Suggestions for Sustainable Sanitation

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(This text was originally written in Spanish to promote more sustainable sanitation in the reconstruction of the Manabí and Esmeraldas provinces of Ecuador, after the 2016 earthquake. Nonetheless, most of the ideas expressed here would be applicable in many other places as well. https://issuu.com/chriscana/docs/sugerencias_para_saneamiento_sosten)

Sanitation is deficient in most of the world, since 90 % of wastewater goes into the environment without treatment, thus constituting the greatest cause of disease on the planet. http://www.grida.no/publications/rr/sickwater/

April 16, 2016, an earthquake of 7.8 on the Richter Scale shook the provinces of Manabí and Esmeraldas, in Ecuador, destroying thousands of homes, in addition to the loss of over 600 lives. Many multi-story buildings fell and certainly many cement sewer lines were also broken.

In this area, there have been grave problems with the scarcity and irregularity of piped or potable water for a very long time, together with the chemical and microbiological contamination of piped water, rivers, aquifers, and the ocean.

The reconstruction of this area represents a great opportunity to improve this situation, by applying knowledge and techniques that were not taken into account during the original construction. This situation is even more important if we remember that one of the principal economic activities in the area is tourism and no one wants to visit a place that is dirty or where there is considerable risk of catching a disease.

The word "sustainable" means that an activity can be carried out indefinitely, without destroying its bases and without damaging society, the economy or the ecosystems. It is worth mentioning that this zone belongs to the greatest endemic bird area in the world, so taking care of the environment is even more important here.

I propose the following general principals to orient more sustainable sanitation:

1. No dumping of wastewater straight into rivers, estuaries, aquifers or the ocean, since water is too valuable to waste or contaminate.
    - Pharmaceuticals (like antibiotics, contraceptives, and antidepressants) and agrochemicals (like insecticides, herbicides, and fungicides) cannot be reliably removed from wastewater, anywhere in the world, with existing conventional technology.
2. Emphasize the application of natural and biological processes, instead of those that depend of chemicals and a great deal of electricity, in order to increase long-term ecological and economical sustainability and avoid the development of microbiological resistance to the chemicals.

3. Promote the separation of different types of wastewater, treatment according to their characteristics, and productive, hygienic recycling, recognizing that every substance is a resource in the right place and a contaminant in the wrong place.
4. Take advantage of the fact that water gets more treatment, at less cost, when it filters through the upper layers of fertile soil, compared to conventional systems with the water in tanks or ponds, especially when plants are also present.
5. Educate about the benefits of Urine-diverting Dry Toilets, promote them, and implement them among the persons who prefer them (inodoroseco.blogspot.com, www.ecosanres.org).
    - These do not waste or contaminate water.
    - Nutrients go back to the soil orderly and hygienically.
    - UDDTs can be done anywhere, in a decentralized way.
6. Strive to conserve water, since if less is used by each person, more people can be served … and our wastewater treatment systems will be more effective.
7. Recognize the importance of properly managing the fecal sludge that comes from septic tanks and latrines, the characteristics of which are very different from those of sewage and, thus, it should not generally be discharged into wastewater treatment plants. There should be strict control to make sure that vacuum trucks only unload fecal sludge in appropriate and approved places (http://www.eawag.ch/en/department/sandec/publications/faecal-sludge-management-fsm-book/).
8. Adapt solutions to local conditions.

The following techniques can help us achieve these goals.

1. Maintain separate different wastewater flows

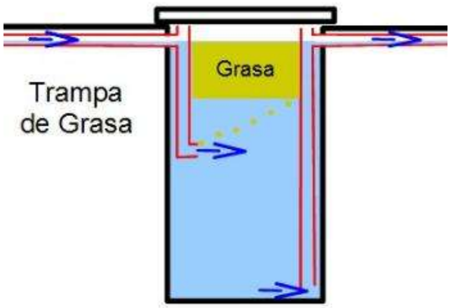
Different types of wastewater have different characteristics, risks, and treatment needs. The most dangerous ones are the blackwaters that contain human excrement and industrial wastewaters that contain toxic chemicals. The other types of wastewater are graywater and storm runoff, which do not represent near as big a risk and, after less intense treatment, can be put to productive use, in irrigation, industry, or for flushing toilets.

