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CONTEXT DEPENDENCIES OF SANITATION SYSTEMS
with Regard to Developing Countries

Diploma Thesis

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Declaration of Authorship

I hereby declare that

I have written this thesis without any help from others and without the use of documents and aids other than those stated above,

I have mentioned all used sources and that I have cited them correctly according to established academic citation rules

Vienna, 26.10.2010 Sandra Nicolics

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Kurzfassung

Angesichts der Herausforderung, die Zahl der Menschen ohne Zugang zu angemessenen sanitären Einrichtungen zu minimieren, sind regional und funktional angepasste Lösungen gefordert. Dies sollte die Entwicklung technischer Komponenten ebenso betreffen, wie auch eine angemessene strategische Planung. Der Transfer und die Anwendbarkeit von in reichen, industrialisierten Ländern häufig angewendeten Systemen in die Gebiete, in denen die Situation besonders präker ist - informelle Siedlungen armer städtischer und ländlicher Gebiete in Entwicklungsländern - scheint allerdings sehr problematisch.

Diskussionen im Abwassersektor waren bisher häufig von der Idee getragen, dass eine einzige technologische Lösung bestimmbar ist, die effizient großflächig eingesetzt werden kann - ungeachtet der vorherrscheinden Rahmenumstände. Vorhandene technologische Möglichkeiten werden oftmals nicht ausdifferenziert betrachtet - sodass weder tatsächliche Funktionen noch gegebene Funktionsweisen näher berücksichtigt werden. Es ist eine Tatsache, dass sanitäre „Infra-Struktur“ stark mit unterschiedlichsten Bereichen in und um eine Gemeinde herum verbunden ist. Angepasste Planungsstrategien in der Siedlungshygiene sollten diesen Aspekt daher genauso miteinbeziehen, wie auch die Idee, dass vorhandene technologische Lösungen charakteristische funktiononelle Unterschiede aufweisen.

Es ist daher Ziel und Interesse dieser Thesis, prägnante Merkmale in einer Gemeinde bzw. um eine Gemeinde herum zu identifizieren, die im Bezug auf die Umsetzbarkeit eines Sanitärsystems ausschlaggebend sind. Zur methodischen Betrachtung verfügbarer und vielfach eingesetzter Technologien in der Siedlungshygiene, wurde auf das Konzept „System Approach to Sanitation“ Bezug genommen, das TILLEY et al. (2008) präsentierten. Darauf basierend wurden Funktionsanforderungen für Beispiele der folgenden Systeme herausgearbeitet: einfache und etwas ausgereiftere “drop and store” Systeme (Latrinen- bzw. Senkgruben basiert), zyklische Systeme, die sich an der Wiederverwendung enthaltener Nährstoffe orientieren, ein konventionelles (kanal-basiertes) System sowie ein alternatives (kanal-basiertes) System. Der Fokus lag dabei auf der Erarbeitung von Anforderungen, die besonders im Hinblick auf die Realisierbarkeit in Entwicklungsländern als ausschlaggebend erscheinen. Gewonnene Erkenntnisse wurden danach dazu genutzt, „Kontext Bereiche“ sowie zugehörige Faktoren zu identifizieren, die für die Siedlungshygiene von Relevanz sind. Durch eine systematische Analyse der Technologien bzw. Systeme konnten somit „Kontext Abhängigkeiten“ erarbeitet werden. Dabei wurde konkretisiert, welche der identifizierten Faktoren tatsächlich für eine Technologie (Prozess-Schritt) wie auch ein ganzes System zutreffen.

Die Resultate zeigten bemerkenswerte Unterschiede zwischen den untersuchten Systemen - sowohl bezüglich relevanter Kontext-Bereiche, wie auch im Bezug auf die Ausprägung beobachteter Abhängigkeiten. Ebenso konnten bei der Verteilung der Abhängigkeiten im Prozessverlauf, Unterschiede betreffend relevant erscheindener Kontext-Bereiche (sowie zugehöriger Anforderungen und Limitierungen) beobachtet werden. So stellten sich bei den unterschiedlichen Systemen, im Hinblick auf die Ausprägung ihrer Abhängigkeit, verschiedene Prozess-Schritte als kritisch heraus.

Es liegt daher nahe, dass in Diskussionen über eine großflächige Etablierung bestimmter Systeme (oder Ansätze) unbedingt zur Kenntnis genommen werden muss, dass jedes System unter bestimmten Rahmenbedingunen („Kontexten“) funktioniert und diese dementsprechend ausdifferenziert betrachtet werden müssen.

Abstract

Facing the challenge of minimizing the number of people without access to adequate sanitation, regionally and functionally adapted approaches are needed - in terms of both technology development and accurate strategic planning of sanitation. However, the transfer and applicability of sanitation systems commonly used in rich, industrialized countries to those areas where the situation is particularly serious - i.e. in informal settlements of poor urban and rural areas in developing countries - is problematic.

A lot of discussions and debates in the sanitation sector are motivated by the idea that there is a single technological concept or solution which could be established efficiently on large scale - independently from the context it is applied in. Available technological options are often not considered in a differentiated manner taking into account their actual functions and functionalities. But it is a matter of fact that sanitation "infra-structure" is highly linked to several domains within and around a community. Accurate sanitation programming strategies must take that into account - as well as the idea that available technological approaches have characteristic functional differences.

It was therefore the interest of this work, to identify characteristics within and around a community which are decisive in terms of the feasibility of chosen sanitation systems. For a methodical overview of available and commonly used technologies, the "System Approach" to Sanitation, presented by TILLEY et al. (2008) was referred to. Based on that reference, functional requirements were elaborated of examples of simple and more sophisticated "drop and store" systems, re-use oriented systems, a conventional water-based system as well as an alternative water-based system. Main focus was on working out distinctive functional requirements - with regards to limitations typically found in developing countries. The gained information was then used for identifying sanitation-relevant context fields and associated factors. By systematically analyzing which factors were actually determinant for a technology/system, "context dependencies" were revealed. For this purpose, evaluations were made for each functional step involved in the sanitation process as well as for whole systems.

The results of this thesis show that there are remarkable differences between the presented systems in terms of context fields of relevance and the extent of existing dependencies. Also, looking at the allocation of dependencies within a system, ranging relevancies of presented context fields (and associated requirements or limitations) were observable. Different process steps appeared as critical - in terms of the peculiarity of their dependencies.

Therefore it is assumed, that when discussing the potential of specific systems (or approaches) to be established on a large scale, one must be aware of the fact that each system operates in specific contexts and that these contexts have to be regarded in a differentiated manner.

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1. Introduction

General Background

Ever since the UN Millennium Development Goals were published in 2000, the importance of sanitation in terms of human kind's development became more and more recognized. Among the eight main goals and several sub-targets, there was target 10, which claims to halve the proportion of people without sustainable access to safe drinking water and basic sanitation supply by 2015 (UN MILLENIUM PROJECT, 2005). According to the UN's WORLD WATER DEVELOPMENT REPORT 3 (2009), however, the proportion of people without improved sanitation has only decreased by eight percent between 1990 and 2006. Based on current trends, in 2015, around 2.4 billion people won't be served with adequate sanitation infrastructure. Therefore, in order to achieve the target, immediate acceleration in progress is needed.

A reasonable proportion of people, who currently lack adequate access to sanitation, are living in large or even "Megacities" of emerging and developing countries. The situation is therefore particularly serious in informal settlements of poor urban areas (UNESCO, 2004). But also the number of people in poor, rural areas without access is truly startling. Thus, transfer and applicability of sanitation systems commonly used in wealthy, industrialized countries is strongly limited. This is not only due to significant differences in terms of climatic conditions but also due to severe disparities concerning socio-economic and cultural conditions. Facing this challenge, the development and application of functionally and regionally adapted technologies becomes crucial (HERBST, 2008). On the one hand, one must be aware of sanitation-relevant characteristics of the community a system should be applied in. On the other hand, one should not forget about the technical "fields of application" of specific technologies in order to decide whether they are "applicable" (or "adaptable") in the prevailing conditions or not.

According to the UN ECONOMIC AND SOCIAL COUNCIL'S COMMISSION ON SUSTAINABLE DEVELOPMENT (2004), sanitation is increasingly recognized as a national development priority requiring adequate policies and budgetary allocations. Thus, decisions and actions towards sanitation improvements should not only be undertaken and considered on planning or project level, but also during political programming and strategic planning.

Incorporating the aspects mentioned above, therefore, efforts have to be made to establish strategies in sanitation which involve approaches towards "functionally and regionally adapted" sanitation. Therefore, when considering "contexts" relevant for sanitation programming and planning, it can be distinguished between "local context" and "technology-specific context". The former is determined by the local conditions found in a community a sanitation system is applied in. The latter is determined by the technology's limitations but also functional advantages - characterizing the general "field of application" of a technology. In Fig. 1, the local context of sanitation systems is represented by the fields "Human Settlement", "Society", "Natural Environment" and "Religion & Culture". These groupings are chosen following AVVANNAVAR & MANI (2008), who investigated various approaches towards sanitation in diverse societies in the world. As they considered factors relevant for determining a community's' approach towards sanitation, their identified system structure is taken as the basis for describing sanitation-relevant characteristics of a community.

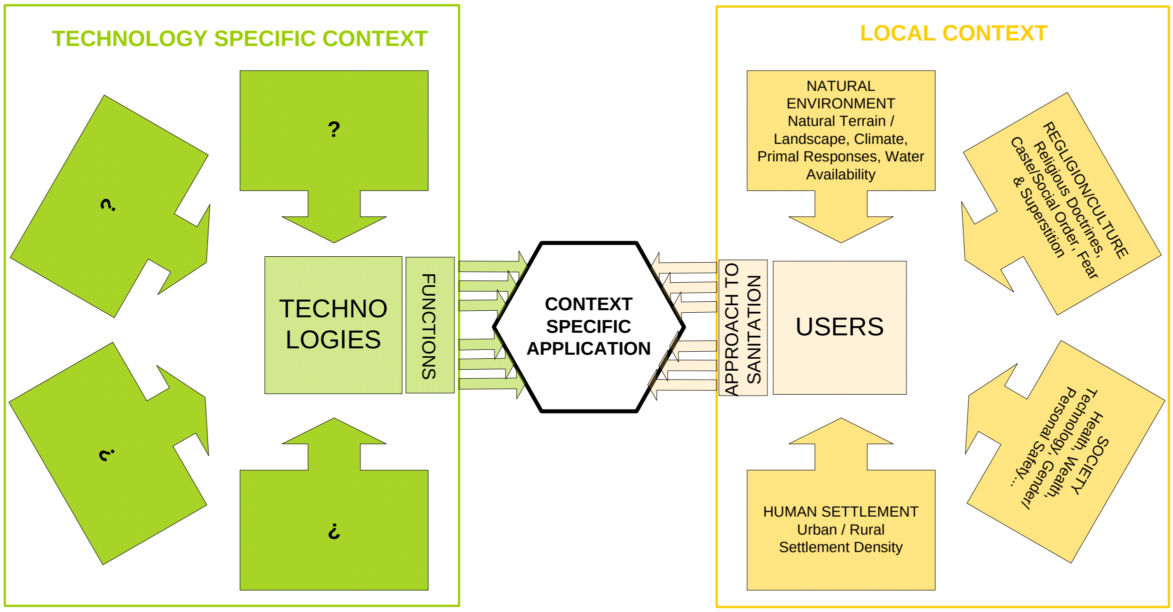

Fig. 1 Context fields relevant for Context Specific Application of Sanitation Systems (adapted from AVVANAVAR & MANI, 2008)

Factors used in Fig. 1 for describing the “local context” are only giving an idea of the range of factors relevant for applying a sanitation system. At actual planning or implementation level, a much wider range of aspects have to be considered in order to describe the actual conditions in a community.

Within this work, however, the focus is on the “technology-specific” context, which finally decides whether a technology’s implementation is feasible or not. As this context builds the second major basis for context specific application of sanitation systems it is seen as an important and remarkably relevant field of research.

The research and its systematic appraisal of the literature which builds the basis for this work, was carried out between December 2009 and July 2010.

Problem Outline

Progress and successful steps in the sanitation sector towards achieving the sanitation-related UN Millenium target are limited. Hence, current approaches and discussions in the context of international sanitation programming are open to question. The central motivation behind this thesis is therefore the assumption that preliminary discussions and approaches in international sanitation programming, have often shown the following shortcomings:

- Available technological options are often not considered in a differentiated manner taking into account their actual functions and functionalities. Instead, a lot of discussions and debates in the sanitation sector are motivated by the idea that there is a single technological concept or solution which could be established efficiently on a large scale - independently from the context it is applied in.
- In many cases, economic efficiency - often contemplated through costs - appears to be a leading interest in the decision making and development process towards sanitation. Obviously, costs and cost-effectiveness are crucial factors for the establishment of infrastructural systems. However, being too concentrated on economics might constitute the risk of disregarding other important factors - such as the characteristics and ultimate functions of applied technologies. It is a matter of fact that sanitation “*infra-structure*” is strongly linked to several domains within and around a community. Thus, a one-dimensional approach - only involving an economic point of view - seems insufficient.

