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Alternatives to Waterborne Sanitation – a Comparative Study – Limits and Potentials

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The study analyses the potentials and limits of alternatives to waterborne sanitation. It is based on a comparison of a waterborne sanitation (WS) to a dry sanitation solution (DS). One very important point is that the introduction of a UDDT (urine diversion dry toilets) solution enables a water provision for 50% more inhabitants. A very important aspect for the situation in Peru which is heavily affected by the climate change, coming to a sharp decrease in water availability in the future.
A cost comparison is carried out which compares a situation of 10.000 households. The comparison is done from the point of view of a sanitation company, as the authors strongly believe that only an organized municipal sanitation service (which could or not be privately operated) can assure a sustainable solution. On the company side the necessary investment for the WS is about 1038 – 1227 USD per household. The DS comes to roughly estimated 935 USD per household.
On the management side a service model is proposed, in which the sanitation company recollects the dried feces and the urine every three months. The operational costs include transport, handling in a central plant, administration costs and education costs. Based on the actual water tariff in Lima (per m³) an advantage of 1 USD/month for each household is calculated.
In total a very clear advantage for the DS can be shown and therefore it is more than necessary to implant large scale solutions in order to be able to optimize the proposed systems.
The comparison does not take into account the economic advantages which could be generated by selling the urine. Based on the price for fertilizer in agricultural use in Lima and surrounding cities this saving would be about 20 USD/household,a for the urine. In the authors view the marketing of the products should not depend on the sanitation company but on agriculture organizations. An additional desert area of 160 ha could be irrigated by using all saved or treated water in the DS model.

Introduction

Peru is one of the most affected countries by climate change, especially in the coastal desert area. This area is less than 15% of the total Peruvian territory, but unfortunately 60% of the population live in this area. The capital, Lima (8 mio. inhabitants) is situated in one of the world's driest areas, 1,3 mio. inhabitants don't have access to the public water supply (MVCS 2006) and live with less than 25 L water per day and around 3 mio. people are considered to use latrines as sanitation facility, which is not an adequate sanitation solution for urban areas.
A similar situation can be encountered in many Peruvian coastal cities. Officially 20% of the Peruvian wastewater passes a treatment plant, but the reality is much worse, because the implanted treatment plants often are not operated correctly, so that most of the collected wastewater (57%) is discharged almost untreated, the problems of water quality in rivers and cost areas are dramatically rising.

In the past there have been some attempts to introduce DS concepts in Lima, but the introduction failed due to a series of problems described in Oswald & Hoffmann (2007). Main reasons were the absence of a sustainable management concept, not resolved technical problems and the perception of the people who regarded the UDDT as a temporary solution. It was very clear, that even poor people in marginal settlements do not have any interest, time or patience left to care for their toilets or to use the products. There was no interest at all on the ecological dimension; the people are only interested in a solution for their disastrous sanitary situation. The only solution they can imagine and are therefore interested, is the flush toilet.

Figure 1: Public latrine, typical sanitary "solution" in the peri-urban settlements of Lima
Source: P.Oswald

Figure 2: Until 2007 UDDT in Lima always mixed greywater with urine, the infiltration often didn't work properly
Source: P.Oswald

Figure 3: This family already is prepared for the connection to the water supply. As in this case the water flush toilets are always preferred.
Source: P.Oswald

A paper by Cordova & Knuth (2005) gives a very detailed analysis for possible failures in large scale implementations. The paper discusses each aspect in detail and points out especially that there is a high need for a sanitation service when it comes to large scale implementations. When it comes to higher numbers of users, a system can not rely on a voluntary service of all users. Therefore this paper is based on the assumption that the whole DS system has to be operated in a "quality" for the user which could be compared with a WS. The term "quality" means in this case that the user receives the same service as in a wastewater or at least waste collection. Speaking of "large scale" implementation one has to see that Cordova & Knuth analyzed cases with a maximum of 600 UDDT.

The only real large scale implementation the authors know of is the case of Durban where more than 60.000 UDDT have been implanted successfully and are operated by the local sanitation company (Gounden et al., 2008). Considering this situation it is highly necessary to implement dry solution projects in various surroundings, in order to gather more experiences which would be way beyond in quality to this theoretical approach. The aim of this theoretical approach is to encourage decision makers to take the "risk" in investing in a real large scale projects. In the case of desert areas as in Lima and the Peruvian coast we do have a "win-win" situation. There will be simply no water for a long term waterborne sanitation, so there is the best possibility for a try out.

