Title	**A tool for selecting sustainable sanitation arrangements**
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Short CV for Introduction Purposes (100 words max)	Jan-Olof Drangert´s focus is on management of sanitation and water at household and community levels. His studies cover both hemispheres and some studies focus on historical data. He is coordinating international courses on ecological alternatives in sanitation.

Introduction

The urban population in the world will double in the next 50 years, and both existing settlements and virgin land to be settled are included in the agenda for proper sanitation. Ideally, an appropriate up-to-date sanitation arrangement aims at being environmentally, technically, economically and socially sustainable. This means, among other things, that they are safe and environment-friendly in that the arrangements protect human health and save on water, prevent water pollution, sanitize and recycle the nutrients and organics to restore soil and soil fertility.

The Millennium Development Goals (MDG) for sanitation now requires that 2.4 billion additional people have adequate sanitation by the end of 2015 i.e., around 440,000 people per day. These figures are very large indeed. A part of all these "urban" people live or will live in periurban slum areas. The choice of sanitation option is wider for residential areas to be established and allows for new approaches to arrange for safe sanitation. In contrast to previous planning, a "solution" should not only move the dirt further away, but the ambition is to return it safely to nature as a resource.

Any sanitation and water arrangement is organising flows of resources to, through, and away from the household and community, and has therefore to adopt a sustainable perspective when being planned. This includes a need to project what will become scarce resources in the future. Here, the focus is on resource issues such as scarcity of water, scarcity of phosphorus, scarcity of cheap energy, and also financial and manpower constraints. This in turn will guide us to what resources should be conserved and/or recovered by the proposed sanitation and water arrangement. The broad aim is to organise inputs to the system and the ensuing output in such a way that sustainability is ensured.

Sanitation arrangements must fit to a wide array of local physical, cultural and economic conditions. Physical conditions may vary from sloping to flat, rocky to sandy, inundated to dry, water rich to water scarce, high density to low-density settlements etc. One kind of system cannot be feasible to all situations, and a major emphasis in the following presentation is that of combining arrangements instead of trying to enforce a uniform one for a whole city.

New challenges require new approaches: three principles for future planning

In the last decades the focus has shifted from providing water (based on water as a human right) to enhancing its wise use in households, so called demand management. Such measures have been successful in saving water and delaying abstraction from new virgin water sources. A new, emerging sanitation and water policy focus is to improve the quality of discharged used water and nutrients from the households in order to make cities more environmentally sustainable. Ideally, recycling of used water would become an almost inexhaustible water resource. We identify three main principles for water and sanitation arrangements, particularly in urban areas.

Principle 1: "*Start the planning from what is acceptable to reuse or to discharge to nature*".
The quality of the effluent and other residues should be of as good quality as possible in order to be easy to reuse or harmless when returned to nature. In a society with few and harmless consumer products the sanitation arrangement can be made simple. However, in the emerging chemical society where thousands of chemical compounds are part of the goods we consume, more varied and sophisticated arrangements are needed to ensure that nature does not suffer. The policy should be proactive and include that manufacturers are requested to replace harmful compounds in their products (P in detergents etc.) or that consumers avoid or boycott harmful products.

Principle 2: "*Adjust the water and sanitation arrangement to the material flows*".

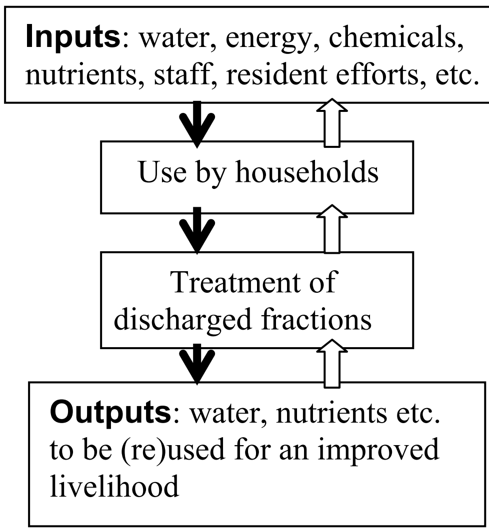
A water and sanitation arrangement receives a wide range of products that have been used by residents. We may compare the design of a sanitation arrangement with that of manufacturing a car. The design of a car not only includes its shape, but also how to compose the car in order to make the disassembling easy by the time the car is to be scrapped. The motivation is to facilitate the collection of different parts for reuse (metal, plastic, rubber, etc.) or for final destruction. This principle does not limit the quality of the car. Similarly, different water and material flows should not be mixed but kept separate to facilitate a cost-effective treatment and reuse, without reducing the service level or comfort of the users.

Principle 3: "*Manage the arrangements at the most resourceful level*".