Based on these assumptions, in this thesis, a step towards a more informed, multi-dimensional strategy planning of sanitation programmes should be elaborated - involving a technologically based perspective of sanitation. Thus, technologies as well as technology-specific contexts will be examined and discussed systematically.

Research Questions

Specifically, the following research questions will be looked at within this thesis:

- What are the characteristics in terms of functionalities, functions as well as fields of application of some common sanitation technologies?
- Which factors ("functional requirements") have an impact on the technology's' applicability? Correspondingly, which relevant "context fields" can be identified?
- Which of these factors can be seen as „limiting" in terms of a technolog's application in the context of a developing country?
- What are the differences between the contemplated technologies in terms of the previous questions? What conclusions can be drawn concerning the different fields of applications of these technologies?

Looking at these questions in detail, should on the one hand illustrate the range of approaches available towards improved sanitation. Moreover, those aspects which determine the establishment of the particular technologies or whole systems should be clarified. Based on that, existing variations in terms of the systems' field of application should be suggested. It is assumed that the presented technologies - and consequently their logical combinations into systems - are showing quite significant differences in terms of their field of application and correspondingly the contexts they can and should be applied in. Neglecting these characteristics - i.e. the technology-specific contexts - in considerations during strategic sanitation planning, will significantly limit the potential of developing regionally but also functionally adapted systems.

2. Methodology

The approach used in this thesis should allow considering and characterizing common sanitation practices in a systematic and differentiated manner. In a first step, based on a literature review, the most commonly and wide-spread approaches are identified. Selected technologies are then structured and logically combined according to their functions within the sanitation process (see chapter 2.2). Distinguishing existing functions builds the basis for examining the technology's (and consequently systems') general technical functionality.

Based on the description of the component's functionalities ("Functional Patterns"), associated functional requirements should be identified. This mainly involves the consideration of the technical conditions (e.g. is a constant supply of water needed or not; does it work for areas with high/low population density; etc.) but also should incorporate socio-economic conditions a community has to fulfil in order to properly install and maintain a particular system (e.g. which level of knowledge or expertise is required; is a stable institutional organisation needed for managing the system; does it involve high/low capital costs/running costs; etc.). By working out major requirements determining a favourable and effective function of the technologies the range of factors - from a "technical" point of view - influencing the establishment of a sanitation system should be reconsidered.

The identified requirements are then used to form "context fields", which should illustrate those domains of a community that are relevant in terms of an application of a sanitation system.

As it has been mentioned before, enhancements in the sanitation sector are of special relevance for developing (and emerging) countries. Therefore, in a further step, the *distinctive* requirements should be determined - i.e. the so-called “limitations”.

Once the most concise limitations are worked out, a systematic appraisal facilitates an investigation of existing differences in terms of “dependencies” of specific components or even whole systems from the determined limitation factors. Being aware of actually “limiting” factors relevant for a technology’s or system’s application as well as the degree of dependency from these factors, should allow evaluation of the appropriateness or even adaptability of a system in terms of potentially prevalent “local contexts”.

2.1 Technology Selection

Based on a literature review as well as through discussions with DI Helmut Jung, the following four sanitation approaches were selected and focused on, as they appear to represent the most common practices found in the sanitation sector of developing countries:

- simple drop and store systems (“**Pit-latrine based** systems”)
- cyclic systems (“**Re-use oriented** systems”)
- a system involving an improved on-site storage (“**Septic Tank** - based system”)
- a conventional water-based as well as an “alternative” water-based system (“**Semi-centralized and Centralized water-based** systems”)

2.2 System Approach to Sanitation

The association of the technologies with „sanitation systems“ is undertaken following TILLEY et al. (2008) and their Compendium on Sanitation. Thus, according to these authors, when considering sanitation technologies, it is vital to discuss them systematically - involving a differentiated observation of their functions and logical combinations of available technologies.

However, before identifying and investigating aspects, which are determining the functionality of sanitation systems, the actual targets and objectives of sanitation have to be considered. According to the ISO 24511/CD, the following principal objectives can be identified for wastewater treatment:

- Protection of the public health: The protection of human health and safety is considered to be the primary and herewith most central target of sanitation
- Protection of the natural environment: This goal implies the preservation and conservation of natural resources, the control of overflows and the preservation of flora and fauna.

Besides these two prominent goals, ISO 24511/CD also adds the goals “Protection of the built/public environment” and “Promotion of Sustainable Development[1]” as objectives for wastewater management. Moreover, it is notable that a wastewater system should be cost-effective and permit a phased development in order to overcome financial constraints – while not compromising the stated objectives.

[1] Sound management of drinking water and wastewater utilities is a substantial contribution to an integrated management of water resources and therefore to sustainable development because social cohesion and economic development within a community are enhanced along with environmental protection.

Sanitation can be defined as a multi-step process where "wastes" travel from the point of generation to the point of use or ultimate disposal (TILLEY et al., 2008). Considering its objectives, it is of importance to realize that this can only be successfully achieved by following a "system approach". In this case, sanitation devices and technologies are considered as parts of an entire system, which involves several steps associated to different functions. Successful sanitation therefore is achievable by iteratively building up logical linkages or combinations of technologies according to their functions within the system. By combining them pursuit to that, an accurate level of hygiene and environmental protection ("sanitation) should be assured.

Following TILLEY et al. (2008) and their Compendium on Sanitation, the following functional groups can be identified, with each representing one step within the sanitation process.

- Capture ("User Interface")
- Collection and Storage
- Conveyance
- (Semi-) Centralized Treatment
- Use and/or Disposal

Beside these identified "functional groups", also "wastes" travelling through the sanitation process can be characterized and distinguished. According to the authors, the following "sanitation products" can be identified:

- Primary inputs: urine, faeces, organics, anal cleansing water, dry cleansing material, drying material (material supporting subsequent drying activities), stormwater, greywater, flushwater
- Products after capture: urine, faeces, excreta, blackwater, brownwater
- Products after storage/treatment: dried faeces, stored urine, faecal sludge, effluent, compost/ecoHumus
- Output after semi-centralized & centralized treatment: treated effluent, treated sludge, biogas, forage

The descriptions of the systems' "functional patterns", which will be undertaken in chapter 3, are therefore all structured similarly. Depending on the system, not all sanitation phases are involved. For all systems, a graphical overview of their functional pattern is provided, which will illustrate both the involved technologies and involved wastes ("products") followed by a description of each sanitation step and associated technological options.

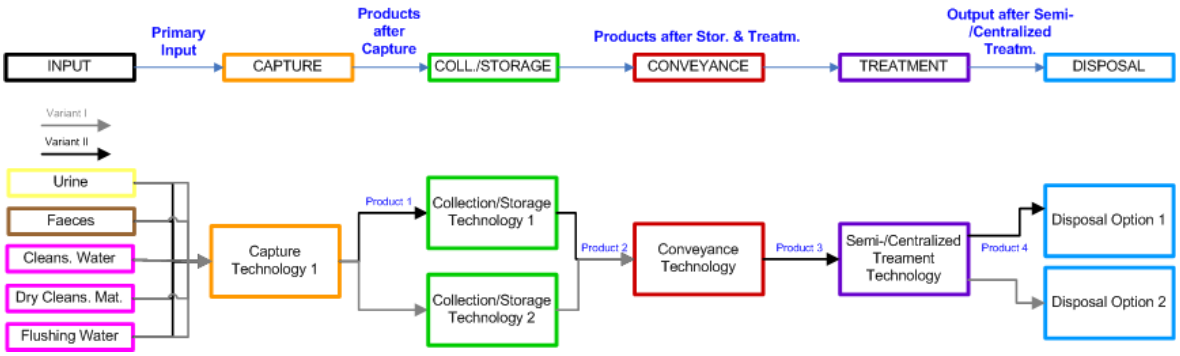

Fig. 2 Structure of a Functional Pattern of a Sanitation System based on the System Approach

As becomes obvious in Fig. 2, there is the possibility that more than one variant of a logical combination of technologies can be presented as examples for a particular system. In this case, the arrows (indicating the travel of the products within the sanitation process) are of different colours.

2.3 Context dependencies

After “Context Fields” relevant for the presented sanitation systems are identified, information gained within the literature review is used to define factors associated with these context fields. The factors are formulated as criteria (variables) for evaluating the extent of existing dependencies of technologies/systems from the identified context fields. By considering how many factors are actually determinant for a technology/system, its “context dependency” should be revealed (see Fig. 3).

The more criteria that apply to a technology/system, the higher is its dependency rated. E.g.: If there are five criteria identified for describing a context field, a match of four out of this five variables results in a dependency value of 80% of a technology from this context field.

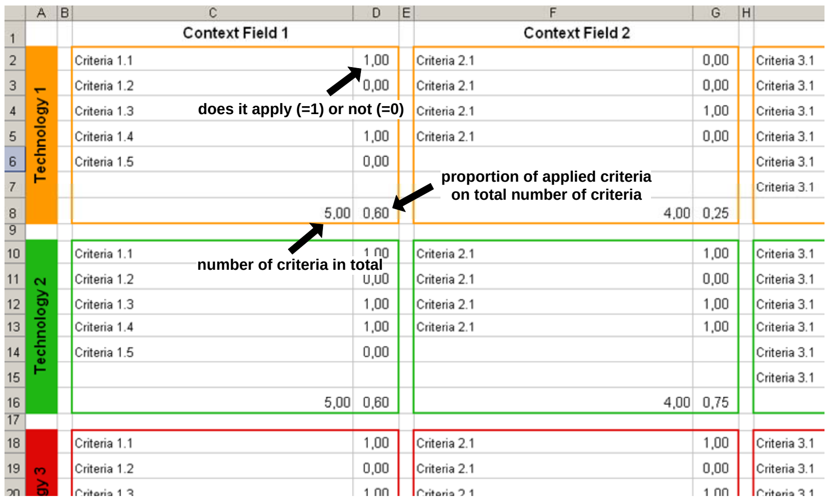

Fig. 3 Evaluation of context dependencies by considering how many criteria do apply for a specific technology.

Elaborated dependencies are then illustrated in radar charts (see Fig. 4) whereas both evaluations of particular technologies and results for whole systems will be clarified. That way, existing differences in terms of the technology’s and systems’ contexts and context dependencies should be made more obvious.

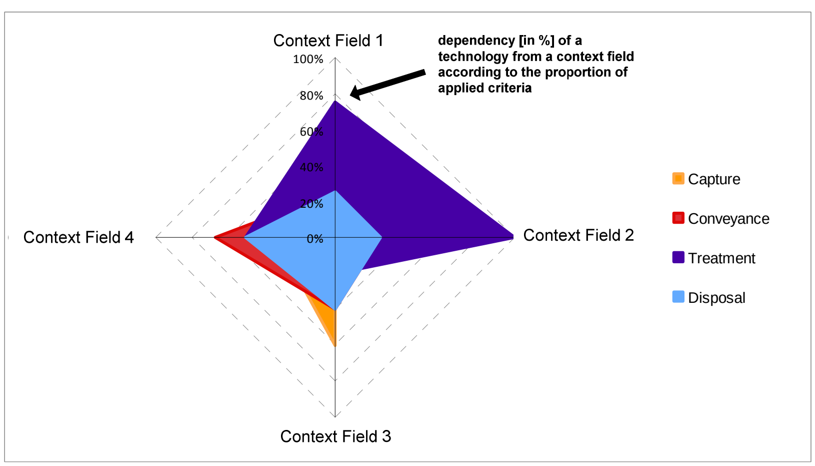

Fig. 4 Example for a radar chart illustrating evaluated component-specific context dependencies

Moreover, for each component the proportion of applying criteria per context field will be illustrated (see Fig. 5). A consolidation of these values leads to a component-specific total dependency value. Comparing these values allows an analysis of development and allocation of dependencies within each system.

	Context Field 1	Context Field 2	Context Field 3	Context Field 4	Sum Ind. Proportion Values (abs.)
Capture	0,60	0,25	0,50	0,00	1,35
Coll./Stor.	0,60	0,75	0,67	0,17	2,18
Conveyance	1,00	[illegible],00	0,60	0,50	
Treatment	0,00	1,00	0,20	0,50	
Disposal	0,00	0,25	0,60	0,50	1,35

Proportion of applied criteria on total number of criteria

Sum of all context field specific values („Sum Individual Proportion values“)

Fig. 5 Example for summary of evaluated component-specific values

It has to be noted that due to the literature-based input for determining the evaluation data, the evaluation criteria used for each context field are not weighted. A more differentiated analysis would be beyond the scope of this thesis, as this would require extensive case studies.

2.4 Consideration Limits

Beside the limitation mentioned in the previous section, the following limits have been set - due to the chosen methods (i.e. literature-based research, with no case studies) and the indicated scope of this thesis.

Only the processing of *domestic* waste(water)s is considered, excluding other types of wastewaters such as stormwater or industrial wastewater. Besides, the undertaken description of the involved technologies and their fields of application should be understood as an outline only of their ideal application. Thus, implementations and applications in reality might look quite different. Furthermore, as stated before, this selection is only a general proposition based on technological practices currently found towards sanitation. Obviously, there is a huge variety of other technologies available as well, which won’t be discussed or mentioned within this thesis. However, the presented approach can serve as potential approach for examining other sanitation infrastructures.

