

## Selection of sustainable sanitation arrangements

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### Abstract

To meet the Millennium Development Goal for sanitation around 440,000 people will have to be provided with adequate sanitation every day during 2001–2015, and the corresponding figure to meet the WHO/UNICEF target of “sanitation for all” by 2025 is around 480,000 people per day during 2001–2025. The provision of sanitation services to such huge numbers necessitates action on an unprecedented scale. This is made even more difficult by the general lack of knowledge on the part of professionals and the intended beneficiaries about which sanitation arrangement is the most appropriate under which circumstances. A sanitation selection algorithm, which considers all the available sanitation arrangements, including ecological sanitation and low-cost sewerage, and which is firmly based on the principles of sustainable sanitation, is developed as a guide to identify the most appropriate arrangement in any given situation, especially in poor and very poor rural and periurban areas in developing countries.

*Keywords:* Developing countries; Excreta; Health; Nutrients; Reuse; Sanitation; Selection; Sustainability; Poverty; Water

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## 1. Introduction

At the end of 2000 there were 2,400 million people without adequate sanitation facilities (WHO & UNICEF, 2000). By the end of 2002 this figure had increased to 2,600 million people (WHO & UNICEF, 2004). The Millennium Development Goal (MDG) for sanitation, which is to halve the number of people without adequate sanitation in 1990 by the end of 2015, was introduced at the Johannesburg World Summit on Sustainable Development (United Nations, 2002): it now requires that 2,400 million additional people have adequate sanitation by the end of 2015, i.e. around 440,000 people per day from January 2001 to December 2015. The WHO/UNICEF target of adequate sanitation for everyone by the end of 2025 (WHO & UNICEF, 2000) requires 4,400 million additional people to be served by the end of this quarter century, i.e. around 480,000 people per day. Roughly half of these people needing adequate sanitation live in rural areas and half in urban areas, although in fact almost all these people in “urban” areas live or will live in low-income high-density periurban areas.

These figures are very large indeed. They require unprecedented action, in effect to more than double the global efforts made in the 1980s and the 1990s when the numbers of people receiving adequate sanitation per day were “only” 200,000 and 210,000, respectively. If there is no improvement in the rate of progress made during 1990–2002, the Sanitation MDG will fall short of its target by some 1,300 million people. Thus there is no time to waste if the Sanitation MDG is to have any chance of success.

However, even if the Sanitation MDG is achieved, the world cannot stand still. During 2001–2050 the global urban population is expected to increase from ~2,800 millions to ~5,600 millions, while the rural population will remain fairly stable (United Nations Environment Programme, 2002). Thus, even if all 4,400 million urban residents in 2025 are provided with improved sanitation, a further ~1,300 millions will require improved sanitation during 2026–2050. This period will see increasingly severe global scarcities of water, nutrients (especially phosphorus) and energy, particularly and most acutely in developing countries (Hunt, 2003). Human waste will thus become an increasingly important resource, not least for small-scale and subsistence farmers in developing countries. Sanitation planning will have to change to reflect the growing economic importance of using both human wastes for energy production and waste-derived nutrients for both energy and food production.

Many new urban areas will be created to house these increasing urban populations, and this offers the opportunity to develop more imaginative and more responsive sanitation arrangements that combine and make use of current options in a sensible way. It is with this long-term perspective that we develop a means of selecting sustainable sanitation arrangements, particularly for those currently most in need – poor and very poor households in developing countries.

### 1.1. Principles of sustainable sanitation

We consider four fundamental principles for sustainable sanitation, as follows:

- *Human health*: Sanitation arrangements should improve human health and must not create any conditions harmful to it.
- *Affordability*: Sanitation arrangements must be affordable for the households using them. In developing countries in particular consideration must be given to the affordability of sanitation arrangements for poor and very poor households.