The reality of waterborne sanitation in Peru and conclusion

Each sanitation system which is operated by a sanitation company in Peru is a waterborne sanitation. WS is regarded as the permanent solution whereas latrines are the solution for the poor people and are considered as a lower class signal. The government of Peru is putting high effort in attending the MDG and is implementing currently a series of sanitation systems all over the country. Almost all of these systems consist in a sewer system, often condominal system and a wastewater treatment by lagoons or Imhoff tanks. The already existing systems show serious operational problems. The picture 4 shows an effluent of an overloaded wastewater lagoon. This effluent is used for agricultural irrigation. Picture 5 shows another typical situation; the sewer was blocked in order to get an overflow to an irrigation channel for crop irrigation. Picture 6 presents a new social settlement in a suburb of Lima, WS with sewer and treatment plant was implemented. The settlement has an age of 2 years and up to now there is no connection to the public water supply, so that the families cannot use their installed WC, but do not have any sanitary solution.

Figure 4: Effluent of a treatment pond system, used for irrigation
Source: H. Hoffmann

Figure 5: Blocked sewer, raw wastewater from the cities used for irrigation in agriculture.
Source: H. Hoffmann

Figure 6: Settlement in Lima with flush toilets (15 L per flush). But there is no water to use it.
Source: H. Hoffmann

On the other hand water reducing technologies or water economizing costumes are almost unknown, in areas where water is available the consumption is about 200 l/hab,d. Figure 7 shows a typical situation; most of the water toilets in Peru almost have a permanent water loss due to malfunctioning of the water valve. Additional the water loss in the public supply is above 40 % (SUNASS, 2008). The parks of the city centre are heavily irrigated (figure 8), often with drinking water. The use of greywater is not practiced; often even the idea of reuse is not accepted. From an economic point of view it is really not interesting because the price for drinking water is very low (fix 3-8 USD per month, counted 0,30 USD for the first 20m³/month).

The consequence is, that the given situation discriminates just the poorest; there is not enough water to supply all people with 200 l/d, and who is not connected to the public system has to pay the highest prices (up to 3,50 USD per m³) for dubious water quality and additionally is more affected by water born diseases caused by deficient water and sanitation services.

Figure 7: Water loss due to malfunctioning of water valves
Source: H. Hoffmann

Figure 8: Irrigation of parks in the city centre.
Source: H. Hoffmann

Figure 9: Greywater on the streets of settlements
Source: H. Hoffmann

The necessary investments to attend the MDG for Peru (2015) in the area of sanitation are calculated to about 1.454 Mio USD (MVCS, 2006), it is considered as an almost impossible investment. These facts led to the following conclusions:

- The situation especially in the high populated, but totally dry costal areas of Peru demand a sanitation system which reduces water loss and water consumption for transportation purposes to a minimum.
- The irrigation with raw or partially treated wastewater, as well as the discharge of untreated wastewater in the rivers must be avoided by the sanitation solution.
- The used water must have a quality which allows a simple onsite treatment and guarantees the secure reuse of the treated water for local irrigation or infiltration, as possible with greywater.
- The social situation demands a sanitation system with considerably lower investment and operation costs than the conventional solution.

The hypothesis is, that a UDDT solution with organized recollection service and onsite greywater treatment or semi-decentralized greywater treatment could be a promising alternative to the conventional waterborne solution. Therefore this study analyses critically this hypothesis.

The basic assumptions

As always when it comes to comparisons, the basic numbers and assumptions are fundamental. Therefore the following section tries to give as much of clear and comprehensive numbers as possible. The way of calculation will be given for each number, therefore giving the possibility to repeat the calculation for an own example or with “better” numbers. The authors tried to use numbers which always are in favour of the WS. The aim it to prove that even under these conditions the above mentioned hypothesis is valid in the given situation of the coast of Peru.