Financial resources and manpower are common constraints. Residents manage the part of the arrangement in the home and yard, and may call on an entrepreneur for a new installation and repairs. Decision-makers are responsible for regulations and monitoring of the communal part of the water and sanitation system, while professionals operate and maintain it. Any sanitation arrangement requires a partnership between the actor groups, and there are a number of tasks that can be taken on either by residents, a CBO, utility, or private business. An arrangement should be designed so as to save on scarce management resources in the community/society.

These new principles emphasize outputs and bottlenecks as represented by the upward arrows in Figure 1, while conventional thinking follows the flow of materials as represented by the downward filled arrows.

Figure 1. The material flow vs. planning schedule



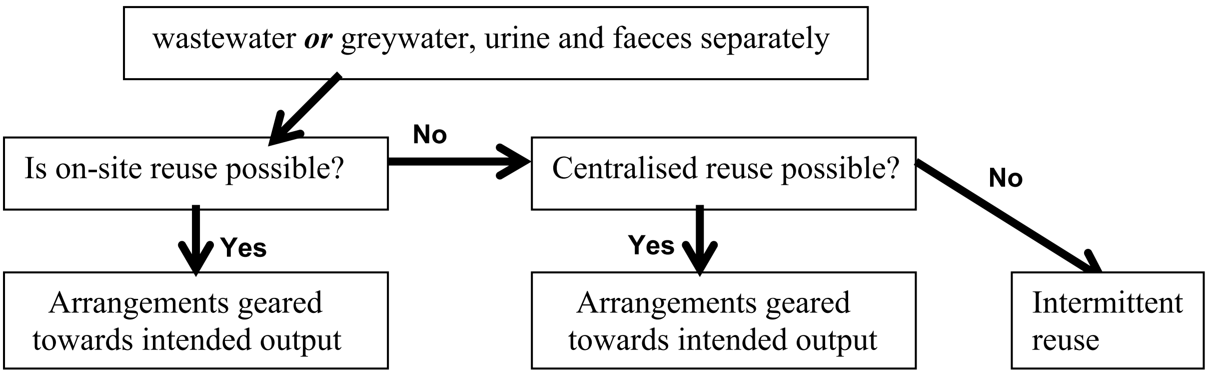
In this paper we discuss how to select an appropriate up-to-date sanitation arrangement, and propose a selection algorithm for this purpose. The intended users of such an algorithm are policy-makers, decision-makers and professionals involved in developing water and sanitation arrangements, and consultants carrying out pre- and feasibility studies.

Recycling and effective resource allocation

All sanitation arrangements produce some kind of discharge, be it black water, urine, dry faecal matter, greywater, or sludge. There are essentially three resources that can be recovered from any sanitation arrangement: water, nutrients, and solid organic waste, and the proposed holistic algorithm comprises all three. There is, to our knowledge, no synergy effect to be gained from including other kinds of solid waste in the algorithm. The particular wish in a community to reuse such discharged resources has a profound impact on the selection of sanitation arrangement: be it for gardening, biomass production, fish feed, biogas, or recharge of the water cycle.

Reuse can take place on-site or off-site. Single households or a neighbourhood may reuse some or all water, nutrients and composted organic waste (decentralised), and what is not reused on-site is transported to off-site farmland, perhaps together with discharges from larger communities (centralised). In case of interest or where financial and/or management resources are scarce, the attention will be to involve households in on-site reuse (Figure 2).

Figure 2. Main flow of algorithm to select a sustainable sanitation arrangement



In cases where neither on-site nor centralised reuse is possible, environmental sanitation will remain problematic with on-site systems desludged every few years, so called intermittent reuse (Mara, D., Drangert, J-O. et al. 2005).

Parameter criteria for a sanitation selection algorithm

A sanitation arrangement serves many goals, and any selection algorithm should incorporate aspects that are of concern in a given community. The algorithm does not – and should not - take anything for given. The purpose is to compare in a fair way various aspects of the options, while being deeply aware of how local conditions from soil properties to societal norms can influence the rating of various aspects.

We may operationalise the three principles through the following criteria grouped under four management headings: environmental criteria, technical criteria, social criteria, and economic criteria. In each group a set of criteria are commented on and they will later on be used as a basis for selecting an appropriate sanitation option.

(1) Environmental management criteria:

- **Wastewater quality**: The focus of the water sector is shifting from provision of water to demand management, and now to the quality of wastewater that residents return after use.

- **Reuse of used materials**: Selection of a sanitation option should ideally be based on environmental standards set for that specific location and ensure that harmful products are not returning to the environment.

- **Resource conservation**: The arrangement should be environment-friendly in terms of its location, energy and water use, wastewater and sludge disposal, etc.