- *Environmental sustainability*: Sanitation arrangements should not result in any adverse environmental impact. The water, nutrients and organic solids in human excreta and domestic wastewater and organic wastes should be treated to an appropriate level and then safely used in aquaculture and/or agriculture. Wherever possible, biogas should be produced by the anaerobic digestion of organic solids and collected for beneficial use.
- *Institutional appropriateness*: Sanitation arrangements should be managed at the lowest appropriate level. The household is a major actor in sustaining human health and the environment. Communities benefiting from the provision of sanitation arrangements, or from improvements to existing sanitation arrangements, must be partners in the planning, implementation and, where appropriate, operation and maintenance of these arrangements or improvements. This is especially important when they are charged for using these services. The different roles and needs of both men and women in these processes must be recognised and facilitated. Of course, sanitation planning cannot be done in a wholly decentralized way: there has to be a coherent city-wide approach to sanitation, but the planning process has to take into account the views of the intended beneficiaries and recognise that the sanitation solutions for very poor, poor and non-poor households are likely to be very different.

These four principles are similar to those in the Bellagio Statement (Sandec, 2000), but they are more pertinent to the process of sanitation selection.

### 1.2. Ecological precepts for sanitation planning

We use the term “ecological” here to refer to a few of the approaches used in ecological engineering (Mitsch & Jørgensen, 2004). One is the redirection of the resources in human wastes to ecosystems where they can be beneficial in, for example, aquaculture and agriculture, while at the same time preventing destructive changes in other ecosystems, such as ground and surface waters. Another is the reliance on mainly local renewable energies, with fossil fuels used to a lesser degree and mainly for construction. Some sanitation arrangements have the potential to accomplish this, while primarily improving human health by reducing the transmission of excreta-related diseases.

The basic philosophy of “ecological sanitation” (which we refer to as EcoSan) is to recycle all the nutrients in human excreta as each person excretes almost enough NPK to produce all the cereals he or she needs (Drangert, 1998). A consequence of this is that the various “streams” of excreta and wastewater should not be mixed as they differ greatly in their volumes and nutrient loads (Table 1). Thus “yellow water” (urine), “brown water” (faeces and toilet flush waters) and “grey water” (wastewater from sinks and showers or baths) should be kept separate to facilitate nutrient and water treatment and reuse (Otterpohl, 2001), although in some EcoSan systems yellow water and brown water are combined to form “black water”.

However, we argue that other sanitation arrangements may be as “ecological” as EcoSan. For example, the sanitation system comprising either conventional or low-cost sewerage (i.e. the conveyance of yellow, brown and grey waters together in the same sewer system), followed by wastewater treatment to produce both biogas and a microbiologically safe effluent, and reuse of the effluent in aquaculture and/or agriculture (or for the irrigation of urban green space or forests), is equally “ecological”. Another example is household-level anaerobic digestion of black water, often supplemented with the excreta of domestic animals and/or household organic wastes, to produce biogas and at least partially treated

Table 1. Flows of, and nutrient loads in, brown, yellow and grey waters.<sup>a</sup>

	Total	Brown water	Yellow water	Grey water
Flow (l/person yr)		~ 50	~ 500	~ 10,000–100,000
Nutrients (kg/person yr):				
Nitrogen	~ 4.5	10% <sup>b</sup>	87%	3%
Phosphorus	~ 0.75	40%	50%	10%
Potassium	~ 1.8	12%	54%	34%

<sup>a</sup>Source: Otterpohl (2001).

<sup>b</sup>Percentage distribution of nutrients in the three waste streams (for brown water these values are based on faeces only, ignoring water used for flushing and anal cleansing).

bio-solids which can be applied intermittently to agricultural land or horticultural plots. The biogas produced from wastewater treatment plants can be used to generate electricity and that from household digesters used for cooking and/or lighting.