Therefore, it is preferable to maintain these different waters separate, so that each can receive proper treatment and productive reuse. It is, thus, recommendable to construct buildings with separate drainage pipes. This way, even if people proceed to mix them for years, the possibility remains to treat them separately, when there is the decision to do so.

For example, we can bathe or shower in a wash basin, transfer this water to a bucket using a cut-off one-gallon jug, and later flush the toilet with it and the same jug. This graywater is not dangerous and it is not necessary or logical to flush toilets with drinking water. In this way, we can reduce considerably the consumption of water, taking into account that in Ecuador it has been estimated that about ¾ of the water that gets to people's homes leaves via their toilets, since these are often not well maintained and water runs through them all the time. This recycling also decreases the volume of wastewater that needs to be treated, thus making whatever system we apply more economical and efficient.

2. Recycle water so it can keep doing the same job

Each liter of water that we recycle is a liter less that we need to take from nature and one liter less that is given back to nature with some degree of contamination.



In many cases, the same exact water can fulfill a function, receive proper treatment, and then go back to continue doing the same task, without needing to constantly use new water. For example, in laundries, car washes, and many industries, it is feasible to install grease traps (see diagram), sand traps, artificial wetlands, and other biological processes to clean the water and then use it again various times or indefinitely, taking into account that it is not necessary to use potable water. Even the same non-biodegradable detergents could continue to do their same task time and time again.

It would be worthwhile to organize community laundry areas where people can wash their clothes in water that gets treated and recycled for washing more clothes. Maybe the final rinse could be done with 'new water', which in dry places would also compensate for the water lost via evapotranspiration of the plants in the artificial wetlands. There could be a small fee to cover the maintenance costs of the system. Other possibilities would include leasing out concessions of these laundries to microenterprises or programs of technical assistance and funding for private laundries who want to save money and protect the environment via this sort of recycling.

It is even feasible to recycle the flushwater of toilets, after adequate treatment, as will be described below.

3. Inexpensive techniques to continue to use flush toilets without contaminating the environment

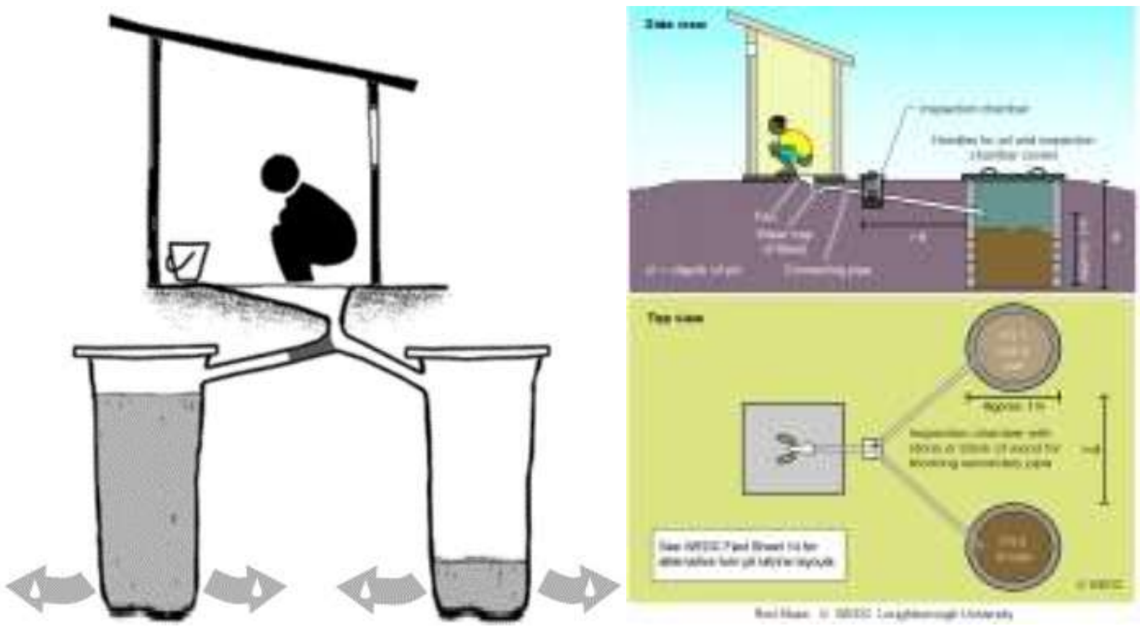
Water-based flush toilets have been used on a massive scale only for less than 200 years, when Queen Victoria ordered their installation in English palaces. They have become the standard in the Western World and they are beautiful on one end of the pipe, but ugly on the other. In particular, conventional wastewater treatment can never fully decontaminate the water, which is even worse in a country like Ecuador, where there are only relatively few cases of wastewater treatment (http://www.chekhovskalashnikov.com/water-sanitation/)

