	20%	
Secondary treatment	HFPF 2, 3, 4 together	85%	90%	25%	40%		90%	2-3 log
End use	Spiral bed							
	Total removal efficiency	88%	92%	33%	46%	70%	92%	2-3 log

As we can conclude from the remaining greywater parameters after treatment, an urgent and proper waste water treatment system needs to be implemented in Sunseed main house because the greywater is reaching the end of the system without an adequate treatment process.

4 Ari Zwick proposal assessment

Ari Zwick was a Sunseed full time volunteer from Oct11 to Feb12. He is strongly proactive, clever and passioned and he proposed a dessign of the Sunseed waste water treatment system of the main house.

He dessigned a system with: the current grease trap as primary treatment; alternating vertical flow reed beds (total 12 m^2) with an automatic flush tank before in Terrace 1 (near compost toilet) as secondary treatment; and a forest garden in same Terrace 1 with a 600 L flushing tank and subsurface irrigation system as tertiary treatment.

This should be the theoretical removal efficiency of the proposed system:

	Elements	BOD	TSS	TN	TP	O&G	LAS	FC
Primary treatment	Filters							
	Grease trap	20%	20%	10%	10%	70%	20%	
Secondary treatment	VFF 1	85%	75%	35%	0%		90%	1-2 log
	VFF 2	85%	75%	35%	0%		90%	1-2 log
End use	Irrigation of a forest garden							
	Total removal efficiency	98%	95%	62%	10%	70%	99%	2-4 log

This system has these strengths:

- High rate of nutrients remaining for reusing, mainly phosphorous.
- The entire hydraulic retention time of the system is about 1 day, preventing from pathogens development. Nevertheless, the grease trap can host pathogen colonies.

But it has these weakness:

- If water pumps are not going to be used, there is an insufficient vertical drop for implement the system. There are around 2 - 3 meters from from the grease trap to the suggested forest garden, nevertheless, the proposed solution needs five meters: 1m per VFF; 0,5m per splitter barrel; and 2m pipe gradient from grease trap to first VFF.
- In case of problems in the irrigation of the forest garden with the greywater, for example an excessive salinity on water or soil porosity clogging, there is not any alternative system.
- It's a closed system without option for further researching in another areas like, for example, hydroponics.

Consequently, despite of to be an interesting and functional tratment system, we don't consider it should be implemented as proposed. Nevertheless, we are going to take in consideration for another possible placements.

5 Proposed solution

As we have proved before, an urgent and proper waste water treatment system needs to be implemented in Sunseed main house because the greywater is reaching the end of the system without an adequate treatment process.

We propose a two phases implementation solution. The first phase should focus on fix urgently the current Sunseed greywater problem. The second one, without the urgent label, should focus on the greywater recycle as a resource.

Phase 1

The scope of this phase consists on implement urgently an accurate and functional treatment system of the waste water with a low maintenance schedule, reusing as many components of the current system as possible.

We propose to added two VFF to the current system, raising a high rate of removal efficiency.

	Elements	BOD	TSS	TN	TP	O&G	LAS	FC
Primary treatment	Filters							
	Grease trap	20%	20%	10%	10%	70%	20%	
Secondary treatment	VFF 1	85%	75%	35%	0%		90%	1-2 log
	VFF 2	85%	75%	35%	0%		90%	1-2 log
	HFPF 2, 3, 4 together	85%	90%	25%	40%		90%	2-3 log
End use	Spiral bed							
	Total removal efficiency	100%	100%	71%	46%	70%	100%	3-5 log

This phase will include:

- To develop a low-tech methodology for analyse water parameters. A method for measuring temperature, pH, salinity, BOD, faecal coliform and other pathogens should be needed. A method for measuring nutrients and surfactants is desired.
- To review the pipe system in terms of straightness, gradient and leaks. Review two sectors of the system: from the main house to the grease trap; from the grease trap to VFF1.
- To make appropriate filters for the three drain collectors.
- To make a shade protection for the grease trap.
- To build the two VFF (possible ferro-cement tank ECM course with the second one).
- To create informational and educational panels about the water treatment and use.
- To introduce a change in the washing up methodology.

Phase 2

The scope of this phase consist on develop improvements in the treatment system focusing on the opportunities that the greywater offers like a resource.

Some ideas about the improvements could be:

- Project 1: to store nutrients of the greywater for fertilising soils (green manures, dehydration, …).
- Project 2: hydroponic crops.
- Project 3: greywater irrigated garden.
- Project 4: greywater irrigated arboretum.
- Project 5: primary treatment structure (for example, biogas plant).
- Project 6: secondary treatment structure (for example, ferro-cement HFPF for replacing the damaged ones).

Appendix 1: Biogas production plant

Factors of the methanogenesis production (Varnero 2011):

- Carbon / Nitrogen ratio: optimum between 20:1 and 30:1
- Total solids (TS): optimum between 8% and 12%
- Different optimum temperature for each kind of anaerobic microorganisms:

Fermentación	Mínimo	Óptimo	Máximo	Tiempo de fermentación
Psycrophilica	4-10 °C	15-18°C	20-25°C	Sobre 100 días
Mesophilica	15-20 °C	25-35°C	35-45°C	30-60 días
Thermophilica	25-45°C	50-60°C	75-80°C	10-15 días

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