## 2. Selection of appropriate sanitation arrangements

Whichever low-cost sanitation arrangement is selected for any given community, it has to comply with the four principles for sustainable sanitation detailed in Section 1.1. In addition it must be technically feasible in the physical environment in which it is installed (for example, consideration has to be given to the local climate, altitude, ground slope, soils, hydrogeology, housing density, liability to flooding, etc.). It must also be compatible both with local socio-cultural practices and preferences and with local socio-economic conditions, including willingness and ability to pay for the sanitation arrangement selected. Professional planners and engineers need to be aware that socio-cultural preferences may be so strongly held so that a particular sanitation arrangement may be either totally rejected or most enthusiastically accepted – for example, on-site sanitation arrangements designed to permit the separate reuse of all human waste streams (i.e. yellow, brown and grey waters) often provokes one of these extreme responses (Drangert, 2004; Jackson, 2004, 2005). Furthermore, hygiene education to induce behavioural change is, if done properly, time-consuming and often expensive, but it comes with no guarantee of success.

We believe that one of the major problems in meeting the Sanitation MDG and the WHO/UNICEF target of Sanitation for All by 2025 is that far too few professionals (in both developing and industrialized countries) are aware of all the available sanitation options and are able to select the most appropriate sanitation arrangement for any given community. This is also true of the intended beneficiaries. There is indeed a vast amount of information available on appropriate sanitation arrangements and their suitability in different social and institutional settings. We are, however, of the opinion that the amount of information is both too large and insufficiently coherent to provide guidance on how to select the most appropriate sanitation arrangement in any given situation. In this paper we therefore develop an up-to-date sanitation selection methodology, taking into account the four principles of sustainable sanitation planning. In addition, the methodology incorporates two comparatively recent sanitation technologies, EcoSan and simplified sewerage, neither of which has been considered in this context before (Kalbermatten *et al.*, 1982b; Mara, 1996).

### 2.1. Low-cost sanitation arrangements

We divide sanitation arrangements into two broad groups: on-site and off-site systems, as detailed in Table 2. Given that all these sanitation arrangements, if properly designed, implemented, operated and maintained, can improve community health (Feachem *et al.*, 1983), we further divide them into three reuse categories: decentralized reuse, centralized reuse and intermittent reuse, as these lead to different sets of sanitation solutions (Figure 1). Decentralized reuse is reuse at household or local community level (a housing block, for example). Centralized reuse is reuse at the level of either natural drainage basins within an urban area or the whole urban area (town, city, metropolitan area); it will normally require wastewater collection in a sewer system followed by wastewater treatment, preferably with biogas production and collection, and then aquacultural and/or agricultural reuse of the treated effluent. It may also refer to grey water collection within a natural drainage basin followed by treatment and reuse. Intermittent reuse refers to on-site systems, including pit latrines, pour-flush toilets and septic tanks, which provide bio-solids for agricultural or horticultural reuse only when they are desludged every few years.

EcoSan can be either on-site or off-site, and it can even be partially on-site and partially off-site. There are many EcoSan variants: some are “high-tech” and high-cost (and are not therefore considered here); others are “low-tech” and low-cost, and may or may not include urine diversion. The latter include double-vault dehydrating or composting toilets with or without urine diversion, and despite some nutrient loss by seepage, the mobile ArborLoo (Morgan, 2000; see Table 2).

Design details (for example, single-pit systems versus alternating twin-pit systems for VIP latrines and PF toilets, back-yard versus front-yard versus pavement/sidewalk locations for simplified sewerage; on-site and/or off-site for EcoSan) are best considered when the sanitation arrangement has been broadly selected (check-lists for all the sanitation arrangements are given in Annex 1). Similarly, no detailed recommendations are made for treatment systems for either wastewater collected in simplified or settled sewers (although natural treatments systems, such as waste stabilization ponds and constructed wetlands, are usually most appropriate in warm-climate countries; see Mara, 2004), or for the separate EcoSan waste streams (see GTZ & IWA, 2004).