Nonetheless, many persons are so accustomed to this system that it would be difficult to get them to switch to anything else. Therefore, three systems are explained below that allow people to continue to use flush toilets, but without contaminating natural bodies of water.

3.1. Twin-pit Pour-flush (TPPF).

With these toilets, one permeable pit is used for two or more years, until it fills, when flow is switched to the second one, thus giving the same amount of time for the contents of the first to dry, decompose, and for the pathogens to die off. Then, the material can be shoveled out, when it is neither disgusting nor dangerous, to be productively applied in agriculture or landscaping. The pits are permeable to allow the water to filter into the soil. Note that only the blackwater from the toilet goes into these pits and household graywater must be dealt with in other ways.

This has the great advantage that the water and nutrients remain on-site, without risking anyone's health. It may be for sitting or for squatting. Normally, water should be added manually, but it should be feasible to use flush toilets with tanks, if they are designed for water conservation (for example, using less than 6 liters with each discharge) and are always in a good state of repair.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(Left: modified from Saurabh Phadke. Right: Loughborough University.)

This system should only be applied where:

- the population is sufficiently dispersed, in rural and peri-urban areas and at single-family urban houses that have big yards;
- the water table is deep and there is no risk of flooding;
- drinking water wells are sufficiently far away.

Over a million of these have been built in India, especially by http://www.sulabhinternational.org .

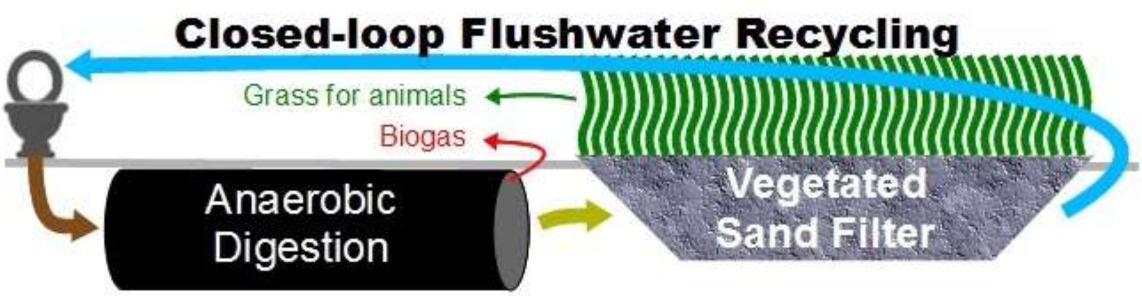
https://www.youtube.com/watch?v=5VSksb0TbjM

Another variation is to keep the urine separate via urine-diverting pour-flush squat pans (see this photo from Nepal) or urine-diverting flush toilet bowls (which do exist). This allows the urine to be dispersed in the soil, among fruit trees and gardens, via a perforated hose buried 10 cm below the surface, thus recycling the nutrients more efficiently. The feces still go to the twin pits, but with less liquid pushing them toward the aquifers and rivers.