In order to evaluate whether a criterion (a requirement) is applicable, it was not explicitly differentiated in terms of its dimensions of quality and quantity. This is also due to the fact that it was not determined how many users are served by a component. Therefore, in the evaluation, it was instead considered whether a criterion in general appears to be relevant or not.

3. Functional Patterns of Selected Sanitation Systems

3.1 Overview of the selected Sanitation Systems

Within the following chapter, a short overview of the functional patterns of some chosen systems should be discussed. Thus, some common combinations of technologies as well as the range of input and output products characteristic of the systems are mentioned. Based on that - in a further step - requirements significant for the systems' functionality should be identified.

For discussing factors and criteria relevant for determining sanitation technology contexts, technology combinations were selected, which are associated to very different fields of application. Correspondingly, an overview of a range of potential contexts should be provided.

As stated before, the following four sanitation approaches were selected and focused on, as they appear to represent the most common practices actually found in the sanitation sector: Fig. 6 illustrates a simplified overview of the technology combinations, which are discussed in this thesis. More detailed schematic illustrations of involved components and waste streams are provided in every subchapter.

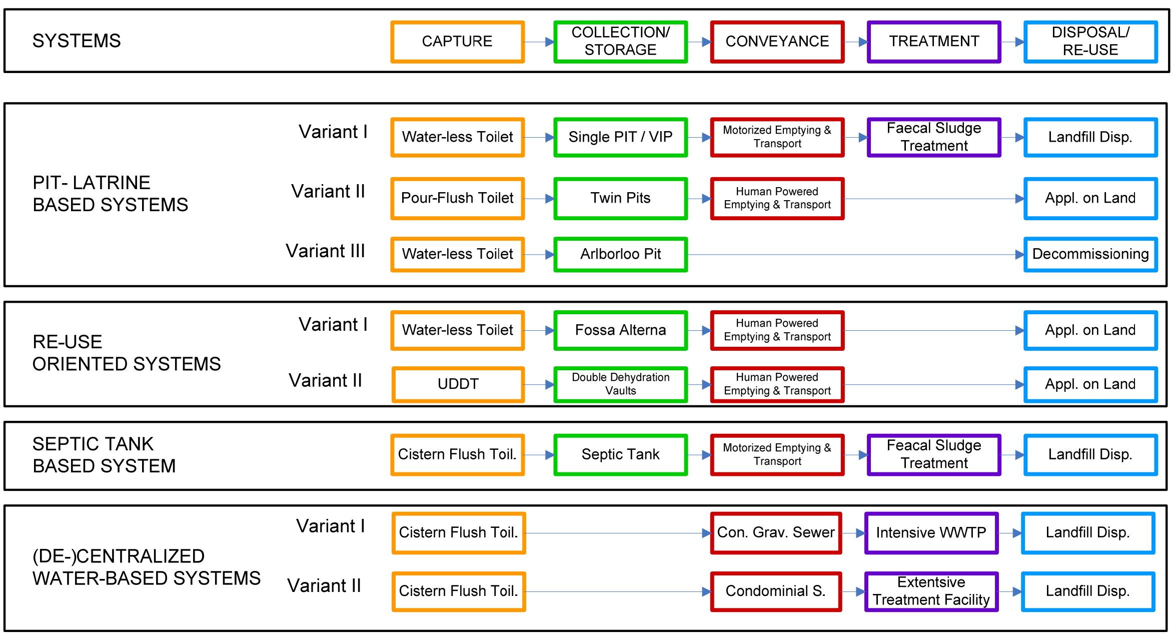

Fig. 6 Overview of the selected Sanitation Systems

3.2 Pit-latrine based systems

Especially amongst the poorer segments of rural society in developing countries the use of pit latrines is very common (UNESCO, 2010). Latrines are amongst the oldest technical solutions for dealing with human excreta. As there is no need for a water connection, pit latrines provide a solution for areas without a reliable water supply (VEST & BOSCH, 2005). In the following, pit latrines are described as part of a logical combination of technologies building up a complete sanitation system. "Latrines alone are not enough (…) Faecal sludge needs adequate treatment and disposal to safeguard public health and the environment (WSP & BNWP, 2008, p.7)."

As approaches discussed in this paper are rather describing the ideal application of technologies, reality unfortunately often looks quite different. Well-designed pit-latrine based systems which include collection and treatment steps in a sufficient manner are only rarely found. Pit-latrine based systems are therefore prone to be poorly managed in terms of insufficient emptying intervals or inappropriate handling of removed sludge (TILLEY et al., 2008). Furthermore, in order to minimize efforts needed for emptying pits, they are often constructed in a way allowing accumulated material to be washed out. Following arguments presented by WATER AND SANITATION PROGRAM & BANK NETHERLANDS WATER PARTNERSHIP (WSP & BNWP) in 2008, the majority of faecal sludge produced in urban environments of several Asian and African countries[2] (where between 50 up to 98% of inhabitants are served by on-site sanitation systems which are producing faecal sludge) would have no sufficient faecal sludge management. Even when emptying is undertaken, requirements for safe pit emptying are often neglected resulting in serious consequences for human health and the environment (PEAN THYE et al., 2009). Most of the untreated sludge therefore would be used or disposed of haphazardly and illegally (WSP & BNWP, 2008). Reasons for explaining this high level of illegal and insufficient sludge management are widespread. On the one hand, there are political impediments, such as an inadequate legal and regulatory basis, which results in a lack of incentives and sanctions. On the other hand, there is a problem in terms affordability, a lack of coordination as well as difficulties to access pits for emptying (PEAN THYE et al., 2009).

However, as the focus of this thesis is the investigation of a safe as possible application of technologies, described approaches encompass not only collection of excreta, but also necessary conveyance and disposal steps.

Fig. 7 presents an overview of functional patterns of three chosen variants of pit-latrine based systems. Similarly, functional patterns of the other presented systems will consequently be provided.

[2] In 2006 85% of Ghana's inhabitants were served by on-site sanitation systems; Bamako (Mali) 98%, Tanzania >85%, Manila 78%, towns in Philippines in general (towns) 98%, Bangkok (Thailand) 65% and Latin America >50%

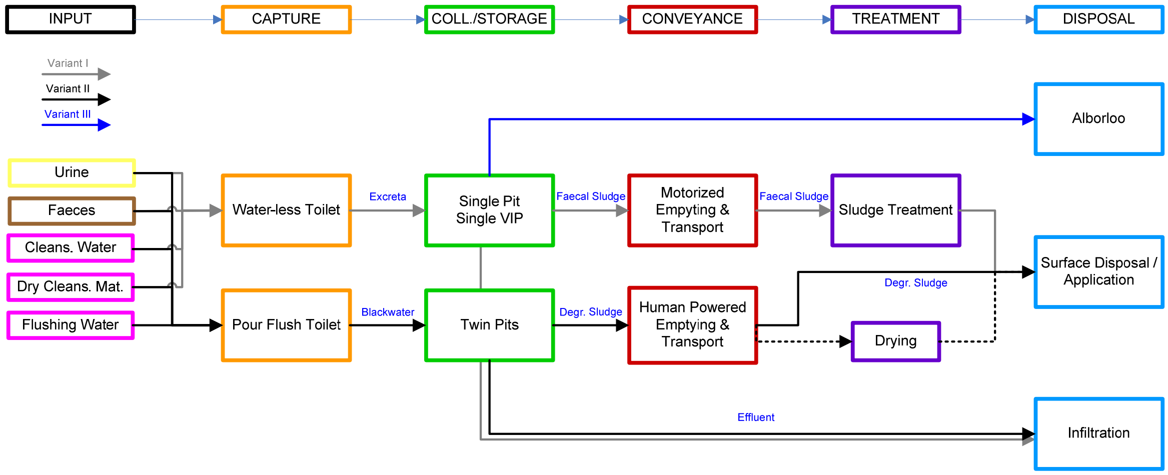

Fig. 7 Systematic overview of different variants of pit-latrine based Systems

“Drop and Store” – the hiding of excreta in (deep) excavations, is the basic principle of pit-latrine based systems. Its design is characterized by the ability of being operated with only very little or even no water (UNESCO, 2010). It is important to note that there are diverse technological combinations involving the use of pits as collection/storage units. In the following some common approaches are considered, which do have very significant differences in terms of their functional requirements.

3.2.1 Captures: Water-less Toilet and Pour Flush Toilet

Depending on the user interface, in this system urine and faeces are collected either with or without flushwater. Common captures are Pour Flush Toilets or Water-less toilets. Inputs therefore can vary with the particularly installed user interface. In general, in terms of cleansing habits, dry cleansing material can be inserted as well as anal cleansing water (TILLEY et al., 2008). In practice, besides excreta and cleansing materials also all sorts of garbage and rubbish get dumped into the pits, which can significantly impede pit emptying (MORGAN, 2007). Therefore, it is of importance to avoid the dumping of these disturbing materials. Greywater is only co-transported in the case of a Pour-Flush Toilet. However, extra Greywater management has to be provided - as it is not generally covered by this system.

Water-less Toilet

A capture method commonly used for Single Pits, are Water-less toilets (Fig. 8). Characteristic for this user interface is its operation without water. Commonly, constructional designs allow users to sit or squat over the drop hole. Urine and faeces are both falling through the hole and form excreta. Depending on the collection and storage facility used in combination with this capture, the toilet has to be mobile. Easy and intuitively useable, this toilet option appears physically comfortable and natural to many user types (TILLEY et al., 2008).

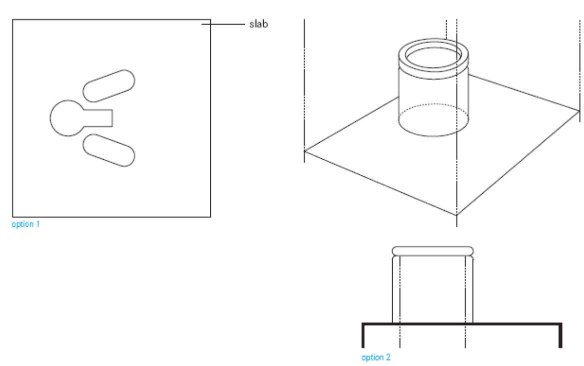

Fig. 8 Design schemes of two design options for water-less toilets (TILLEY et al., 2008)

Pour Flush Toilet

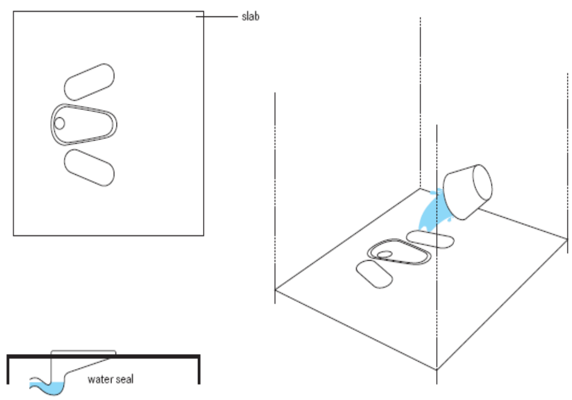

Fig. 9 Design scheme for a Pour Flush Toilet (TILLEY et al., 2008)

With this capture (Fig. 9), excreta are deposited into a bowl and flushed away with water, which is poured in by the user himself. Therefore, this interface depends on a constant water source. However, this water supply does not necessarily rely on a piped supply, as recycled water such as collected rain- or greywater can be used as well (XANTHOULIS et al., 2008). Water forms a seal above accumulating excreta and thereby prevents the dispersion of odours and flies. Flushing has to be strong enough for moving generated black water through an s-shaped pipe ("water seal"). Dry cleansing material such as toilet paper can therefore increase the need for water and should preferably be disposed of separately (TILLEY et al., 2008).

3.2.2 Collection/Storage: Single Pit, Single VIP, Twin Pit, Arborloo Pit

Material gained at the capture can subsequently either be collected in a ventilated or a not-ventilated storage fraction ("pit"), which is dug into the soil (TILLEY et al., 2008). In the case of soft ground, reinforcement of the excavation with wood or bamboo is an option (XANTHOULIS et al., 2008). Excreta and other input material accumulate and finally fill up the pit.

In general, pits are used at household and community level. Thus, organization of maintenance can vary for these two areas of use. However, in general – users themselves carry out incurring works or hire local labourers (BRIKKÉ & BREDERO, 2003).

Single Pit

Either connected to a Pour Flush Toilet or Water-less toilet, this facility collects excreta along with anal cleansing materials (liquid and solid) and optionally also flushing water. An example for a technical design scheme is provided in Fig. 12.

A single latrine mainly consists of an excavated pit, a base slab and a superstructure supporting the user interface (GTZ, 2000 & BRIKKÉ & BREDERO, 2003). In GTZ's publication about "Basic sanitation and human excreta disposal in latrines" published in 2000, the following mean values for pit dimensioning are mentioned (in terms of volume required per capita and year):

- 0,06m^3 for pits connected to a Water-less toilet
- 0,04m^3 for pits connected to a Pour Flush Toilet with infiltration of liquids into the surrounding soil
- 0,40m^3 for pits connected to a Pour Flush Toilet without any infiltration (e.g. due to impermeable soils or packed material at the bottom)

Generally, it is desirable to design the pit in a manner that a storage period of at least one year is provided, before emptying becomes necessary (UNEP, 2010).