We do not include conventional sewerage as this is much too expensive for poor households in periurban areas and small towns (Kalbermatten *et al.*, 1982a; Lenton *et al.*, 2005), but we recognise its applicability in city centres and high-value commercial and industrial areas.

### 2.2. Sanitation selection algorithm

Our sanitation selection algorithm is given in Figure 2. The algorithm is a series of boxes containing abrupt questions (for example, “decentralized reuse?”) with up to four symbols which indicate the criteria which should be used to answer the question. The symbols are \$ (to indicate cost and affordability), ⊕ (socio-cultural acceptability), ✱ (technical feasibility) and ♻️ (environmental impact and reuse potential). It may be useful if the extent to which each of these criteria is met in any given situation is scaled from 1 to 5 (or 1 to 10) so as to enable both planners and stakeholders to evaluate how well each of these criteria are met in the different steps in Figure 2.

We start by asking about reuse alternatives as we take it for granted that all of the low-cost sanitation arrangements in Table 2 can improve community health and that many are ecological systems in the

Table 2. Available sanitation arrangements.

Arrangement	Diagram	Description	References
<i>On-site:</i>			
"EcoSan" toilet		Toilet for the safe reuse of excreta-borne nutrients either with or without urine separation (if separated, urine is collected and stored in a tank for 6 months in container or tank); and with externally accessible alternating twin vaults for dehydrating or composting faeces, paper and organic wastes (possibly with sieves or nets for separating water used for anal cleansing from the faeces). Stored urine applied to garden/field; composted faeces and organic wastes used as soil conditioner; and grey water applied in garden/field with or without prior treatment. For EcoSan toilets without urine diversion anaerobic treatment of black water for biogas production and use, and garden/field application of digested sludge.	Del Porto & Steinfeld (2004); Winblad & Simpson-Hébert (2004)
Biogas generator		Household-level anaerobic digesters treating black water, often with animal excreta and/or household organic wastes. The biogas produced is used for in-house cooking and/or lighting.	Nguyen (2003)
ArborLoo		A simple moveable wooden cover slab and superstructure unit placed over a shallow pit. When the pit is full the ArborLoo is positioned over a second pit and a tree planted in the first pit, and so on.	Morgan (2000)
"SanPlat" latrine		An otherwise unimproved pit latrine fitted with a concrete cover slab (called a "sanitation platform" or "SanPlat").	Brandberg (1996)
Ventilated improved pit (VIP) latrine		A pit latrine with the pit and the superstructure slightly offset to permit the installation of an external vertical vent pipe fitted at its top with a fly screen. The vent pipe exhausts faecal odours and the screen minimizes fly breeding.	Morgan & Mara (1982); Mara (1985a)
Pour-flush (PF) toilet		A manually flushed water-seal toilet discharging into an adjacent leach pit.	Roy <i>et al.</i> (1984); Mara (1985b)
Septic tank system		A large watertight tank, commonly with two compartments, which receives domestic wastewater (or only black water) for solids settlement and anaerobic digestion of the settled sludge. Effluent disposal is in soil infiltration trenches or infiltration pits; alternatively in periurban areas, settled sewerage (see below) may be used.	Mara (1996)
<i>Off-site:</i>			
"EcoSan" system		"EcoSan" urine-diverting toilets, communal urine pipes and storage; grey water sewers and treatment; household- or community-level composting or dehydration of faeces and toilet flush water; agricultural or horticultural reuse of stored urine, composted/dehydrated faeces and treated grey water.	Esrey <i>et al.</i> (1998); Winblad & Simpson-Hébert (2004)