(2) Technical management criteria

- **Engineering design**: A building act/regulation often sets standards for the technical design, such as depth of trenches for water and sewer pipes. Such standards are not easy to apply everywhere, yet oftentimes they do not allow for alternatives. However, exceptions can often be made for experimentation and tests.

- **Density of buildings**: Population density may limit economic, management and technical options. For instance, open space per person has an impact on the proportion of greywater, faecal and other organic material, and urine that can be reused on site.

- **Existing sanitation arrangement**: Already existing installations may be adjusted or made part of an improved arrangement, while the choice of installations in new settlements on virgin land are more open-ended.

- **Health/hygiene requirements**: A health code prescribes what toilets and other installations are allowed. The code is often inspired by WHO recommendations. Presently, WHO is preparing new guidelines for reuse of urine, faeces and greywater that will affect national and local policies and regulations.

(3) Social management criteria

- **Social acceptability**: Norms and attitudes on reuse differ. Toilet behaviours differ vastly, and a sensible design of the toilet and collection system can cater for acceptability. Offering a range of sophistication may also enhance acceptability.

- **Capacity to manage the arrangement**: The on-site and home sanitation arrangements are usually managed by the residents, while installation work and off-compound installations are under the control of a public utility, CBO or private company. The arrangement should fit to the existing capacities and capabilities of the various stakeholders.

(4) Economic management criteria

- **Cost and affordability**: Investment costs, lifespan of the installation, as well as operating cost are always considered. Judgement of the affordability may include willingness among users to pay, available subsidies, and loan arrangements.

Steps to be taken in the selection algorithm

The algorithm is designed so as to cater for a wide range of local conditions from individual households to large housing areas and cities. The sequence of questions and comments is essential and it characterizes the selection algorithm.

1 ***Is there an aim/policy of reuse or sustainability?***

If ***yes***, then containment, protection, and reuse of water and nutrient can be addressed. However, a national support for sustainability and the millennium development goals is not necessarily reflected at the local level, and there may even be resistance to change.

If ***no***, the introduction of a holistic approach has to be negotiated with local stakeholders. Local acceptance of a proposed measure is crucial to successful improvements in sanitation arrangements and for its long-term sustainability.

2 ***Is the wastewater quality considered a major concern/problem?***

The quality of wastewater is determined by what households put into the water when using it such as the kind of detergents, shampoos, medicines, paint residues, etc. It may be fair from homes where few chemicals are being used and from families who refrain from throwing unwanted products into the toilet and sink. There may also exist a treatment before discharge such as a grease trap or septic tank reducing nutrient and pathogen loads.

If ***no***, the wastewater is considered of **fair quality**, and the next set of steps is as follows:

3 ***Is there enough space and infiltration/ evaporation capacity on site?***

If ***yes***, the fair-quality wastewater can be productively used directly in gardens, and thereby replacing clean water for this purpose.

However, if ***no*** space is available on site or infiltration is not possible in e.g. flood-prone areas or areas with very high water table, the wastewater will have to be conveyed off site. If pipes e.g. simplified sewerage are not affordable, a simple open swale may be suitable for the task. The fair-quality wastewater may be used to irrigate plants, feed a fish pond, recharge groundwater, or for some other purpose.

If the wastewater is considered of **poor quality**, and causing environmental degradation on site or further away a general recommendation to facilitate the treatment of wastewater is to mix as few flows as possible. This concept is rapidly gaining ground with industrial wastewater and has proved to be very successful. Many manufacturers actually earn extra by recovering and reusing valuable compounds that have been used in the production processes. Likewise, municipalities have abandoned combined sewers for stormwater and wastewater. In the case of wastewater from households, there are also affordable ways to keep some streams separate. The next set of steps for poor-quality wastewater is as follows:

4 ***Are poor wastewater quality caused by other compounds than excreta?***

If ***yes***, the reason why quality of wastewater from households is deteriorating is probably that more and more chemical products are being used, and complex chemical compounds are discharged together with the used water. Such pollution can be eliminated by legislation prohibiting the chemical product to be sold on the market (or replacing it), or that residents refuse to buy and use it. Consumer action may be enhanced if the individual household is using the used water for watering the garden or absorbing the dust in the yard, since they are then likely to be reluctant to dispose of known harmful chemicals. A final but long-term solution is to enact a regulation that requires each manufacturer to propose an affordable method to treat its product after use in order to become harmless.

If the quality can be sufficiently improved by such source-control measures, it may be used in situ (follow sequence 3). However, if the quality remains poor, treatment on site should be contemplated. On-site treatment can be a sand filter, septic tank, UASB, biogas digester or some other method that reduces the amount of pathogens, solids, chemical compounds, and nutrients in the effluent (Mara 2004).