The example is carried out for a settlement, a small city or a suburb of about 40.000 inhabitants living in 10.000 households. As there is no UDDT solution for more than 3 floors up to now, this calculation does not apply to areas with a high verticalization. The number of 10.000 households was chosen in order to come close to large scale implementation. The basic water consumption was assumed to 150 l/p.e.,d for the WS. In the case of the DS it was assumed that the water consumption comes to 100 l/pe,d.

Description of the dry sanitation solution

Intending an implementation of a dry sanitation solution, one has to offer a sanitation quality which fulfils all basic needs for sanitation of the users. The basic needs can be described as: clean toilet without smell and flies, possibility to have the toilet in the house, integration in a regular bathroom (see figure 10,11), no handling of fresh faeces. In a total of 40.000 people it can not be expected that all users are ecologically orientated and are interested in putting effort in a sustainable sanitation solution. Therefore a sustainable solution should not cause more work than a solid waste collection. The authors believe, that in the current situation success of a DS concept only can be guaranteed, when there is a strong incentive in favour of the DS solution. This is necessary until the moment, when the use of DS is seen commonly as an equivalent for WS. The following pictures give some examples for dry sanitation installations in bathrooms just to show the general applicability.

Figure 10 : Dry toilet integrated in the bathroom
Source: www.rinconesdelatlantico.com

Figure 11: Dry toilet in Mexico
Source: U. Windblad

Management and operation concept for the dry sanitation solution

The authors developed a theoretical management model based on the idea of a recollection for dried faeces and urine every three month. By this it is necessary to install storage tanks which have a storage capacity which is significantly higher than the average production. We suggest at least a 50% larger storage. For the urine storage there can be build in a piping system which ends in a storage tank, close to the collection point. The average urine production is 1,1 l/p.e,d. (UNESCO IHE, 2008). For a 3 month recollection cycle a 4 person household would need a storage of 400 l, we considered a 600 l storage tank. In the case of the faeces

the average production is about 51 l/p.e.,a. (Vineras, 2002). As the water content of the material is about 80% (Vineras, 2002) it looses water very quickly and therefore reduces largely in size and weight. Some of the size loss is equilibrated by the dry material which should be added after each use. We estimated the total annual volume to about 107 l/household,a or 27 l/ 3 month cycle. We considered a storage box of 90 l in order to guarantee a good air circulation. The box will be in use for three month and than put for resting for three more month. Only after a period of 3 month without any new loading the content will be recollected.
The transport from the bathroom to the collection point close to the property limit is an aspect which needs further development. In this model we assume that the transport is done in a container which is very similar to the waste bins with rolls. The user has to transport the container to the collection point as he has to do that in the case of solid waste collection.
For the recollection we intend to use a 10 m³ truck which has a divided tank and two suction devices. A 9,2 m³ compartment would be for the urine transport, 0,8 m³ for the dry faeces collection. The volume is sufficient for the recollection of about 23 households. In total there is a need for 4 trucks of this kind to attend the 10.000 households. Detailed calculation is given in the section about calculation of costs of operation. The material is transported to a central treatment facility which consists of a composting place for the faeces and urine storage as recommended as secondary treatment in the WHO guidelines (2006). There the faeces are composted in order to guarantee a hygienically clean product. The guidelines recommend a composting of at least a week with temperatures above 50 C (WHO, 2006 Tab. 4.4). In the model a two month period for composting was used.
Considering urine the WHO guideline recommends storage of 6 month in order to allow an application on all crops (WHO, 2006 Tab. 4.6). The 6 month storage period is given by three month storage in the individual storage tanks and a central storage of 4 month.
The central treatment considers 2 places for offloading the material and two places for recollecting the fertilizer products.
The sanitation company has to introduce an education system in order to guarantee an efficient introduction of the new concept. On the economic side the water tariff has to be strongly progressive in order to avoid that people use waterborne sanitation in an area which is meant to operate on dry sanitation. The aspect of controlling the use of water for flushing purposes is one of the most important aspects for a successful implementation.

Investment costs for the client in both scenarios

As in every sanitation system the costs for a bathroom implementation have to be paid by the client. The construction of a UDDT bathroom is slightly cheaper than a conventional bathroom. In the case of the WS the connection to the sewer is charged usually with about 150 - 250 USD. For the urine storage (600 l) and the grey-water treatment (sand filter) a total of 450 USD has to be considered. The onsite storage (urine) or treatment (grey water) helps to cut down costs for the Water company. Therefore we suggest in this model, to give a payback to the customer which leaves him equal to the investment for a WS. The discussion whether there should be an economic incentive or not for the DS model will not be discussed in this paper.