According to the Technical Compendium of UNESCO (UNESCO, 2010) pits should measure between 1 to 1.5m in diameter and at least 2m in depth. By raising a shaft on top of a pit using concrete rings or blocks, previously small volumes can be extended ("Cesspit") (XANTHOULIS et al., 2008). Nevertheless, 3m of depth should not be exceeded as the risk of collapsing rises significantly. Therefore, especially the upper 0,5m of the excavated pit requires lining in order to prevent collapsing (UNESCO, 2010 and BRIKKÉ & BREDERO, 2003). The stability of a pit and related requirements concerning lining depend on the structure of the surrounding soil (TILLEY et al., 2008). In the case of loose soil it might be necessary to line the whole pit – e.g. by using old oil drums or stones (BRIKKÉ & BREDERO, 2003). A stabilization of the steep walls can be achieved by using brick material. In Fig. 10, a design scheme of a Single is presented.

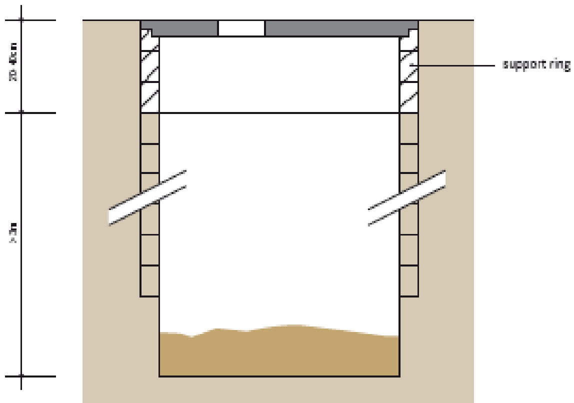

Fig. 10 Design Scheme of a Single Pit (TILLEY et al., 2008)

Normally, pits are designed in a way that solid material accumulates within them, whereas liquid materials such as urine or anal cleansing water are absorbed into the surrounding soil or percolate through the bottom of the pit into the soil. This can be enhanced by neither consolidating nor lining the ground plate. The percolation of liquids is especially relevant in the cases, where excreta are mixed with flushing water. Obviously, infiltration strongly depends on the particular soil conditions (UNEP, 2010). Therefore, there are also cases, where actually no infiltration takes place. In this case, filling times might be shorter and sludge emptying has to be done at shorter intervals.

As mentioned above, soil conditions can be very relevant in terms of the pit's stability. Besides, they are also significant for degree and efficiency of microbial degradation and removal during the migration of the effluent through the soil matrix (XANTHOULIS et al., 2008 and TILLEY et al., 2008). The success of purification during infiltration is determined by the moisture content of the soil as well as the distance the effluent travels.

However, it is important to note, that solid material which accumulates in the pit, undergoes only limited treatment – involving anaerobic, aerobic, dehydration and composting processes. Therefore, sludge removed from a pit has not been significantly reduced in its organic or pathogenic load. Thus, further treatment of faecal sludge evolving from pits is required (TILLEY et al., 2008 and UNEP, 2010).

Looking at the level of application of this component, TILLEY et al. (2008) suggest that a Single Pit is most appropriate for supplying one or several households. In terms of managing this facility, the authors note that either a single family or also a group of households can take over the responsibility for operation & maintenance.

Twin Pits

In order to provide superior treatment, there is the option of installing two pits, which can then be used alternately. In contrast to Arborloo pits (described below), Twin Pits (see Fig. 11) are designed to constitute a permanent structure. There should be a minimum distance of 1m between the two pits, in order to minimize the risk of cross-pollution. The accomplishment of a longer storage period facilitates a safer handling of the arising sludge (TILLEY et al., 2008 and UNEP, 2010).

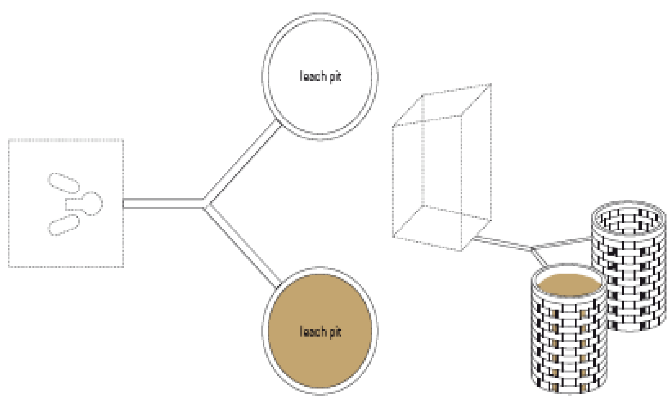

Fig. 11 Design scheme of Twin Pits (TILLEY et al., 2008)

The pits should be dimensioned in an adequate size for accommodating material up to one or two years. This period allows the contents to transform into a soil-like material. The level of application as well as management responsibilities can be organized similarly to the case of Single pits (TILLEY et al., 2008).

Single Ventilated Improved Pit (VIP)

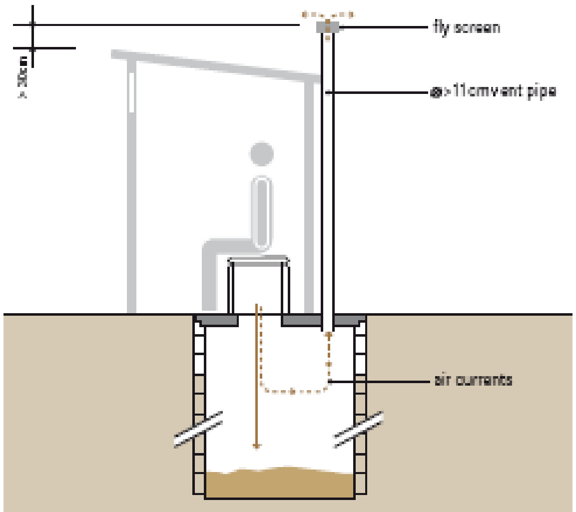

Fig. 12 Design Scheme of a Single Ventilated Improved Pit (TILLEY et al., 2008)

This system represents an improved design of the previously described Single Pit by reducing the two main disadvantages of traditionally designed pits – namely odour and fly problems (GTZ, 2000 and BRIKKÉ & BREDERO, 2003). The installation of a ventilation pipe allows the shifting of air through the facility and herewith minimized odours. A fly-screen on top of the pipe traps insects, which try to escape towards the light, once they've been in contact with contaminated material (see Fig. 12). The vent should reach at least 30cm above the highest point of the toilet superstructure and should be at least 15cm in diameter (TILLEY et al., 2008 and GTZ, 2000). Painting the pipe of the vent black increases the effectiveness of aeration, as the heat difference from the "colder" pit and the "warmer" vent creates an updraft of the airmass (TILLEY et al., 2008).

Arborloo

Characteristic for Arborloo pits (see Fig. 13) is their shallow dug design with a depth between 1–1,5m. A concrete slab sits on a ring beam which protects the hole from collapsing. The site of this system is temporary, as it is decommissioned after being filled up to 2/3. Thus, the superstructure should be moveable. The pit and its content are later on used as the basis for planting a tree. Therefore, it is of importance that Arlboroo pits are unlined, as lining would prevent the plant from growing properly (TILLEY et al., 2008 and MORGAN, 2007). Arborloo does not only describe a "storage/treatment" step, but rather a combination of storage with a "use/disposal" option. A conveyance step is not necessary.

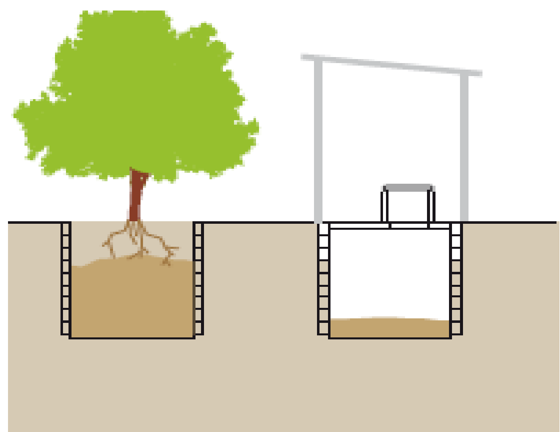

Fig. 13 Design Scheme of an Arborloo Pit (TILLEY et al., 2008)

Before use, leaves are put on the base of the pit. Soil and wood ash are added after defecation in order to facilitate the conversion of the accumulating excreta into compost. Besides that, soil and ash also help to reduce flies and odours. Periodical dumping of dry leaves (if available) can improve the material's porosity and the air content of the pile, which favours composting (MORGAN, 2007). As soon as a pit has been filled up, a new pit has to be dug out, which characterizes this approach as an "impermanent" structure.

3.2.3 Conveyance: Human Powered and Motorized Emptying and Transport

Before a pit is totally filled up, its usage should be stopped (TILLEY et al., 2008 and PEAN and THYE, 2009). Generally, there are several options for a proper and safe handling of the contents.

- Emptying and direct Disposal of the sludge (after accurate resting time)
- Emptying and Transport to a Faecal Sludge treatment facility

In the following section these options are considered separately.

Emptying and direct disposal/use of the sludge

Besides decommissioning, there is the possibility of directly disposing of sludge either onto land or into water, provided it has been left untouched for at least two years – which can be facilitated by using “Twin Pits” (BRIKKÈ & BREDERO, 2003). Once the material has rested long enough and remained untouched in one pit, it can be removed manually - without posing any health risk. Due to its consistency, motorized emptying is not very common. Beside disposal, there is also the option of using the material as soil conditioner (TILLEY et al., 2008). Some information about manual emptying procedures as well as other approaches for emptying can be found below.

Emptying and Transport to a decentralized Facility

In the case there is only one pit in use and excavation of new pits is not an option, a very common approach is the regular emptying of the pit’s content and its transport to a decentralized facility (PEAN THYE et al., 2009). This option is especially of importance for those cases where there is not enough space available for new-digging or ground water levels are too high to dig excavations for drying and disposing the faecal sludge.

The possibilities for emptying and transport procedures and their dependency depend on the consistency of the sludge. Sludge removed from Twin Pits is much more solid than sludge from ordinary Single Pits. Sludge consistency is not only determined by the input material (which again depends on the capture and user habits) but also by the storage and retention time before removal. While solid sludge rather has to be removed and transported by human power, liquid sludge can more easily be handled by motorized means - in the case of very thin sludge by means of a vacuum truck (TILLEY et al., 2008 and WSP & BNWP, 2008). In general, emptying and discharge can be carried out by city-wide service providers such as the municipality or by a private sanitation enterprise (VEST & BOSCH, 2002). Besides, provided that the users are sufficiently skilled and committed, they can proceed with the emptying “self-helped”.

In the following, an overview of three emptying and transport classifications is given, in order to underline the variety of approaches available.

<u>Simple Human Powered Emptying & Transport</u>

This term describes different approaches for manually operated emptying and transporting procedures. The simplest variants of these approaches are characterized by using simple tools such as spades, buckets and shovels and can be found in many areas worldwide. In this case, a team of workers accesses the pit for digging out sludge. High unit costs, significant health risks and low acceptance are commonly named disadvantages of this method. In contrast to that, low maintenance and service access can be mentioned (TILLEY et al., 2008 and PEAN and THYE, 2009).

According to TILLEY et al. (2008), human powered emptying can be applied for single households as well as up to several hundred households (“neighbourhood”), whereas the households themselves can take over the responsibility as well as a cooperative of households or even a public authority.

Human Powered Emptying and Transport using Simple Mechanical Means

More sophisticated methods of "manual cleaning" rely on simple pumping systems appropriate for manual use ("Manual Pit Emptying Technology", MAPET and "Manual Desludging Hand Pump", MDHP) (PEAN THYE et al., 2009). Which of these approaches is actually used, is mainly a question of affordability. Depending on the consistency of the material, a combination of pumps and simple tools might be necessary. This is due to the fact, that it can be quite difficult to operate manual pumps on thick sludge. Generally, in contrast to motorized emptying options, manually operated pumps are low cost variants in terms of operation and maintenance (BRIKKÉ & BREDERO, 2003).

Manual emptying or emptying using mechanical means, becomes relevant for areas with limited or even no accessibility for vacuum trucks or other motorized vehicles. Especially in densely populated settlements often found in informal, poor communities, this problem can be significant. In Dar es Salaam, Tanzania, MAPET was used in settlements that cannot be accessed by large suction trucks. Their design allowed a transport on push carts, which minimized the problem of inaccessibility. The relatively simple pumping and storage technology hence replaced other more unhygienic manual emptying procedures (UNEP, 2010 and BRIKKÉ & BREDERO, 2003).