Continued

Settled sewerage	A sewer system receiving the solids-free effluent from a septic tank serving a single households or a group of neighbouring households. As the sewer does not convey settleable solids, its hydraulic design is fundamentally different from that used for conventional and simplified sewerage. Secondary wastewater treatment and effluent reuse in aquaculture and/or agriculture or local horticulture.	<i>Sewer design:</i> Otis & Mara (1985); Mara (1996) <i>Wastewater treatment and reuse:</i> Mara (2004), WHO (2006a, b)
Simplified sewerage	A sewer system receiving unsettled domestic wastewaters. Sewer design is based on the same hydraulic principles as those used for the design of conventional sewers, but without any of the very conservative rules-of thumb and safety factors used for the latter. Simplified sewerage uses a minimum sewer diameter of 100 mm and self-cleaning of the sewers is ensured by using a minimum peak flow of 1.5 l/s and a minimum tractive tension of 1 kN/m <sup>2</sup> (= 1 Pa). This results in minimum sewer gradients that are shallow but satisfactory: for example, the minimum gradient for a 100-mm sewer is 1 in 200 (i.e. 5‰). Simple junction boxes are used, rather than manholes. All these factors contribute to low costs and typically simplified sewerage costs by 20–50% of the cost of conventional sewerage.	<i>Sewer design:</i> Sinnatamby (1986); Mara et al. (2001) <i>Wastewater treatment and reuse:</i> Mara (2004), WHO (2006a, b)

broad sense defined above. The first question asks if decentralized reuse is locally feasible; if it is, then the possible sanitation options are either EcoSan systems (with or without urine diversion) or biogas digesters treating household black water (often supplemented with animal excreta and/or household organic wastes). If centralized reuse is feasible the options are EcoSan systems (with urine-diverting toilets, communal urine pipes and urine storage tanks, grey water sewers, centralized collection and reuse of composted faeces), settled sewerage or simplified sewerage. If centralized EcoSan systems are not feasible, the algorithm asks if most households already have septic tanks. If they do, but the local arrangements for septic tank effluent disposal are unsatisfactory, the preferred option is settled sewerage (if they are not, then there is no need to upgrade the existing system). If they do not, then simplified sewerage is selected.

If decentralized and centralized reuse are both locally infeasible (for example, due to physical space constraints, the cost of even low-cost sewerage, or a lack of interest in or strong socio-cultural objections to reusing human wastes), one or more of the four principles may have to be infringed. Then the preferred option is either ventilated improved pit (VIP) latrines or pour-flush (PF) toilets with adjacent infiltration pits. However, in very poor communities “SanPlat” latrines (Brandberg, 1996) may be the only affordable option.

Some very poor periurban communities will not be able to be served with even “SanPlat” latrines if the housing density is too high and other sanitation arrangements too expensive. For these communities and also for families and individuals living “on the street” (for example, pavement dwellers in India and elsewhere and the homeless, including “street children”), communal sanitation is the only possible sanitation option. The precise sanitation arrangement adopted in communal sanitation blocks is relatively unimportant (more important aspects are user charges, privacy and security at night, especially

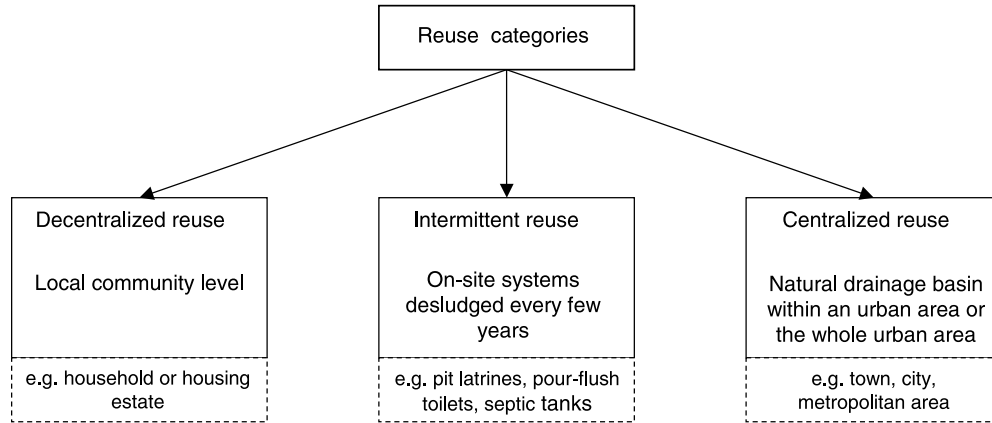


Fig. 1. Broad sanitation categories based on the arrangement of water and nutrient reuse.