Investment costs for sanitation - the waterborne solution

In order to determine the total sewer length, a median width of 10 m per property and properties on both sides of the street was assumed. This leads to a specific length of 1,25 m/p.e., which is a low number. This assumption is a very Pro-WS assumption for the case of Peru. The costs were taken of various studies in Northern Peru. In this case only the final costs for the sanitation company are interesting, therefore the direct costs were transformed to final costs (without VAT) by applying a 20% raise (for indirect costs and utility of the construction company). The specific costs for the canal are estimated with 31 USD/m. The control pit was estimated with a cost of 642 USD for each 80 m. In total the secondary sewer was estimated with 41 USD/m. The main sewer was estimated with a total length of 10 % of the secondary sewer. These costs were not considered.
Each connexion to the main pipe was calculated with 192 USD.
For the wastewater treatment two approaches were carried out. In order to come to the lowest possible limit in the WS, it was assumed, that the wastewater could be treated in a larger wastewater treatment lagoon for more than 200.000 p.e., together with the wastewater of the rest of the city. The design of this plant would be an anaerobic lagoon as a pre treatment with a manually operated grit removal and facultative and maturation lagoons with a detention time of 20 d (removal of coliforms). In this case the investment would

be around 36 USD/p.e. This design was chosen for the purpose of a pro-WS design in terms of costs, it is still a very common treatment design, but nevertheless the authors do not consider this as a recommendable solution. An open anaerobic lagoon always provokes a severe odour problem; not even mentioning the negative climate aspects due to venting of methane. Currently the existing anaerobic lagoons are in discussion and in Brazil for instance more and more are covered with a plastic liner or substituted for UASB reactors. Nowadays a sustainable wastewater treatment should not consider anaerobic lagoons without a gas capture. Therefore was utilized a second approach considering a mechanical pre-treatment, a UASB and a secondary treatment just for the 40.000 p.e. The estimated costs for this situation are 71 USD/p.e. Comparing these costs with costs published by the Brazilian National Water Agency in 2001 (ANA, 2001) the mentioned costs are in the range. ANA (2001) gives a cost of 38 USD/p.e. (R$ 65/p.e) for the cheaper solution and a range of 44 to 61 USD/p.e for the second version. It has to be considered that the costs presented in ANA (2001) have not been transformed to today's prices.
Furthermore the costs of the connection to the sewer, at least one central pumping station and a pressure pipe to reach the treatment plant have to be considered. The costs all components, also for the pumping and the pressure pipe, are expressed in table 1. In total the WC solution has a range from 574 USD/household. to 764 USD/household. or 143 – 191 USD/p.e.

Item	WS min	WS
	USD/household	USD/household
Min. Investment for Sanitation	574	764

Table 1: Investment costs of the sanitation part of the WS solutions

Investment costs for sanitation – the dry sanitation solution

In the case of the DS the investment costs had to be developed on a theoretical base, as there are no examples worldwide.
As mentioned before a central treatment plant will be installed. The compost is designed with a two month storage time. The necessary volume for the storage is 180 m³. The design was carried out with three composting areas 120 m² each, considering a high of 1,5 m for the compost. The composting area was calculated with a 20 cm concrete and a 10 cm gravel bed and a coverage. The costs sum to 47.000 USD.
The necessity for a 4 month storage of urine comes to a volume of 5.280 m³ (1,1 l/p.e, d * 120 d * 40.000 p.e). The storage was considered in 10 storage tanks of LDPE liner, each 3,0 m deep, 10,0 m wide and 17,6 m long. The storage is totally closed as shown in the example of Bornsjön, Sweden (Figure 12) (IHE, 2008).