Motorized Powered Emptying

Vacuum trucks (or also called "vacuum tanker") but also other vehicles equipped with a motorized pump and/or storage unit can be listed under this category. Vacuum tankers can be seen as a method for pit emptying conventionally used in industrialised countries. A tank with a capacity from 1 to 10 m^3 is mounted on a truck and equipped with a vacuum pump which sucks out sludge. It can be seen as the fastest means of excreta exhaustion (PEAN THYE et al., 2009). Depending on the consistency and density of sludge, a purely motorized emptying may not be possible. In these cases, when the material can't be completely removed, manual procedures have to be applied additionally. Furthermore, water may be needed for thinning the remaining material to facilitate its removal, making the procedure less efficient (BRIKKÉ & BREDERO, 2003 and TILLEY et al., 2008)

Application levels are similar to the case of simple human powered procedures, however, management is rather carried out by a public authority, than by households themselves (TILLEY et al., 2008).

Transportation after emptying depends on the consistency, volume and quality of the transported material. The output of Twin Pits can be conveyed in buckets or by using other simple tools – provided its point of use/disposal is not far distant from its point of generation (0,5-1km according to TILLEY et al., 2008 and PEAN THYE et al., 2009).

On the other hand, faecal sludge evolving from Single Pits, has to be transported with care – as it is still highly contaminated. Thus, it should be transported to a dedicated Faecal Sludge Treatment facility (TILLEY et al., 2008). Besides, PEAN THYE et al. (2009) and TILLEY et al. (2008) are also mentioning the options of either transporting the sludge to an access point of a municipal sewerage network or to an intermediate point of transport (Sewer Discharge Station or Transfer Station). Within this work, however, only the variant of transferring sludge directly to a "decentralized" faecal sludge treatment facility will be discussed in more detail.

3.2.4 Treatment: Faecal Sludge Treatment Facility

If the pits are not designed as Arborloo (3.2.5) nor as Twin Pits, the excavated material has to be treated accordingly. BRIKKÉ and BREDERO (2003) as well as TILLEY et al. (2008) note that Twin Pit's output material can be used directly after removal. PEAN THYE et al. (2008) however recommend the use of drying beds for material evolving from Twin Pits, in order to leach out residual liquids and to decrease its volume before actual disposal/use.

Material evolving from Single Pits or Single VIPs, which has to undergo further treatment prior to disposal or use, should therefore be transported to a dedicated faecal sludge treatment facility.

Faecal sludge is not a uniform product and has to be treated according to its specific quality. It therefore can be distinguished as being high strength sludge and low strength sludge. Whereas the former is rich in organics and has not been degraded significantly, the latter has already undergone some (anaerobic) degradation (TILLEY et al., 2008). High strength sludge is difficult to dewater and has to be “stabilized” first, while low strength sludge can directly be transferred to dewatering/drying.

Raw sludge (“high strength sludge”) – e.g. evolving from primary wastewater treatment – or also partly treated sludge (“seepage” or “low strength sludge”) – evolving from Septic Tanks or Pit Latrines – poses a considerable risk as transmitter of diseases associated with contained pathogens. In the following, a short overview of different sludge treatment steps is given. As faecal sludge treatment is also part of other systems, more information will be provided in the chapters 3.4.4 and 3.5.3.

- Stabilization: A major issue during stabilization is BOD reduction. This process can be carried out under anaerobic as well as aerobic conditions.
    - *Aerobic stabilization* can be part of a composting process. Composting can then either be carried out in a specifically built composter or - more simply - in windrows (UNEP, 2010).
    - *Anaerobic stabilization* is a bacterial decomposition process for stabilizing organic wastes while producing a mixture of methane and carbon dioxide gas. It is usually carried out in specially built “digesters”. Besides, it also can be carried out at slower rate by using an unmixed tank or pond. Important when considering anaerobic digestion is the production of biogas, which can be collected for further use (UNEP, 2010).
- Thickening, Dewatering and Drying: Depending on its origin, sludge can have a high water content. Therefore, several steps are necessary to minimize its water content. Increased solid contents are more suitable for composting. (Optionally, other dry materials can be added. Besides, due to the associated reduction in volume, further transport is facilitated (UNEP, 2010 and TILLEY et al., 2008).

According to TILLEY et al. (2008) the following technologies can be mentioned as examples of facilities providing the previously described steps of faecal sludge treatment. Depending on the sludge’s quality, a combination of two or more of the following four options can be necessary.

- Sedimentation/Thickening Ponds
- (Un-)Planted Drying Beds (Thickening & Drying)
- Co-Composting with bio-degradable solids (Aerobic Stabilization)
- Anaerobic Biogas Reactor (can receive raw sludge as well as blackwater)

All of these approaches are characterized by being applied for a neighbourhood or even a whole city. Thus, a public authority is needed for managing operation and maintenance (TILLEY et al., 2008).

3.2.5 Disposal: Arborloo concept, Disposal of (treated) Sludge

Arborloo

One possible approach for dealing with a pit’s content - skipping its conveyance - is the pit’s “decommissioning”. In this case, the excavation is covered with soil, followed by the planting of a tree on top of it. As the plant is thriving and prospering in a nutrient rich environment provided by the accumulated material in the pit below, the pit contents are stabilized and subsequently degraded (TILLEY et al., 2008 and BRIKKÉ & BREDERO, 2003).

To allow the pit contents to rest and compost for a while, before planting a tree, can make a positive impact on growing conditions as well as regulating watering of the soil cover. The nutrient-rich environment of soil and composted excreta provide good growing conditions for the tree/plant. In general, fruit trees (banana, papaya, guava, etc.) as well as other kind of plants, such as tomatoes or pumpkins can be used for this purpose. While growing, the plant's roots penetrate the soil. Stabilization and binding of soil is therefore a significant benefit deriving from this concept – besides the provision of food, fuel or building materials (TILLEY et al., 2008 and MORGAN, 2007)

Due to the fact that pit excavations are not re-used, this option is only practicable in areas where continuous new installations can be undertaken without posing a risk to human health or to the natural environment (TILLEY et al., 2008 and MORGAN, 2007).

In general, Alborloo pits are adequate for an application for one or several households – up to a whole neighbourhood of households. However, management in terms of operation and maintenance is carried out at household level.

Disposal of (treated) sludge

In the case the material is not excavated from the pit(s), there are the following options for accurate disposal. As treatment steps are different for material evolving from Twin Pits and that from Single Pits, these disposal steps are varying as well.

In the case of Twin Pits, material is already degraded during the storage phase and can directly be used as soil conditioner or disposed of after being excavated from the pits. For disposal, another excavation is dug which can consequently be filled with material. At least 30cm of dry soil are added on top of the pile. A main limitation of this form of disposal is the distance of the disposal site from the pit that is emptied. Emptying and transportation technologies/capacities should be capable to reach the disposal site easily. For manual emptying for example a distance exceeding 1km is impracticable (PEAN THYE et al., 2009 and BRIKKÉ & BREDERO, 2003). Besides, this option obviously depends on the availability of space.

There are different approaches for finally disposing of sludge which has been treated in Faecal Sludge Treatment Facilities. As the approaches are similar to the ones used for sludge evolving from (semi-)centralized water-based systems, their description can be found in chapter 3.5.4.

3.3 Sanitation Systems focussing on Re-use

Especially when considering more recent dynamics in the context of sanitation improvements in developing countries, there is a big discussion about “cyclic systems”. These systems intend to re-use nutrient streams contained in human excreta. The arguments and conceptual idea of this approach to sanitation are often associated with the term “ecosan” which is discussed more in detail in Annex I.

In the following chapter a selection of systems is discussed which are dedicated to re-use valuable contents of collected excreta. The composition and functional patterns of the two discussed systems differ significantly and will therefore be described separately.

- Water-less-System with Alternating Pits
- Re-use System based on Urine-Diversion

Both systems do have in common that the material gets already sufficiently degraded during the collection and storage phase. Therefore, it is a significant feature of these systems that there is no need for an extra treatment unit.

The aspect of “re-use” is moreover discussed in the context of Water-based wastewater systems (see chapter 3.5.5).

3.3.1 Functional Pattern of a Water-less System with Alternating Pits

There is no water needed for running this system (see Fig. 14) properly - actually, water input should be avoided. Thus, anal cleansing water should be kept to a minimum or in the best case even be excluded. Similar to the Single Pit System, Greywater is not processed and therefore has to be managed separately (TILLEY et al., 2008 and XANTHOULIS et al., 2008). Whether dry cleansing material can be processed within the system depends on the particular collection, storage and treatment technology applied (TILLEY et al., 2008).

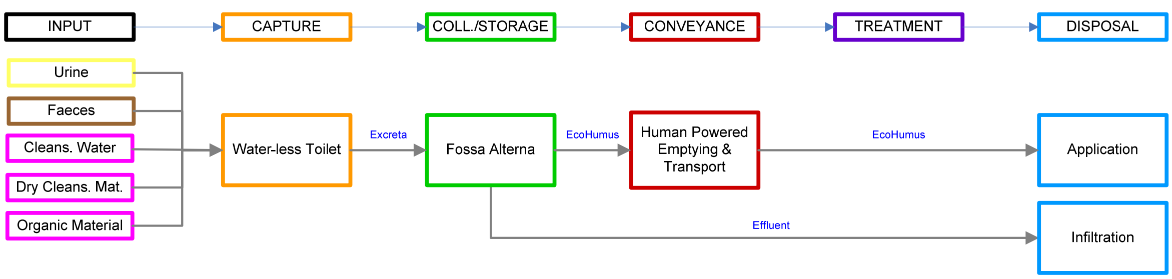

Fig. 14 Schematic overview of a Water-less System with alternating pits

3.3.1.1 Capture: Water-less Toilet

This capture operates without water and is commonly designed to allow users to sit or squat over a hole, where both urine and faeces are dropped. As the collection and storage facility consists of two units used in an alternating manner, the toilet (as well as superstructure) has to be mobile. A concrete slab and superstructure are moved correspondingly to the respective “active” pit. Easy and intuitively useable, this user interface appears physically comfortable and natural to many user types (TILLEY et al., 2008). In order to maintain conditions favourable for degradation processes within the storage unit, ash and other biodegradable materials are added after defecation. More details of a Water-less Toilet (as well as a design scheme) are also provided in chapter 3.2.1.

3.3.1.2 Collection/Storage: Fossa Alterna

Subsequently, a collection/storage unit will be presented, which represents a very prominent solution - the Fossa Alterna. Obviously, the presented technical solution is only one option for a storage component focussing on re-use of its output material.

Activation of two vaults for storing the excreta makes it possible to build up an (indefinite) usage-cycle - and thus a “permanent structure”. Thus, one chamber is filled, while the other one - that has been filled before - remains out of service in order to ferment or compost collected excreta, which is similar in the case of Twin Pits (XANTHOULIS, 2008). A design scheme for a Fossa Alterna is provided in Fig. 15. Drainage and degradation allows a transformation of stored excreta into a nutrient-rich, hygienically improved, humic material. By composting excreta together with other biodegradable components, the material becomes inoffensive. The formerly contained pathogens are destroyed and the material can be used for improving soil quality, in terms of an increasing amount of nutrients available for plants, a raised organic matter content and an improved water-holding capacity (WINBLAD & HÉRBERT, 2004). Already in chapter 3.2.2, the concept of using two collection units alternately to provide longer resting times and an infinite usage-cycle was discussed. Different from Twin Pits, where collected and stored excreta are only partially treated, a Fossa Alterna intends to fully degrade the material in order to generate EcoHumus (TILLEY et al., 2008).

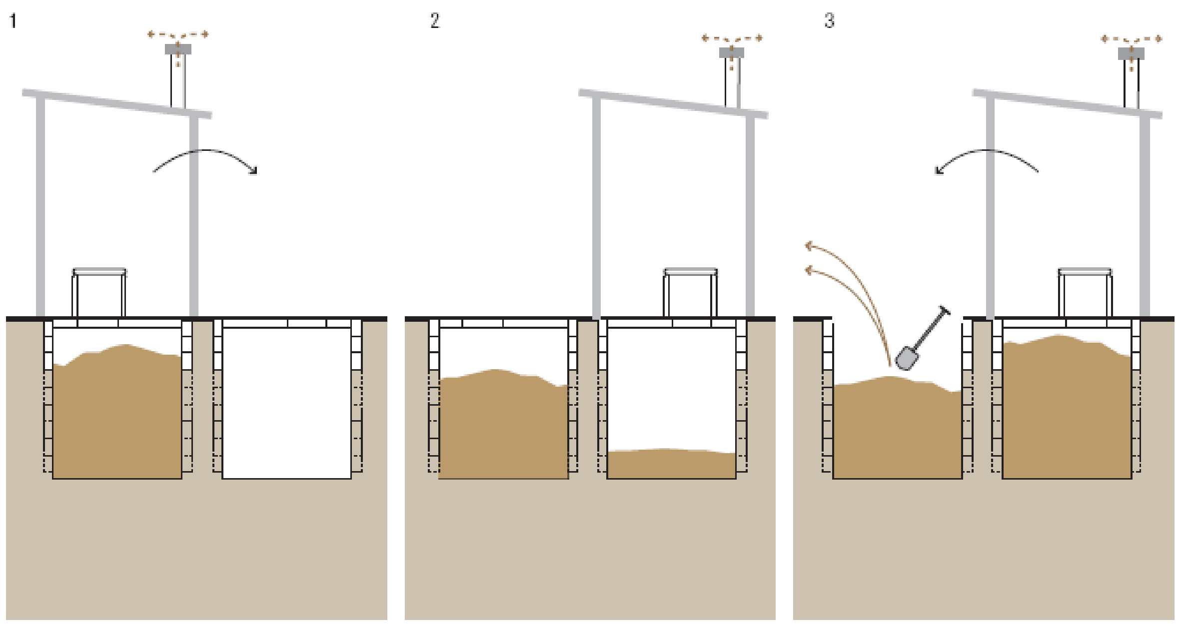

Fig. 15 Design Scheme for a Fossa Alterna (TILLEY et al., 2008)

Excreta are deposited together with soil, ash and leaves to encourage degradation activities. It is similar with the aeration of the material – therefore, the installation of a ventilation pipe is crucial. Both is enhancing the sanitation process and for this reason shortening the period needed for successful decomposition of the excreta. Furthermore, moisture has an impact on the efficiency of degradation. The more moisture gets into the vaults, the more air-voids are closed and the less efficient becomes the decomposition process.