for women and children), but it should be similar, if not identical, to that used locally in poor households. For example, in India pour-flush toilets are generally used, although wastewater disposal is to sewer rather than to infiltration pits (Singh, 2000); and in parts of China improved septic tanks are used and the biogas is collected and used by an adjacent household which has the responsibility for the operation and maintenance of the communal facility (Nguyen, 2003).

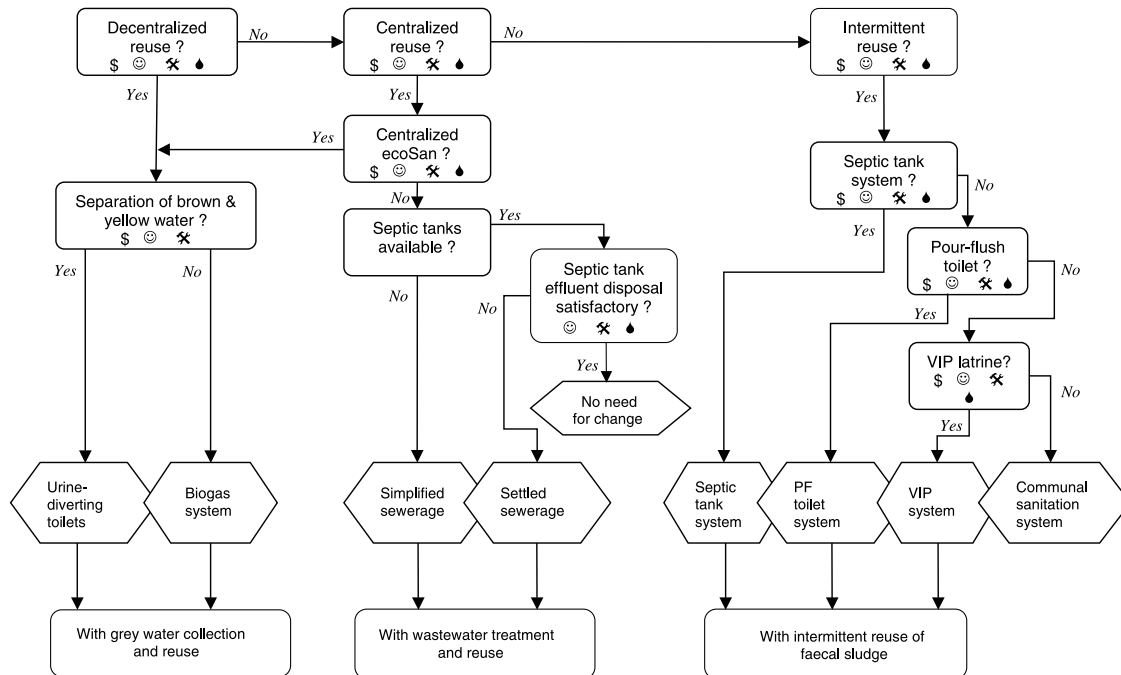


Fig. 2. Sanitation selection algorithm.

### 3. Discussion

An important function of the selection algorithm is to invite discussion between all local stakeholders on a number of issues that are often not on the agenda. Generally the most important of these are costs and institutional arrangements.