(Photo: http://www.sswm.info/content/pour-flush-toilet)

3.2. Closed-loop Flushwater Recycling.

This consists in using water as a permanent conveyor belt, instead of something cheap and disposable. Water carries excrement to the Anaerobic Digestion, where the solids remain to ferment and be converted into biogas, while the liquids continue to the Vegetated Sand Filter where they are purified to the point of having no color, smell or danger and to be of sufficient quality to go back to same toilets and flush them again. No one touches or drinks this water and no one would imagine that this recycling is happening until we tell them. The water that is lost via the evapotranspiration of the plants can be compensated by adding graywater when needed. This system requires more hoses and pumping, but the benefits outweigh those investments … and we can install pumps that serve as exercise equipment (https://www.youtube.com/watch?v=gkcnSki9unk).



This system has the following advantages:

- Water consumption in an average house would be reduced by more than half;
- Rivers are not polluted with excrement, pharmaceuticals, or drugs; and
- Grass for animals and biogas for cooking are produced.

Despite this being so logical, no one has done it yet and we can be the first. Some buildings in New York City recycle treated sewage for flushing toilets, but not in a closed loop, as I propose here, and they keep contaminating the rivers with the chemicals that no wastewater treatment plant can eliminate.

3.3. Maintain blackwater separate from graywater, treat it via Anaerobic Digestion, and filter it all under the surface of the soil in tree plantations

In this case, Anaerobic Digestion is used once again for the task of separating solids from the water and converting them into biogas, which can be used in cooking, water heating, or industrial processes. This also prevents the solids and greases from plugging the system. Only a small amount of sludge would have to be removed periodically and it could be buried in deep trenches where trees will later be planted (see below).

The water is dispersed in the soil among trees via buried and perforated hoses or conventional leach fields.

This could be done with all the wastewater of a neighborhood or a city, but it is better to do this only with the blackwater, in order to keep the volumes manageable. Graywater could also go to tree plantations, agriculture or gardens, after first passing through grease traps, sedimentations tanks, or maybe faster and less intense anaerobic digestion.

If all the wastewater of an entire city is included, the area of the tree plantations would be very large and, in fact, this could be integrated into plans to recover degraded, desertified lands. The government of Egypt has created new forests that add up to a bigger area than all of the country of Panama, by irrigating deserts with treated wastewater (http://www.elmundo.es/elmundo/2010/11/08/ciencia/1289207071.html http://dw.com/p/1J3XJ https://www.youtube.com/watch?v=dmCXfub8tgY).
In similar fashion, a mining company in Peru has created an entire forest by watering dry, barren lands with water that should not go into the river (https://www.youtube.com/watch?v=AkhfV--GBxo)

One could plant fruit trees, timber species, or do native reforestation. Bamboo, cane or other species that are useful for making baskets, houses, or other useful things could also be planted. It is hygienic to consume the fruits from these trees, since pathogens cannot filter through meters of wood to get to the fruits. Also, since the hoses are buried, pathogens are not blown around or stepped upon.

This is a great alternative, since nutrients return dispersed into the soil and public health is preserved. The key is to not dump contaminated waters into the rivers and, instead, take advantage of them as a resource.

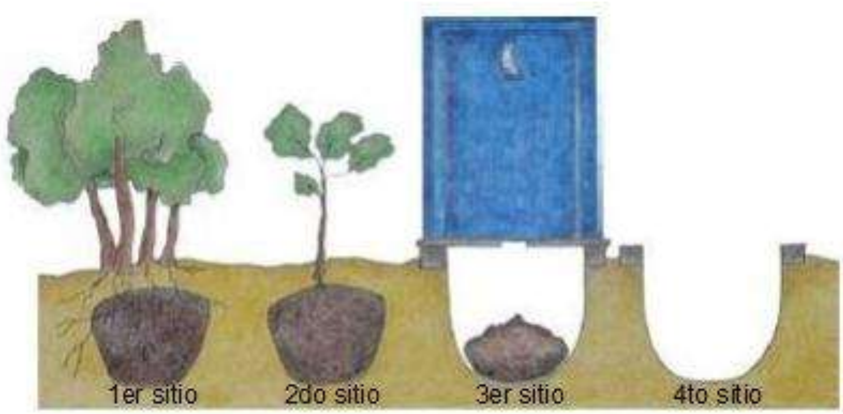
4. Toilets that do not use water

These represent the purist and most direct solution, since precious clean water is not wasted and everything becomes productive again, without any doubts about how much we contaminated the water, how much we decontaminated it afterward, and how far away we may be affecting ecosystems and other people.