Organisms like worms, fungi and bacteria contained in the soil increase the decomposition process and the pore space. As it is a main idea of a Fossa Alterna to use its output material, it is very important to prevent the dumping of garbage and other materials - as problematic components could be introduced (MORGAN, 2007).

The pits should have a depth of about 1.5m, supported by a ring beam. With this dimension, a family of about 6 people should be served for at least one year when it gets consequently filled with material. (An active pit is used for 12-24 months.) Once it is full, the other – till then inactive

– pit is put into use. While it gets filled up, the contents of the first pit are composting. The frequency of swapping the two pits should provide a composting time of at least one year, resulting in a dry, earth-like mixed output material (TILLEY et al., 2008 & MORGAN, 2007). Using two vaults in parallel, impedes the system's function substantially – as no appropriate resting time is provided. Users therefore must be aware of correct usage. In the case the filling rate is faster than one year, compost quality might be worse, which has to be taken into account when applying it (MORGAN, 2007).

Generally, Fossa Alternas are typically applied for single households or small groups of households. Thus, also in terms of managing operation and maintenance, responsibilities are mainly taken over by the households themselves or small cooperatives (TILLEY et al., 2008).

3.3.1.3 Conveyance: Human Powered Emptying & Transport

As the output product of a Fossa Alterna should be safe and directly useable, the "humus" can be manually moved out of the inactive vault and transported to the point of application. This work can be undertaken by an official body or by the users themselves (either organized on household or neighbourhood level) (TILLEY et al., 2008). Removal and emptying has to be done in a regular manner requiring high user commitments (BRIKKÉ & BREDERO, 2003). For more details about manual emptying procedures, please see chapter 3.2.3.

3.3.1.4 Re-use: Application on Land

In the case there are doubts about the output product's quality in terms of its safety for agricultural purposes, it can be further composted in a dedicated composting facility. In general, however, compost can be directly applied (or disposed of) after having been stored (TILLEY et al., 2008). As this system is discussed as example a sanitation process focussing on re-use, disposal procedures are not explained.

According to WINBLAD and HÉRBERT (2004) material evolving from Fossa Alternas is very attractive for agricultural application - due to its high nutrient load. They stressed this opinion by comparing nutrient levels occurring in natural topsoil (in Zimbabwe) with those in humus generated in a Fossa Alterna Pit (see Tab. 1).

Tab. 1 NPK concentrations in natural topsoil and in humus from Fossa Alterna Pits (WINBLAD and HÉBERT, 2004)

Source of soil	**N (mg/kg)**	**P (mg/kg)**	**K (mg/kg)**
Natural dryland topsoil	38	44	192
Fossa Alterna Soil	275	292	1763

When considering these concentrations, it becomes obvious that soil evolving from Fossa Alternas proved to have a much higher NPK content than the top soil it was compared with. However, TILLEY et al. (2008) on the other hand stress that it should not be seen a substitute for normal fertilizer, since the amount of contained NPK would not be enough for fulfilling this purpose. Generally, compost application should rather focus on soil amendment than immediate fertilising (GTZ, 2000).

Therefore, in order to use its valuable contents efficiently, the "compost" can be mixed with local topsoil in equal proportions. Applying the mixture to vegetable gardens can then enhance the plant's growth potential (WINBLAD and HÉBERT, 2004). When applying compost directly on crop meant for human consumption it is of importance to consider residual pathogen contents. Therefore, in order to minimize health risks, it should be applied no later than three weeks before harvesting.

Following TILLEY et al. (2008), application of ecohumus is mainly done on household or neighbourhood level and correspondingly managed on this scale.

3.3.2 Functional Pattern of Systems for Re-use using Urine Diversion

The basic principle of this system is the separation of urine from faeces already at source. In some parts of the world (e.g in Yemeni Cities) Urine diversion is a traditional solution. Using a Urine Diverting Dry Toilet (optionally in combination with a urinal) as capture(s), this system is independent of a constant water source. Diversion of urine from faeces at source allows a separated and therefore more efficient handling of the material. Besides, problems such as smell nuisances or vector breeding can be minimized (VEST & BOSCH, 2002). Making faeces safe for humans and recovering urine for beneficial use should be the over-all targets. In the case local cleansing habits favour the use of anal cleansing water, it has to be separated via a third diversion. Once it is collected, it can be infiltrated through a soak pit. Whether Dry/Solid cleansing materials can be processed strongly depends on the storage unit (TILLEY et al.). A schematic overview of a water-less system based on urine diversion is provided in Fig. 16.

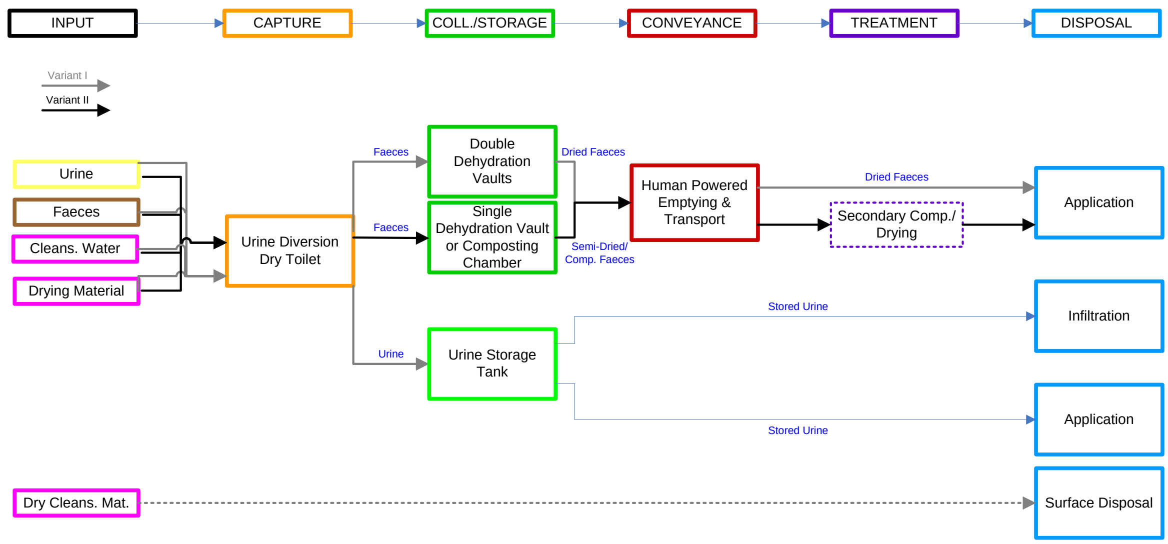

Fig. 16 Schematic overview of a Water-less System with Urine Diversion

3.3.2.1 Capture: Urine Diversion Dry Toilet

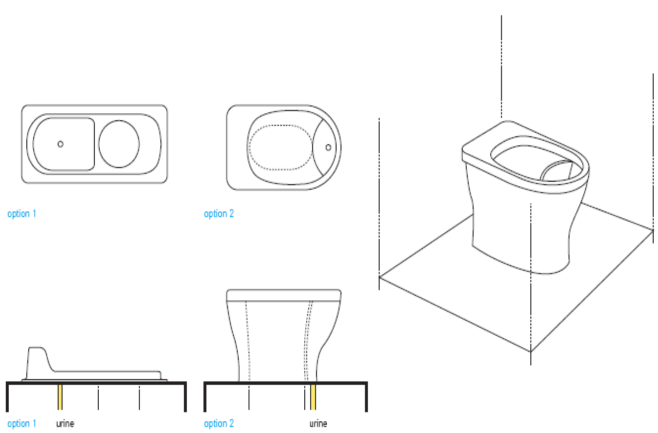

Fig. 17 Design Schemes of two design options for Urine Diverting Dry Toilets (TILLEY et al., 2008)

Water-less urinals and UDDTs (Fig. 17) are common user-interface options for systems where urine and faeces are collected and treated separately. Urine diverting dry toilets are therefore a technology commonly used for implementing Ecological Sanitation [see Annex I] (ESREY et al., 2001). Their design allows a diversion of urine and faeces at source – facilitating a separated handling of the two streams. Already implied by its notation, a UDDT operates without water, draining urine from the front area of the toilet, whereas faeces are falling through a large hole in the back (TILLEY et al., 2008).

To ensure a successful operation, the two sections must be well separated. Otherwise, there is a risk of clogging the urine collection area with faeces or wetting the dehydration chamber with urine splashes. Depending on the local washing customs, some UDDTs are also featured with a third hole for separating anal cleansing water. Since the dryness of accumulated faeces is of crucial importance, attention should be taken when cleaning the facility with water (TILLEY et al. 2008 and ESREY et al., 2001).

As using a UDDT is not as intuitive as a Water-less toilet, education and acceptance are required in order to ensure correct maintenance and use.

3.3.2.2 Collection/Storage: Dehydration Vault(s), Composting chamber and Urine Storage Tanks

After being diverted at the user interface, faeces and urine are subsequently processed separately. Whereas urine is stored in an adequate storage tank, faeces are either dehydrated using either one or two water tight dehydration vaults or composted using a composting bucket/chamber. It is of importance to take into account that the vault(s) is/are commonly built above ground which is a significant difference to excavated pits (MORGAN, 2009). Keeping the vault(s) as dry as possible encourages the hygienization of the collected material. Due to the consequent adding of ash, lime or dry earth a barrier against flies and odours is provided. Furthermore, the pH can be raised, which also takes a positive impact on the sanitation process (TILLEY et al., 2008). In the case of dehydration vaults, dry cleansing materials should be collected and disposed of separately, as they are only dried and not degraded within the dehydration chamber.

Following publications from TILLEY et al. (2008), MORGAN (2007) and ESREY et al. (2001) collection of the material can either be undertaken in two alternating dehydration vaults, a single dehydration vault or a composting unit. Storage times and grade of dryness (and hence grade of sanitization) of the output product are strongly dependent on the collection unit. In the case a single vault or bucket is used, removal of the material is undertaken more frequently than in the case of double dehydration vaults, resulting in a semi-dry output product which has not undergone sanitization. Semi-dry faeces must be transported to a second sanitization unit. As storage times in Double Dehydration vaults are longer, drying is efficient enough to achieve a significant degradation. Therefore, the output material (dried faeces) can be directly applied for agricultural use (TILLEY et al., 2008 & MORGAN et al., 2007). However, dried faeces are not considered to be fully hygienized.

The following presented storage units, are commonly applied for single households or probably a small neighbourhood of households. Management of operation and maintenance therefore is also rather organized on a household level or by a co-operative of several households (TILLEY et al., 2008).

Urine Storage Tank/Container

In the case urine can not be transported elsewhere (using an adequate conveyance option - e.g. jerrycans), on-site storage in containers or tanks is possible. Urine should be stored at least for one month. Storage times exceeding six months provide nearly complete sanitation. However, storage guidelines (see Tab. 2) for urine correspond to the temperature of storage and intended crop. It is desirable to prevent the nitrogen in urine from escaping as a gas into the atmosphere. This should encourage the availability as nutrient for micro-organisms. Using the urine in agriculture requires a strict separation from anal cleansing water (TILLEY et al., 2008).

Tab. 2 Recommended Swedish guideline storage times for urine mixture [a] based on estimated pathogen content [b] and recommended crop for larger systems [c.1] (WINBLAD and HERBERT, 2004)

Storage temperature	Storage time	Possible pathogens in the urine mixture after storage	Recommended crops
4°C	>1month	Viruses, protozoa	Food and fodder crops that are to be processed
4°C	>6 month	Viruses	Food crops that are to be processed, fodder crops[d]
20°C	>1 month	Viruses	Food crops that are to beprocessed, fodder crops[d]
20°C	>1 month	Probably none	All crops[e]

[a] Urine or urine and water. When diluted it is assumed that the urine mixture has at least pH 8.8 and a nitrogen concentration of at least 1 g/l.

[b] Gram-positive bacteria and spore-forming bacteria are not included in the underlying risk assessments, but are not normally recognized as causing any of the infections of concern.

[c] A larger system in this case is a system where the urine mixture is used to fertilize crops that will be consumed by individuals other than members of the household from which the urine was collected.