#### 3.1. Costs

Local variations in the physical and socio-cultural landscape necessitate local input into the selection process; any preconceived ideas should be held at bay. For example, the algorithm in Figure 2 asks several questions where the answer depends on costs and affordability. Local capital and operation and maintenance costs have to be determined in each case for discussion with the targeted community to enable it to come to a decision based on affordability. In-country comparative costs of different sanitation arrangements are given by Sinnatamby (1986) for northeast Brazil, by Gramalaya (2004) for India and by the National Sanitation Task Team (2002) for South Africa; however, in general there is very little recent information available on such costs (United Nations Millennium Project, 2004). Even when comparative costs are available, it is not clear if they are truly comparative – i.e. no evidence is given that the different sanitation arrangements were designed to the same overall standards. For example, “Option A” may have a “better” and hence more expensive superstructure than “Option B” but, given the relative unimportance of detailed superstructure design, the resulting cost comparison is unfair to Option A. Thus it is important that agencies reporting comparative costs do so on a wholly transparent basis, so that only the “true” basic costs of each sanitation arrangement are presented.

#### 3.2. Institutional arrangements

All sanitation arrangements are prone to mismanagement during planning (including sanitation selection), installation, and operation and maintenance. Therefore a comparison of sanitation arrangements needs to include an assessment of who is responsible for what and the likelihood that these responsibilities can and will be effectively discharged over the appropriate timeframe (they are a mix of short-, medium- and long-term commitments). Such an assessment requires both in-depth local knowledge and a non-prescriptive professional attitude. Rigid building and plumbing codes may act against the latter, but they can be difficult to revise or to circumvent, particularly if there are powerful professional, political and/or commercial interests in maintaining the *status quo*. However, change is possible – for example, the Brazilian national sewerage code was modified to embrace the basic design concepts of simplified sewerage (see Mara *et al.*, 2001).

#### 3.3. The not-too-distant future

Agriculture currently uses 70% of global water abstractions (Turner *et al.*, 2004). However, as water and nutrient scarcity increases in many parts of the world the policy of “fresh water for the cities and treated

wastewater for agriculture” will have to become more common. Only in this way will it be possible to maximize the efficient use of water and human-waste-derived nutrients to produce food for expanding urban populations. The efficient use of water means that agriculture will have to use less water (“more crop per drop”), industry will have to embrace more seriously the concept of cleaner production and new and existing houses and offices will have to use in-house water-saving plumbing fixtures, including low-volume flush toilets (3–5 litres per flush). The efficient use of nutrients means that urban organic solid wastes will have to be composted (or co-composted with faecal wastes) or fermented and the nutrient-rich residue applied to agricultural land and horticultural plots. In other words the strategy will have to change from exploiting new water sources and new phosphorus deposits, and fixing even greater amounts of di-nitrogen (resulting in correspondingly increased emissions of greenhouse gases), to reusing what is readily available. By using water and nutrients wisely, simple treatment may be enough to allow for the repeated use of the same water and nutrients. As a result the resource base expands considerably. Selection of appropriate sanitation arrangements will contribute to this development.

#### 4. Conclusions

- Narrow prescriptive perspectives are not conducive to sustainable sanitation planning. Thus, all possible sanitation arrangements have to be openly considered at the planning stage if a sustainable sanitation arrangement is to be selected. This requires the allocation of sufficient resources (human, financial and time) for the planning process.
- Affordability is the prime consideration when planning sustainable sanitation for poor and very poor households in developing countries. However, good data on comparative costs of sanitation alternatives are scarce and an agreed costing methodology has yet to be developed.
- The sanitation selection algorithm is a useful tool to inform and direct the process of sustainable sanitation planning, as it transparently considers all available sanitation arrangements and their associated financial, socio-cultural, technical and environmental constraints. In this sense, and given the general lack of sanitation expertise at local level in developing countries, it is an essential planning tool which will greatly facilitate the achievement of the Millennium Development Goal for sanitation.