Figure 12: Urine storage at Bornsjön, Sweden (Source: P. Jensen)

Additionally a filling and draining system was considered. Total sum for the urine storage was calculated to 107.000 USD.
In order to guarantee a fast off and on loading 4 loading places are considered, each of them with a length of 10 m and a width of 4 m. In addition 200 m² of moving area were calculated. In total the areas come to 10.000 USD.
The most significant investment are the 4 suction trucks and a backhoe loader. We used adopted prices from Brasil. The truck can not be compared with normal Hydrojets as there will be no pressure system installed. Instead of that the truck will be equipped with two suction pumps. The costs were estimated to 300.000 R$ or 176.000 USD for each truck and 217.000 R$ for the backhoe loader (127.000 USD).
The complementing installations come to 25.000 USD. We considered: a small operation house, a fence, water and electricity connection, raw in all non traffic areas and a large porch.
In total the necessary investment for the DS comes to 1.032.356 USD or 103 USD/household on the public side.
As pointed out in the investment cost comparison for the consumer we used an approach in which the Service company does the investment for the urine storage (150 USD) and the greywater filter (300USD). This sums up to a total investment of 553 USD/household.

Investment costs for water provision

The medium water loss in Peru is actually 42,4% (SUNASS, 2008). A target for the water distribution systems is 35% of water loss. This value was used in the current study. Water production in Peru is designed with a 1,3 factor in order to consider the day with the highest water consumption. The planning of reservoirs considers at least 30% of the daily consumption.
The necessary water production capacity comes to 12.000 m³/d (eq.1) or 138 l/s for the WS and to 8.000 m³/d or 93 l/s for the DS.

(eq 1) prod. capacity = hab.*(spec. consumption)/(1-water loss)*(factor for highest consumption)

The necessary storage capacity is 3.600 m³ (eq.2) for the WS and 2.400 m³ for the DS.

(eq. 2) Storage capacity = prod. capacity * 30%

Considering the distribution system a rough estimation was made. The total 50 km secondary distribution system was completed with a primary distribution of various diameters and a 1 km main pipe to the water storage tank.
Table 2 show the specific costs which were used for the comparison. All costs are costs shown for the complete object without VAT.

Item	WS		DS	
	Specific Cost	Unit	Specific Cost	Unit
Water treatment plant	8.990	USD/(l/s)	9.603	USD/(l/s)
Reservoir	150	USD/ m³	150	USD/ m³
Distribution system (without accessoirs)	20	USD/m	17	USD/m

Table 2: Specific costs for the study (costs are drawn form projects in Peru and adopted for the case)

The total length of 51.000 m was estimated with a cost of 20 USD/m for the WS. The Dry solution has a specific cost of 17 USD/m due to smaller diameters. In order to simplify the study the costs for valves and other accessories were considered the same in both solutions and therefore not considered.
Table 3 shows the results for the study. The total investment costs for the water system in the case of the WS come to 4,6 Mio USD or specific costs of 464 USD/household whereas the costs for the DS sum up to 3,8 Mio USD or 381 USD/household. The DS system therefore has an economic advantage in investment of 82 USD/household.

Item	WS	DS
	Specific Cost	Specific Cost
Water treatment plant	1.248.608	1.067.051
Reservoir	540.000	360.000
Distribution system (without accessoirs)	2.849.102	2.386.137
Total	4.637.710	3.813.188
Spec. cost/ household	464	381

Table 3: Total investment for drinking water supply in both scenarios

Theoretical calculation of operational costs for the dry solution

The DS is based on an assumption of a three month recollection cycle. Therefore in total it comes to 40.000 visits a year. The determination of the recollection costs is the most significant step for the model.

The material which has to be recollected is located with a good accessibility at the limit of each property. The emptying truck recollects at the same time urine and dried feces. Typical suction pumps have a flow of 500 l/min. Therefore the emptying time for the urine storage will be around 2 min. In total we estimated the working time for each household in 5 min. As one of the authors owns a suction truck for septic tank emptying, the authors do have practical experience in the handling and calculation of such service. We estimate the total necessary time for each household, including the translation to the next household, in 7 min. As this number is very sensible for errors and in order do use a conservative approach (pro WS) and in the lack of real specific experiences, we used 10 min/household as basic assumption.

The transporting distance we set to a 8 km distance. Considering that a city of 40.000 inhabitants has a total area of about 4 – 6 km² this distance would correspond to at least 5,5 km distance from the city limit. The velocity was estimated in 40 km/h. The time for offloading was estimated to 15 min. The total time per trip is 4,52 h (eq. 3)

(eq.3) total trip time = 23 households* 10 min/household + 16 km/ 40 (km/h)* 60 min/h + 15 min

In total the 40.000 visits sum up to 1.722 trips or 973 days (8 hours) or 44 working month. For the model we assumed the use of 4 trucks by this having a 8 % reserve or about 2 days per month for maintenance.