[d] Not grasslands for production of fodder.

[e] For food crops that are consumed raw it is recommended that the urine be applied at least 1 month before harvesting and that it be incorporated into the ground if the edible parts grow above the soil surface.

Double Dehydration Vaults

After being diverted from urine at the user interface, faeces are collected and stored in two vaults working in an alternating manner (see Fig. 18). One chamber is “active” and gets filled, while the other one is “inactive” for dehydrating and decreasing the volume of stored material. TILLEY et al. (2008) assume that in six months around 100l of faecal storage space are required per person. This dimensioning already takes into account space needed for airflow, visitors and a non-even distribution of material in the vault. Due to the alternating use of two vaults, this sanitation unit is a permanent structure.

For minimizing the risk of accidents and maximising the efficiency of the drying process the inactive vault should be sealed. In order to control flies and odours as well as removing humid air a vent is required (ESREY et al., 2001 and TILLEY at al., 2008).

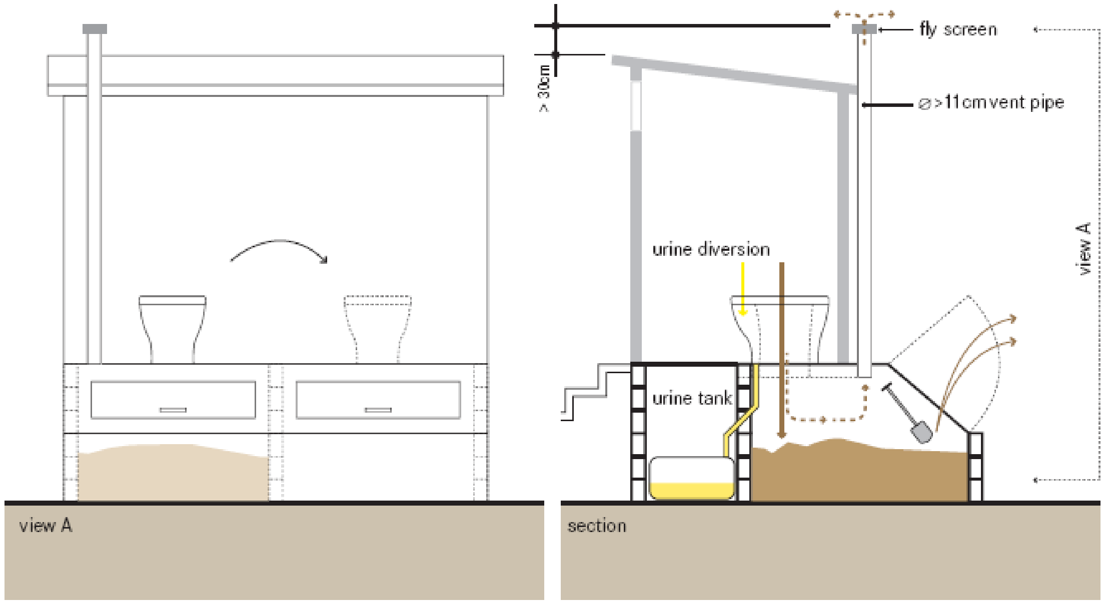

Fig. 18 Design Scheme for Double Dehydration Vaults (TILLEY et al., 2008)

In the absence of urine and other liquid materials, faeces can be successfully dried out and organism growth is minimized. Dry cleansing material should not be added, as no actual degradation takes place and the material does not actually get decomposed. Diversion of the liquid urine from the “dry” faeces makes it possible to use desiccation, increasing pH or elevating temperatures as processes for sanitising gathered faeces (ESREY et al., 2001). Depending on their availability, drying materials such as lime, ash or earth should be added in the faeces-hole after defecation. Added lime raises the pH which accelerates the pathogen destruction process. Beside that, this constant supply of covering material allows a minimization of odours and provides a barrier between faeces and potential vectors (flies). Also, adding organic material ensures that sufficient nitrogen is retained (BRIKKÉ & BREDERO, 2003). The success of the dehydration process is very dependent on the sustainment of dry conditions within the vaults. Therefore, neither anal cleansing water nor any other liquids such as surface-runoff, rain or greywater should be put into the dehydration chambers (TILLEY et al., 2008). This aspect should also be considered when cleaning the capture.

Single Dehydration Vault

There is also the option of using only one vault for dehydrating accumulating faeces. In this case, a bucket or sack is filled up in order to move the material easily, once it has been filled up. As applied drying periods are reasonably shorter than in the case of Double Dehydration Vaults, dehydration should be continued at another site (MORGAN, 2007 and VEST & BOSCH, 2005).

Composting Bucket/Chamber

Receiving faeces from the capture, a single vault or even a bucket held in a brick vault can be used for storing. After defecation, ash and soil are added in the vault or bucket (or sack). The contents of the bucket or vault should be removed regularly and deposited for further processing in shallow pits or compost heaps (secondary compost site). Composting processes take between 6 – 12 months (MORGAN, 2007 and AVESTÉGUI, 2005).

3.3.2.3 Conveyance: Human Powered Emptying and Transport

Once the faeces have dried or been composted, they only pose little risk to human health and therefore can be removed from the vaults manually. More details about Human Powered Emptying procedures can be found in chapter 3.2.3 (pit-latrine based system).

3.3.2.4 Re-use: Application on Land

Similar to the previously described system, there is no extra treatment step necessary. Degradation and decomposition takes already place within the collection/storage unit.

As streams are collected and treated separately, also in terms of application procedures there is a distinction between urine and faeces streams.

Application of Urine

Different from faeces, which have to pass a sanitation procedure, urine can be disposed of or applied on land without treatment. Since it is - in most cases - nearly sterile, it does not pose any risk for human health or the environment. In the case there is no direct need for applying urine on land, it can either infiltrated or stored and transported in jerry cans or via motorized conveyance technologies (TILLEY et al., 2008).

Urine, which is generated in relatively small volumes, can be disposed of easily without posing reasonable health risks. It therefore can either be diverted directly to the ground serving as land application or irrigation, or beinfiltrated into soil through a Soak Pit. Using the urine in agriculture requires a strict separation from anal cleansing water (TILLEY et al., 2008).

Due to elemental nutrients contained in urine, it is worth using urine as fertilizer in agriculture. According to WINBLAD and HÉRBERT (2004) there are different application options for urine:

- Undiluted before or at sowing, or even directly to the young plant. Or to soil beds before planting.
- Application in one large dose or in several smaller ones during the cropping season.
- Diluted with water, it represents liquid plant food which can frequently be added to the soil. This option only becomes relevant in the cases where vegetables are regularly watered.
- Concentrated and fermented, it can be applied to beds of dried leaf mold, providing a medium for growing vegetables and ornamental plants.

Using urine for diverse purposes can be applied at household level up to a whole city. Thus, management can also be carried out as well by single households as by neighbourhoods or a public authority.

Application of Dried Faeces / Composted Faeces

Even if faeces have not undergone complete degradation they can be applied in agriculture. However, in order to minimize the risk of hygiene problems, composting or dehydration should be undertaken as long as possible. The products can then be introduced into agriculture in many ways, such as adding it to compost, to planting trenches or pits for planting trees (MORGAN, 2007 and ESREY et al., 2001). Besides, dehydrated faeces can be used for soil amendment in the case of devastated land which has to be revitalized. In the case there is no demand for reusing the material, both urine and dried/sanitized faeces can be disposed of safely.

Considering on which level the re-use is applied, households appear to be an appropriate scale. Management and responsibilities, however, can also be taken over by co-operations of several households. Different from the case of urine, application and management on city level, including a public authority as the responsible body, is, however, not suggested (TILLEY et al., 2008).

However, when discussing the application of urine but also faeces as fertilizer in agriculture (this also refers to the use of compost described in section 3.3.1), it is essential to note the problem of micropollutants. Micropollutants are substances evolving from medicines and hormones, which are subsequently metabolized in the human body. Many of the substances ingested and transformed in the body, are excreted in urine or (faeces). This obviously represents a drawback in terms of the material's use in agriculture (NOVA 5, 2007). Thus, research is undertaken dealing with this topic (including potential treatment options) in order to decrease the risk evolving from micropollutants. However, a more detailed discussion of this problem as well as associated problem solutions exceed the scope of this thesis.

3.4 Septic Tank-based System

Another well-proven option for handling excreta in peri-urban and urban environments is the (pre-)treating of Blackwater with systems such as Traditional Septic Tanks (or Aqua Privies) (Fig. 19). This is especially of importance for those areas where there is no possibility of connecting households to a public sewer network (VEST & BOSCH, 2005). For decades, Septic Tanks have been applied in different parts of the World.

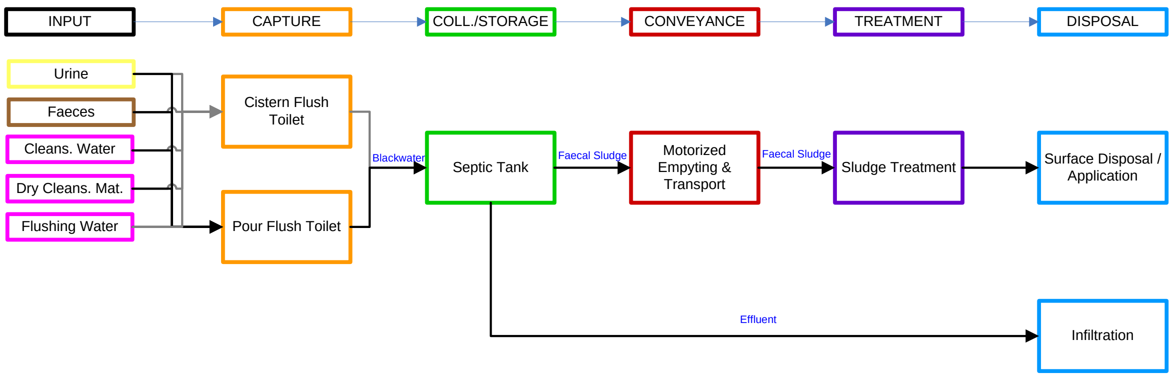

Fig. 19 Schematic overview of Septic Tank based System with Infiltration

3.4.1 Captures: Pour Flush Toilet and Cistern Flush Toilet

A sanitation system involving an on-site pre-treatment like a Septic Tank is typically used for storing and pre-treating blackwater evolving from flush-toilets. Septic Tanks can be of special relevance for the management of wastewater with a high amount of settleable sediments (GTZ, 2001). As it requires a constant source of water (although that does not necessary refer to a water connection at household level), this is a typical “water-based” sanitation system. Significant for water-based systems is their need for storage and/or conveyance technologies capable of handling large volumes of wastewater. Greywater can be treated along with blackwater as well as fluid and solid[3] cleansing materials, as long as they don’t tend to build up blockages.

Pour Flush

At this capture, excreta are flushed away with water, after being deposited into a bowl. Since there is no cistern used for supplying the flushing water, the user himself has to pour in the water. Thus, a constant source of water is needed. However, this water supply does not necessarily rely on a piped supply, as recycled water such as collected rain- or greywater can be used as well (XANTHOULIS et al., 2008). The flushing has to be strong enough to move generated black water through an s-shaped pipe (“water seal”). The water forms a seal above the accumulating excreta and thus prevents the dispersion of odours and flies. Usage of dry cleansing material such as toilet paper can therefore increase the need for water and should preferably be disposed of separately (TILLEY et al., 2008).

Cistern Flush

[3] “Traditional” dry cleansing material such as leaves, rags, stones and newspaper or also materials used for pot cleansing such as sand or ash, can harm the system as it can cause or exacerbate blockages (BUTLER & DAVIES, 2000).

This capture commonly consists of a water tank supplying flushing water and a bowl, where urine and faeces are deposited (Fig. 20). Flushing away excreta with waterforms blackwater. Depending on the particular design applied, up to 20l of flushing water may be used per flush. A reliable, constant water source for supplying the water tank is therefore required. Furthermore, a proper connection to a collection unit for receiving the Blackwater is needed (TILLEY et al., 2008).

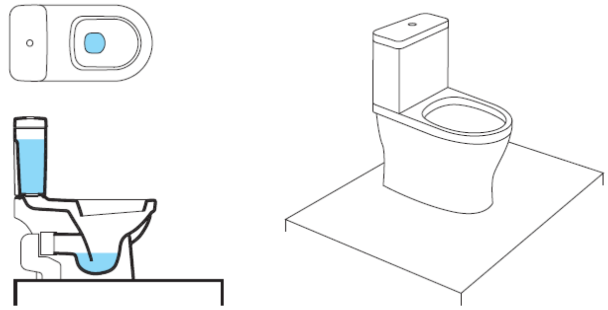

Fig. 20 Design scheme of a Cistern Flush Toilet (TILLEY et al., 2008)

3.4.2 Collection/Storage: Traditional Septic Tank

During the collection and storage phase, solids are settled out and organic and pathogen load gets reduced due to anaerobic processes. A common approach is the Traditional Septic Tank which is built up by two or three communicating (storage-)chambers (Fig. 21). Typically, a septic tank has the shape of a square or a circle. Located underground, the tank is surrounded by walls and a bottom in order to prevent liquids from infiltrating in the ground. Commonly used construction materials are bricks, stones, concrete or composite plastic (XANTHOULIS et al., 2008).