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## Annex 1. Post-selection check-lists for detailed design

### *All sanitation arrangements*

1. Ascertain preferred local defecation position (sitting or squatting) and provide appropriate units. Ascertain preferred local defecation position (sitting or squatting) and provide appropriate units.
2. Design superstructure to be architecturally compatible with house.
3. Develop user instructions for correct use and routine operation and maintenance. Develop user instructions for correct use and routine operation and maintenance.

*On-site sanitation arrangements*

1. VIP latrines and pour-flush toilets:

- a. Decide whether to have single-pit or alternating twin-pit systems (former suitable in rural areas and in periurban areas if mechanical pit emptying feasible; latter suitable in periurban areas if manual emptying feasible, in high-groundwater-table areas and/or if there is shallow unpickable rock).
- b. Decide whether pits are to be emptied mechanically or manually (if mechanically then use single pits; if manually use alternating twin pits, except for long-life (~ 10 years) pits in rural areas). Decide on reuse/disposal of removed faecal sludge.
- c. Raise pit cover slab by (300 mm above ground level in areas of permanently or seasonally high groundwater table).

2. EcoSan toilets:

- a. In case of urine diversion, design tank volume for a 1-year fill-and-store period based on the number of users and 500 l of urine excreted per person per year. Ensure responsibility for regular emptying of urine tank for agricultural use.
- b. Alternating twin vaults for dehydration or composting of faeces should be built above ground and protected from flooding. Design volume of each vault is based on a 6-month use period, the number of users and 50 l of faeces excreted per person per year.
- c. Check whether faeces have to be separated from any liquid (e.g. water used for anal cleansing) by nets, sieves, etc. to permit effective dehydration or composting. The separated liquid should be treated together with the household grey water.
- d. If urine diversion is not suitable for any reason, treatment of black water (together with animal manure) in anaerobic digesters should be selected. The anaerobically treated sludge can be used as fertilizer.

*Off-site sanitation arrangements*

1. Settled sewerage:

- a. Decide on settled sewerage layout (at rear or in front of houses; adequate number of inspection points).
- b. Determine hydraulic feasibility of settled sewerage layout (no back-flow from sewer to any solids interceptor tank; adequate hydraulic gradient over any long flat sections).
- c. Transfer responsibility for desludging interceptor tanks to sewerage authority. Decide on reuse/disposal of removed septic tank sludge.

- d. If there are any pumping stations, ensure that the sewerage authority can operate and maintain them.
- e. Decide on wastewater treatment and evaluate reuse potential.

## 2. Simplified sewerage:

- a. Decide on simplified sewerage layout (at rear of houses, in front garden or under pavement/sidewalk; adequate number of inspection points).
- b. Determine hydraulic feasibility of settled sewerage layout (adequate minimum gradient and minimum sewer diameter for daily peak flow, both at start and end of project life, to ensure self-cleansing of sewers).
- c. Ensure that sewerage authority can operate and maintain the sewer network.
- d. Decide on wastewater treatment and evaluate reuse potential.

## 3. EcoSan systems:

- a. Decide on yellow water sewerage layout (at rear or in front of houses; adequate number of inspection points).
- b. Determine hydraulic feasibility of urine sewerage layout (no back-flow from sewer to any urine diversion toilet; adequate hydraulic gradient over any long flat sections).
- c. Ensure that sewerage authority can operate and maintain the yellow water sewers (attention has to be given to the appearance of any incrustations which may lead to sewer blockage). If there are any pumping stations, ensure that the sewerage authority can operate and maintain them.
- d. Ensure that sewerage authority or responsible authority can oversee regular emptying of the yellow water collection tanks by local farmers and instructs them in the most appropriate way to use urine as a fertilizer.
- e. Check whether faeces should be separated from any liquid (e.g. water used for anal cleansing) by nets, sieves, etc. to permit effective dehydration or composting. The separated liquid should be treated together with the household grey water.
- f. For grey water sewerage, see above under simplified sewerage.
- g. Ensure regular removal of treated faecal matter from the EcoSan toilet vaults and its correct agricultural use.