4.1. One that fertilizes the soil for planting trees (ArborLoo)

Some may thing that this is the hated, old-time pit latrine, but it has four well-thought-out differences:

(1) The outhouse is lightweight and can be lifted by 2 or 4 persons, in order to be able to move it from one place to another;
(2) The pits are not so deep as to touch or contaminate the water table;
(3) Soil is added after each use to control flies and smells; and
(4) Trees are planted on top of the holes that have filled.



This is excellent for planting lots of trees, but, if there is not so much space, for example on a city lot, one can plant species that do not live very long, like Papaya, Banana or even Squash, since the same spot can be dug again after maybe several years. We can build with whatever materials we like, as long as they are light and preferably easy to clean. It could be made from recycled plastic.

In places where it does not rain very much, it can be built without a roof, to let in more light and fresh air, plus this allows the little bit of rain to wash surfaces and the sun to sterilize them, in addition to reducing the cost and weight of the outhouse. When it rains, people can use their jackets and umbrellas.

This could seem like something rustic, to be applied only in emergencies, but the advantages of permanent use include:

- Hygienic encapsulation of feces into the soil, without having to deal with them and without contaminating the environment;
- Recycling of nutrients via the trees;
- Low cost; and
- Ease.

ArborLoos should only be done where the soil is absorbent and the water table is deeper than about 2 meters. Obviously, this is not feasible in flood-prone areas during the rainy season.

There are more than 55,000 ArborLoos in Africa.

http://inodoroseco.blogspot.com/2012/08/scroll-down-for-english-en-abril.html
http://www.ecosanres.org/ecologicaltoilets.htm
https://en.wikipedia.org/wiki/Arborloo

4.2. Urine-diverting Dry Toilets (UDDT)

It can sound complicated to separate the urine, but the human body already does it and we just need to put a funnel in the right place toward the front, where both men and women urinate. At the end of urination, women may drip a little farther back, in the part that corresponds to the feces, but that little bit is not a problem.

There are important advantages to keeping the urine apart:

- It is excellent fertilizer for plants and does not transmit disease;
- It is the part that most produces bad smell when mixed with the feces;
- The volume of infectious material is kept small and, thus, more manageable;
- By keeping the feces drier, they receive more oxygen from the air, decompose in a more orderly way, and generate less stench;
- The nitrogen in urine is volatile, so, if we do not give it back quickly to the soil and the plants, it gets lost to the air as the stench of ammonia.

With each use, a cup of dry soil is added on top of the feces to control odors and flies. Some use wood ash or sawdust as dry cover material, but soil is better, because it inoculates the feces with beneficial microbes that break them down, in addition to being the most effective at controlling smell and flies. The feces are stored at least 6 months in tropical countries (or at least a year in The North, Argentina, or Chile), protected against the rain, so that the pathogens die and it converts to soil. This is the preferred soil for throwing on top of the new feces. This recycling is very important when we want to implement UDDTs in entire cities, since ashes and sawdust would be scarce, we do not want to deforest just to cover our feces, and very little transport would be needed. By recycling this soil, we also have the best material for covering the feces.

When we try to kill germs in wastewater with chemicals, evolution goes against us and the microbes get resistant. When we recycle the soil in dry toilets, natural selection and evolution are in our favor, with the soil microbes getting more and more efficient at decomposing everything that we deposit.