The costs per truck are calculated as presented in table 4, total sum is 4.588 USD/month.

The salaries are typical salaries for Peru. The petrol is a rough estimation by experience in operation and the maintenance is based on a rate of 3% per year of the investment. The trucks are calculated with a 10 year lifetime.

monthly costs per truck	USD/month
Truck driver	911,76
Worker	705,88
Petrol	1.058,82
Maintenance	441,18
Depreciation	1.470,59
Total	**4.588,24**

Table 4: Monthly costs for transportation of urine and dry feces per truck

Multiplied by the working months and divided by the number of households results a sum of 1,74 USD/household, month for recollection of the products.

On the central treatment site were considered 1,5 persons for the supervision of the reception. A backhoe loader was considered with maintenance costs of 3% per year of investment. The purchase of the backhoe loader is an overestimation. The compost has to be moved once a month, a necessity of 180 m³ per month and an on loading to a truck of 90 m³/month. Table 5 demonstrates the composition of costs, resulting in 0,33 USD/household,month for the treatment and handling of the products in a central treatment plant.

Item	un.	unit	Total USD/month
Operator	1,5	month	1.324
Equipment	3%	a	1.064
Prev. Maintenance	2%	a	331
Energy		gb.	88
Guard		gb.	529
Total			3.336
Total / household			0,33

Table 5: Monthly costs for handling of urine and dry in the central treatment plant

In addition costs for education and administration have to be considered. The necessary sanitation education was based on the experiences of Gounden (2008) in Durban, where about 7% of the users are "critical" users. We considered one social worker for the education, summing up to 0,10 USD/household, month.
Administration costs were estimated with 20% of the product handling costs, coming to 0,41 USD/household, month.
Total operation and maintenance costs for the DS solution are 2,59 USD/household,month. In Peru a VAT of 19% has to be considered. Total cost for the consumer is 3,08 USD/household,month.

Cost comparison

Point of view of the water company

Comparing the total investment costs, the WS solutions more expensive than the DS solution (table 6). Capitalizing this difference with a 30 year period of payment and a 2% interest rate (very pro WS assumption), the difference comes to an advantage for the DS solution of 0,38 – 1,09 USD/household, month for the sanitation company.

Item	WS min	WS 2	DS
	USD/household	USD/household	USD/household
Min. Investment for Sanitation	574	764	553
Investment for water provision	464	464	381
Total	1.038	1.227	485
Difference in favor of DS	103	293	

Table 6: Investment costs of the sanitation part of the WS and DS solutions

Point of view of the consumer

From the point of view of a consumer the situation presents itself as presented in table 7.

		WS	DS
Water consumption	m³/month	18	12
Water tariff	USD/ m³	0,30	0,30
Wastewater tariff	USD/ m³	0,14	
Monthly bill (water)	USD/month	5,43	3,62
Monthly bill (sanitation)	USD/month	2,45	3,08
Total bill	USD/month	7,88	6,70
difference in favor of DS	USD/month		1,18

Table 7: Comparison of the monthly bill for an average household WS and DS solution

The DS solution presents an advantage of 1,18 USD/month for an average household. It has to be considered that this evaluation is done under the current situation in Lima. In Lima water is still very cheap and wastewater is charged only by 45% of the water tariff. This practice will change soon. Since this year the water companies are forced (or better, have the possibility) to calculate the wastewater based on real costs. These costs for sure will be higher than 45% of the water tariff. In Brasil for instance wastewater tariffs are in between 80% and 100% of the water tariff. This would result in a difference of at least 3 USD/month for each household.

The ecologic potential of the dry solution

Irrigation with greywater

The model is orientated towards a greywater treatment on site, in future it will be interesting for the houses to have water for irrigation available. A simple sandfilter is a sufficient treatment for the greywater (100 l/p.e.,d) which therefore could be reused in the property. Basic calculation for irrigation is normally a 5 mm dose per day in the dry coastal areas of Peru, at least in the summer time (5 l/m²,d) That means, that the greywater of a family (300-500 l/d) is sufficient for a constant irrigation of 60 - 100 m² of green area. The treatment filter will need an area of 3-4 m². The water can be used for green areas around the houses, gardens with vegetables, fruits, flowers or also for parks. The irrigation with drinking water, as practiced in many parks of Peru, uses water which could be used to supply more families with clean drinking water.