5 ***Is treatment on site effective and affordable?***

If ***yes***, there is an affordable treatment that achieve a quality that does not cause concern, and the effluent water can be used in irrigation or for other desired purposes (follow sequence 3). The sludge from the treatment process may remain a problem.

If ***no***, the wastewater has to be conveyed off site in pipes such as settled sewerage. If the quality problem requires more sophisticated treatment it may be treated in a biogas reactor or a wastewater treatment plant. The cost for this may not be affordable, and then a compromise has to be struck by lowering the required quality.

If, on the other hand, the wastewater quality problem is ***caused by excreta***, a first check is source separation i.e. whether urine and excreta can be separated from the wastewater stream. The flows of urine, faecal material, and greywater are occurring separately in the home and, if not mixed, these flows can be made hygienically safe and therefore posing a low health risk for residents, caretakers, and professionals (Schönning and Stenström, 2004).

Keeping material flows apart starts in the apartment, where management and socio-cultural aspects come to the fore. Most people seem to favour the flush toilet, despite the fact that it mixes urine and faeces, mainly because it is indoors and provides privacy, easy access to water, and safety from assaults. However, there are on-site arrangements with indoor urine-diverting toilets that provide the same benefits (Drangert 2003). A wide range of designs and sophistication are emerging on the market (Winblad and Hebért-Simpson 2004).

6 Is diversion of urine an affordable option?
If ***no***, treatment of wastewater on site will be considered (follow the sequence 5 above).
If ***yes***, there is a chain of questions and considerations to be tackled.

7 Can faecal matter be composted on site?
If ***yes***, the faecal matter (and paper) may undergo a primary treatment in the collection bag or vault. The dry matter should be composted together with organic waste from the kitchen in order to add extra carbon to raise the temperature of the compost (Jönsson et al. 2004). This will enhance pathogen die-off (hygienisation) and also make use of the nutrients in the organic solid waste. The mature compost can be used as a fertilizer and soil conditioner in the garden.

If ***no***, there is no space or interest to compost the faecal matter, and it may be incinerated on site and the ashes (containing phosphorus and potassium, but no nitrogen) can be applied as fertilizer. Otherwise, the primary treated faecal material and organic kitchen waste can be brought to a communal composting station run by professionals. This may be done at the site where the municipality recycles garden refuse etc. Faecal matter and organic waste can also be collected and made part of the input for a biogas reactor for the neighbourhood. The gas can be used as energy in the household, and the sludge can be used as a fertilizer.

Some 80% of the nutrients in household wastewater originate from excreta (Otterpohl, 2001). Urine contains 2-9 times as much nutrients as faeces, so recycling of urine is more important.

8 Can urine be stored and used on site?
If ***yes***, stored urine from a single household may be used straight away in the garden. There are no health restrictions except to allow at least a one month period between application and harvest of edible vegetables (Schönning and Stenström 2004).
If ***no***, lack of storage space or lack of interest with the household necessitates some transport of the urine. A suction truck can be used to collect and transport the urine to sport fields, golf courses, and the like or to farmland. If this is done properly, the nitrogen loss is minimal and all phosphorus and potassium can be reused (Stockholm Water Company 2001). The value of the nutrients in the urine makes it profitable to transport it hundreds of kilometres to farmland (Stockholm Water Company 2001).

The greywater is of good quality in this part of the algorithm and can be used for irrigation or groundwater recharge on site.

Concluding remarks

In most countries existing urban sewerage and drainage systems are combined systems where domestic wastewater is collected, mixed and piped together with industrial wastewater and stormwater. A large part of the piped wastewater is not treated or treated inadequately before discharge to the environment (Unicef and WHO 2003). Adding to the problem is that wastewater treatment plants are designed to reduce only some of the polluting compounds, so this is usually an expensive and sophisticated exercise with limited treatment effects. If there is a wastewater treatment plant, often little reuse of water and nutrients is taking place.

Costs for investment, operation, and maintenance in conventional sewerage and drainage networks, including pumping stations and treatment plants, are in most cases unaffordable for inhabitants in poor cities. A number of sanitation projects have therefore not been implemented, while many that have are not operating or are operating with very low efficiency. The health cost for conventional on-site systems such a pit latrines and septic tanks are often very high in terms of morbidity and mortality.

These circumstances call for an open screening of sanitation alternatives when new housing areas are being developed. The algorithm provides a tool to organise the selection process of a sanitation arrangement. The comparison between different options can be done in a number of ways: from attaching weights to each parameter and compare total points, or to organise panels of residents or other groups to prioritize the options according to their valuation of the information for each option.

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