There are many different models of UDDTs to adapt to different preferences (like sitting or squatting, cleaning with paper or water, etc.), budgets, degree of permanency, and population density. One model costs essentially nothing and it would allow the poorest person in the world to rescue some selected bits of plastic out of the garbage, put them together, and then control fecal contamination.
http://inodoroseco.blogspot.com/2013/10/a-free-minimalist-uddt-part-1.html
http://inodoroseco.blogspot.com/2013/10/a-free-minimalist-uddt-part-2.html
Other models are more elegant, with floors and benches made with ferrocement and ceramic tiles or with wood and linoleum, as can be seen in other part of that blog.

There are other models for high-rise apartment buildings, taking advantage of the height differential. It has been estimated that there are over a million UDDTs in China, hundreds of thousands in Mexico and Central America, and some 200 in Ecuador, including the more than 60 that we have done among the indigenous Achuar of Amazonian Ecuador. There is more information on UDDTs in the following links:
http://www.chekhovskalashnikov.com/human-waste-disposal/
https://en.wikipedia.org/wiki/Urine-diverting_dry_toilet
http://www.ecosanres.org/pdf_files/Ecological_Sanitation_2004.pdf

4.3. Waterless Urinals

Urine holds 90% of the nutrients in our excrement and none of the health risks, if it is dispersed in the soil. If it is dumped in the river, it fertilizes algae that turn the river green and, in many cases, the algae later die and absorb all of the oxygen present and nothing can live there. In water, urine can also transmit schistosomiasis and other diseases. In contrast, if it is dispersed in the soil, we close a cycle, putting nutrients back where they came from. It is a great fertilizer and is very similar to chemical fertilizers, only better and with fewer heavy metals. Each year, the average person pees outs about 4 kilograms of urea, nitrogen in the form and quantity that plants need to produce food for that person again.

The key thing is to control the odor, which is achieved in one model (left, center), because the hose from the funnel goes all the way to be bottom of the jug, such that the urine itself covers the tip. When the user urinates, the same quantity of smelly air comes out, filtering through fertile soil

that absorbs the smell, which allows us to store the urine for weeks.
http://inodoroseco.blogspot.com/2015/12/un-nuevo-modelo-de-urinario-sin-agua.html

Women can also use this urinal, by peeing in another container (like the urinal on the right or a yogurt basin), emptying it in the urinal, rinsing it, and throwing the water on the soil among plants or in a potted plant in the house. The lid of the container can be replaced and it can be put away for the exclusive use of the same woman, thus more hygienic than the conventional system. This other model (right) is much simpler and is easier for women to use (by leaning it back), but should be emptied and rinsed with water within 12 hours.
http://inodoroseco.blogspot.com/2013/05/urinarios-ecologicos.html

It is also feasible to make urinals that feed directly into perforated hoses that are buried in the soil. In this way, this liquid disappears automatically by gravity, fertilizing the plants and trees.

We can make these urinals very easily, with readily available materials. It is not necessary to import Waterless Urinals that cost more than $400 each. Those are designed to dump urine into the sewer and have expensive systems to keep stench from coming back out. In addition, those urinals generally have expensive replacement parts that have to be changed periodically. In our case, we do not connect to sewers, there are none of those gases, we control stench in a more practical way, and we do not waste the fertilizer value of the urine.

5. Biodigestors and phytoremediation at slaughterhouses

Instead of contaminating rivers with all the waste from slaughtering animals, it is feasible to build biodigestors to receive excrement, stomach contents, and waste grease to convert them into biogas, which can be used in the same slaughterhouse to sterilize surfaces, heat water, and burn the hairs off pigs. The digestate that comes out of the biodigestor can go into Planted Drying Beds (see below), where we grow valuable species, plus the leachate can irrigate and fertilize other crops on land or in ponds.

The waters with blood could be productively used to irrigate and fertilize the same or other crops. On the other hand, the wastewater from moments of cleaning with lots of disinfectants and detergents could be treated in ponds of floating vegetation, vegetated sand filters, or both, in order to reuse this same water for thus same task. As much as possible, it would be preferable to clean and disinfect with hot water, fire, and biodegradable products, avoiding the use of toxic chemicals that accumulate in the environment.