Saving of freshwater resources

With the saved freshwater of 40.000 people (3.076 m³/d) it would possible to irrigate a dessert area of at least 61 hectares (5 mm/m²,d; calculated for high water consumtion plants), which could be used for agriculture production.
In total, a desert area of 141 hectares could be irrigated, when the drinking water consumption of 40.000 people is reduced by one third and when all greywater is treated and reused for irrigation purposes.

Substitution of fertilizer

Urine is characterized by a high amount of Nitrogen, Phosphorus and Potassium. These elements are the most important nutrients for plant growing. The urine of one person and year is equivalent to 4 kg of Nitrogen, 0,4 kg of Phosphorus and 1 kg of Potassium. In the case of an urine separation these nutrients can be used more or less directly as fertilizer (UNESCO IHE, 2008). The yearly urine of 40.000 people contains 160 t of Nitrogen, 16 t of Phosphorus and 40 t of Potassium.
The most important nutrient for the Peruvian agriculture is Nitrogen and in 2008 the prices for synthetic urea raced up a 50%, due to high energy prices. Actually synthetic urea costs 600 USD/t (El Comercio, 2008), which is too expensive for small farmers. Synthetic urea has a content of 46% N; therefore the urine of 40.000 people would replace 348 t of synthetic urea, which has an actual economic value of 208.700 USD or 21 US$ per year for a 4 person family.
Cultures as corn, potato, wheat or cotton normally require between 100-200 kg N/ha during growing season, therefore the urine of 40.000 people would be sufficient for a Nitrogen fertilization of at least 800-1.600 ha of agricultural cultures.
From an ecologic point of view the use of urine instead of synthetic urea reduces directly the CO_2 output, because it avoids the use of natural fuels for urea production. In difference to synthetic urea the urine also has potassium and phosphorus compounds, both normally are used as additional fertilizers in form of commercial products with 10-50% P_2O_5 and 30-60% KCI or K_2SO_4, which causes additional costs for the farmers. But the main problem to be pointed out, is the limitation of the natural resources for Phosphor, which are predicted to run out in about 50 to100 years (UNESCO IHE, 2008)
The use of urine as a fertilizer for private gardening would result in higher economic benefits; this calculation was carried out for a UDDT application (Jönssson et al., 2005). Repeating the approach for Peru the situation presents as follows. In Peru a common 30:10:10 NPK fertilizer costs about 1,50 US$/kg, and 1 kg is recommended for a 15 m² application (0,02 kgN/m²). By this the urine of a 4 person family has a theoretic value of 80 US$ per year. But two points have to be considered: a) the family has enough urine to fertilize 800 m² or more (normal size of the property 250 m² with a max. of a 100 m² of green areas), b) the NPK fertilizer for 100 m² will cost only about 10 US$ per year. By this it is obvious, that this approach can not be used for large scale applications in urban regions in Peru with area restrictions.

The way forward

For the presented theoretical example, which still has a lot of potential for more details, the Dry sanitation has proven itself as the better economic and ecologic solution. Considering that the authors always tried to do Pro-WS assumptions, the Dry sanitation has to bee seen as **THE** adoption to climate change for desert areas.

Furthermore the DS offers much more flexibility in construction, as there is no need for an immediate complete investment. The **DS offers a step by step approach**, growing exactly in the velocity the necessity is there, as most of the investment and operational costs are directly related to the number of households demanding service. In the opinion of the authors this is the most important aspect of the dry sanitation solution. More people can be reached in a shorter period of time applying DS instead of WS.

If it is so, why don't we already have much more DS solutions implanted?

We need practical examples! It is nice to have a theoretical model and there are proven solutions for every aspect, but there is no complete application. There is no danger for a sanitation company that the model would not work. The only point is that **we need supported examples to overcome the problems; a new approach always has in practical implementation.** This is necessary in order to be able to further develop the model to full mass application.

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