In the following document in Spanish, I explain more details on how the waste and wastewater from a slaughterhouse can be treated economically and ecologically:
https://issuu.com/chriscana/docs/ideas_para_el_camal_de_puyo.docx

6. Planted Drying Beds to treat sludge

This type of constructed wetland or phytoremediation can be used to treat fecal sludge from septic tanks, latrines, or the fermented material that comes out of biodigestors (see above). It consists in an excavation similar to a fish pond, except that there is a network of perforated pipes in the bottom, under layers of gravel and sand, to drain out the water, while marsh grasses are planted in the sand to help control stench, treat the material, and maintain the permeability of the bed. Sludge is discharged on the surface and the grass that grows abundantly is useful to feed animals, while the water that filters through is apt for irrigating crops that will not be consumed raw. The constant growth of roots in the sludge promotes beneficial microbial activity and opens up new micro-channels for water to flow down through. When the accumulated sludge starts to reach the dike, the bed is allowed to dry and decompose for a number of months, while other beds are used, then the processed sludge is dug out to put on agricultural fields. There is more information in this chapter of the book, Faecal Sludge Management (http://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/EWM/Book/FSM_Ch08_lowres.pdf).

7. Deep Row Entrenchment

This is a matter of digging deep ditches, dumping biodegradable waste (including faecal sludge) into them, and filling back in with soil. This can be combined with the planting of trees on top, in a similar way to the ArborLoo. Sites should be chosen to be prudent distances from rivers and water wells (>100 m?) and where the water table is deep (>6 m?). The trenches may be dug with machinery, like backhoes, or by hand.

Apparently, this is the best option for disposing of the fecal sludge from porta-potties, which often contains formaldehyde. According to searches on the internet, this chemical decomposes in the soil within 3 weeks.
sitem.herts.ac.uk/aeru/ppdb/en/Reports/359.htm

It would be best to avoid such chemicals and, in any case, make sure that this sludge does not go into rivers, where water is used for human consumption and for irrigation, or into the ocean, where fishing and tourism take place.

There is more information on this and other techniques in this chapter of the Faecal Sludge Management book:
http://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/EWM/Book/FSM_Ch05_lowres.pdf

More information on sustainable options

There are many ways to apply sustainable sanitation during this reconstruction. The following book, which can be downloaded free from the internet, explains many of these, together with their advantages and disadvantages:
http://www.eawag.ch/en/department/sandec/publications/compendium/

In terms of Faecal Sludge Management, the book of the same name, which was edited by Strande *et al.*, offers 428 pages of alternatives for properly treating the material that accumulates in septic tanks and latrines, which is very different from wastewater. I translated this book into Spanish and both versions are available here:

http://www.eawag.ch/en/department/sandec/publications/faecal-sludge-management-fsm-book/

The Sustainable Sanitation Alliance, www.susana.org, has a permanent forum with more than 5000 members throughout the world, who participate via the internet. It also has an online library, with many documents in a variety of languages.

This Youtube playlist shows some of these techniques: https://www.youtube.com/watch?v=G2sPbBoliSo&list=PLvBe4CpoHJD9ZUvtzGKc7czAuMwj2T0Fi

Finally, there is more additional information in this document: http://www.sswm.info/sites/default/files/reference_attachments/SASSE%201998%20DEWATS%20Decentralised%20Wastewater%20Treatment%20in%20Developing%20Countries_0.pdf

Help, advice and rights

It is important to spread the word on these techniques, for the good of all. Most are in the public domain, but some are new. For this reason, I have put out this document under a Creative Commons license, to prevent anyone from coming along and patenting pieces of this. I also ask that my authorship be recognized, and I request to be informed of the use of – and improvements on – these ideas. (http://creativecommons.org/)

If you have questions, please write to me and I will help you at no cost. If you want my assistance in construction, management, education, and consciousness-raising, we can come to an agreement. It would be a pleasure to help universities to investigate and demonstrate these topics. In the same way, it would be an honor to help communities, neighborhoods, municipalities, foundations, ministries and governments protect people and the environment.