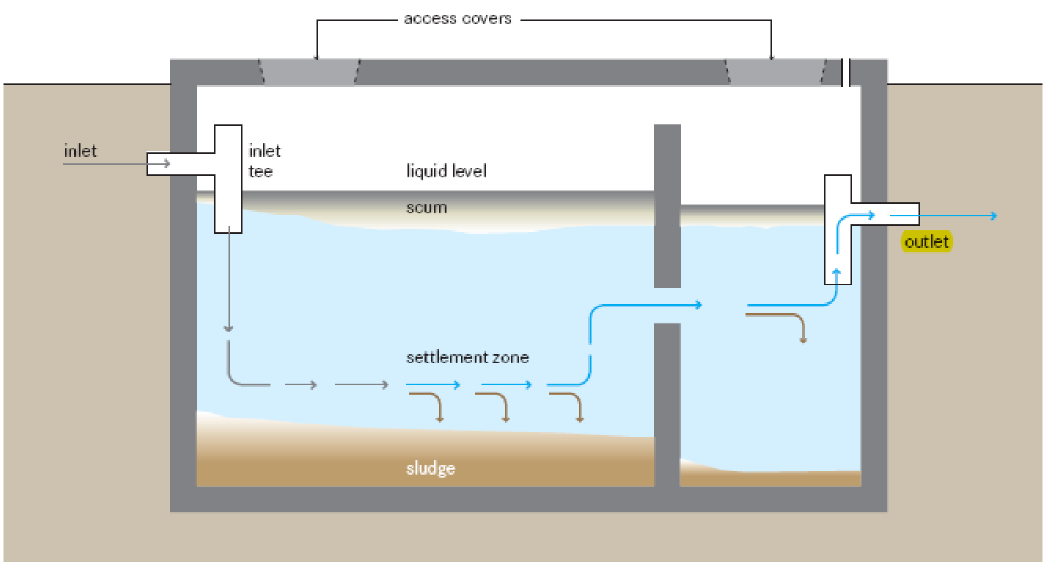

Fig. 21 Design scheme for a Septic Tank (TILLEY et al., 2008)

During storage, basic wastewater treatment is undertaken such as

- settling: due to the long residence time of liquids in the tank and slow stream velocity, most sediments stay in the tank.
- sludge fermentation: during their retention time, organic substances in the sludge are fermented under anaerobic conditions. Fermentation is acid and generates gas bubbles of H_2S and CH_4. Whereas H_2S dissolves only in a limited manner and CH_4 not at all. Gas bubbles are generated which rise to the surface. As the bubbles bring some suspended solids and some kind of grease with them, scum is formed.

Particular dimensioning and design of the tank depend on factors such as the number of users, the amount of water used per capita, the characteristics of the wastewater but also the annual average temperature or pumping frequency. XANTHOULIS et al. (2008) describe some design principles as follows:

- 2 chambers for domestic wastewater volume of less than $10m^3$/day (with the first chamber covering 75% of the wastewater volume)
- 3 chambers for domestic wastewater volume of less than $25m^3$/day (with the first chamber covering 50% and the other chambers covering each 25% of the wastewater volume)

Depending on their design, septic tanks can serve just one household or building or a group of households if they are connected with a small network (VEST & BOSCH, 2005). According to a Technical Information Sheet published by GTZ in 2001, up to about 50 households can share a Septic Tank. When it comes to managing of operation and maintenance, single households can be responsible as well as a co-operative of households or even a public authority (TILLEY et al., 2008).

Micro-organisms in the storage tank treat accumulating wastewater (XANTHOULIS et al., 2008). Sediments and coarse material are settled out generating sludge which is consequently fermented. Fluid components on the other hand gradually pass through the storage chambers and finally flow out (GTZ, 2001). Depending on the dimensioning, storage times[4] for fluids are variable (HOPHMAYER-TOKICH, 2006 and VEST & BOSCH, 2005). In the case of a 2-chamber septic tank, solids are settled in the first chamber, while the second chamber is used for treating liquid components by suspending small lightweight particles. A 3-chambered tank achieves higher effluent qualities, since wastewater remains longer inside the facility. In all three chambers sedimentation of solid components and their beginning decomposition takes place. A partially anaerobic process inside the third chamber further polishes the wastewater (VEST & BOSCH, 2005).

As the treatment process is not thorough, both products – effluent and sludge – are not suitable for direct use and should therefore be processed appropriately (TILLEY et al., 2008). In order to upgrade the effluent quality, there is also the option of using filter systems such as a sand filter or an aerobic filter (HOPHMAYER-TOKICH, 2006). In some cases, the last chamber of a Septic tank can serve as soakage pit, by being fitted with a water permeable base (VEST & BOSCH, 2005).

3.4.3 Conveyance: Motorized Emptying and Transport of Sludge

When considering conveyance steps, it is important to differentiate between the two proceeded streams. In the design chosen for this work, effluent arising from a Septic Tank is not conveyed but directly disposed of on-site. Thus, in the case of the effluent, no conveyance step is necessary.

<u>Effluent</u>

Clarified effluent flows out of the tank and can either be drained, e.g. using a soak pit (which is described below) or a leach field, or it can be discharged into a sewer (see chapter 3.5.2 settled sewer) (TILLEY et al., 2008 and HOPHMAYER-TOKICH, 2006). A discharge of the effluent into the stormwater drains should only be considered, if the effluent is of high quality and on-site treatment or transport to a centralized treatment are impossible. Especially in the case of densely populated areas, a transportation of the effluent via sewers to a centralized treatment plant is highly recommended (TILLEY et al., 2008).

<u>Sludge</u>

[4] 1-3 days for 2-chambered tanks; up to 10 days for 3-chambered tanks (VEST & BOSCH, 2005)

Besides the effluent, faecal sludge is formed, which has to be removed regularly (every 2-3 years depending on the size of the tank and the number of users) and consequently transported for further treatment (TILLEY et al., 2008 and VEST & BOSCH, 2005). BRIKKÉ & BREDERO (2003) suggest an emptying interval of up to 5 years. Moreover, a layer of scum builds up over time consisting of floating material such as grease, oil, hair and small pieces of wood. During the fermentation process sludge particles are carried upwards which also contribute to the development of a scum layer. As this layer decreases the tank's capacity, its regular removal is necessary (VEST & BOSCH, 2005).

Depending on the climatic conditions sludge should be fermented for at least three months. After emptying around 20% of the total sludge volume remains inside the tank (XANTHOULIS et al., 2008). Residual sludge is important for ensuring appropriate anaerobic conditions (VEST & BOSCH, 2005). The sludge is highly pathogenic and should therefore neither get in direct contact with humans nor be used directly for agricultural application. Conveyance and treatment procedures for this further treatment are very similar to the ones described in chapter 3.2.3 and 3.2.4 for treating the sludge gained from pits. Normally, desludging is carried out with a Vacuum Truck. After sludge has been removed from the tank it is transported to (semi-)centralized Faecal Sludge Treatment Facility or a Wastewater Treatment facility (TILLEY et al., 2008 and HOPHMAYER-TOKICH, 2006). In this work, the focus is on the first of these two options.

3.4.4 Treatment & Disposal: Effluent Infiltration and Faecal Sludge treatment

When considering treatment and disposal options the material streams proceeded from Septic Tanks, it appears useful to distinguish between effluent and sludge.

Effluent: Soak Pit

There are different variants for disposing of effluent arising from a Septic Tank – involving technically more sophisticated options as well as relatively simple ones. In order to focus on variants relevant in the context of Developing Countries, a comparatively simple technical option should serve as an example.

With this utility, effluent evolving from on-site (pre-)treatment/collection facilities but also pre-treated greywater can be slowly soaked into the ground. In general, there are different options for designing this disposal variant: either an empty chamber is walled with porous material or a chamber is left unlined and filled with coarse rock and gravel. Both designs prevent the chamber from collapsing. A layer of sand and fine gravel at the bottom helps to disperse the flow. The flows evolving from a soak pit are percolated through the surrounding soil matrix. It is therefore of importance to maintain a minimum distance to drinking water sources of about 30m.

Along the way, small particles get filtered out and micro-organisms digest organics contained in the wastewater flow. Due to the risk of clogging the porous structures of the pit, the water should already have passed pre-settling. In the case the performance of the Soak Pit deteriorates, material inside the facility can be excavated and refilled.

Sludge: Faecal Sludge Treatment Facility

Considering further processing of the sludge accumulating in the septic tank, similar steps as in the case of Single Pit systems are applied. Thus, once motorized emptying and transport has been undertaken, the material should be treated in a dedicated faecal sludge treatment facility. More details of treatment in such a facility as well as disposal procedures are discussed in chapter 3.2.4 and 3.2.5.

3.5 Semi-centralized and Centralized Water-based Systems

In the following, systems will be described, which are characterized by their capacity to deal with increased volumes of "wastewater" compared to the rather household-centred approaches discussed so far. The blackwater is transported to a centralized treatment facility without involving any specific step of collection/storage in between. Transport is carried out via a sewer network which basically consists of underground pipes building up branches of different functional orders (TILLEY et al., 2008). As water has a large dispersion, dilution and carriage capacity, it is commonly used as carriage medium, characterizing this system as typically water-based (XANTHOULIS et al., 2008).

As wastewater treatment activities are not undertaken close to or at the point of generation, they can be referred to as "off-site" systems (HOPHMAYER-TOKICH, 2006 and XANTHOULIS et al., 2008). TILLEY et al. (2008) refer to (Semi-) Centralized Treatment as sanitation technologies that are generally appropriate for large user groups (i.e. multiple households).

Depending on the particular sewer system and treatment approach applied, the "grade" of centralization can vary. Whereas some technical options provide a capacity to serve a whole city, others are rather orientated to manage wastewaters deriving from neighbourhoods or agglomerations. Therefore, in order to describe the systems' characteristics, a distinction is made between "centralized" and "semi-centralized" systems.

Since this paper mainly focuses on sanitation systems for settlements in developing countries, variants will be discussed which appear relevant for this context. Therefore, technical variants involving highly sophisticated features, such as a pressure or vacuum drainage, or very challenging treatment procedures are not discussed.

Especially in European countries, but as well in other industrialized countries, a water-based transportation of wastewaters from the households to a treatment facility outside the settlement is the most prevalent approach for urban areas (HOPHMAYER-TOKICH, 2006).

<u>Historical development of Conventional Water-Based Systems</u>

Before describing Centralized Sanitation systems and their field of application, it appears very relevant to mention their historical development. It is of crucial importance to realize that sewerage systems are only used and necessary for transporting sanitary wastewater but originally for reasons of urban drainage. Channels with the purpose of draining stormwater away from (urban) settlements were already found in early ancient civilisations. This highlights the original function of sewers for controlling natural water movements in order to protect human built environments. Covering the land with impermeable surfaces as it occurs especially in urban settlements, limits the ability of the natural environment to drain occurring stormwater. Sewers are an option for substituting the natural drainage function in order to prevent inconveniences, damages, flooding and eventual health risks arising from accumulating stormwater (BUTLER & DAVIES, 2000).

Not until the 17th century were sewers actually associated with wastewater. With increasing population numbers in European cities, the handling of "bodily" wastes (sanitary products) became an issue. Under-capacity of established sanitation (mostly cesspits) in combination with progressive urbanization led to serious hygiene conditions causing outbreaks of typhus, cholera and other diseases in many major cities (BUTLER & DAVIES, 2000). As soon as it became clear that there is a relation between direct contact with faeces and existing health problems, the transportation of wastewater out of the city appeared useful (HOPHMAYER-TOKICH, 2006). Effluents evolving from cesspits were therefore more and more discharged into already existing sewer networks. By the time of rapid population growth driven by the industrialization, new-built houses increasingly got directly connected to the sewers (BUTLER & DAVIES, 2000). By that time, more and more large-scale sewer systems for carrying wastewater away got constructed in several major cities of central Europe (HOPHMAYER-TOKICH, 2006). The alignment of sewer networks was loosely based on the natural network of streams, releasing collected water directly into the rivers.

However, sanitary problems arising from an increased population number and density were not successfully solved but only moved elsewhere – to the natural streams intercepting the mixed stream of wastewater and stormwater. The natural self-purification capacity of the intercepting surface waters was soon exceeded resulting in reasonable pollution, which again caused the spread of severe epidemics and massive deterioration of water quality (BUTLER & DAVIES, 2000).

As a reaction to that, options were searched for options for making releases from sewers less hazardous to the natural environment. Mechanical treatment in order to remove settleable solids got established (HOPHMAYER-TOKICH, 2006). Not until the 20th century was biological treatment of wastewaters prior to discharge introduced and implemented stepwise (BUTLER & DAVIES, 2000). Until the 1950s, Trickling Filters were a common technology, which by now are increasingly replaced by Activated Sludge technology (HOPHMAYER-TOKICH, 2006).

Fig. 22 provides a schematic overview of a Semi-/Centralized Water-based System as it is built up nowadays.

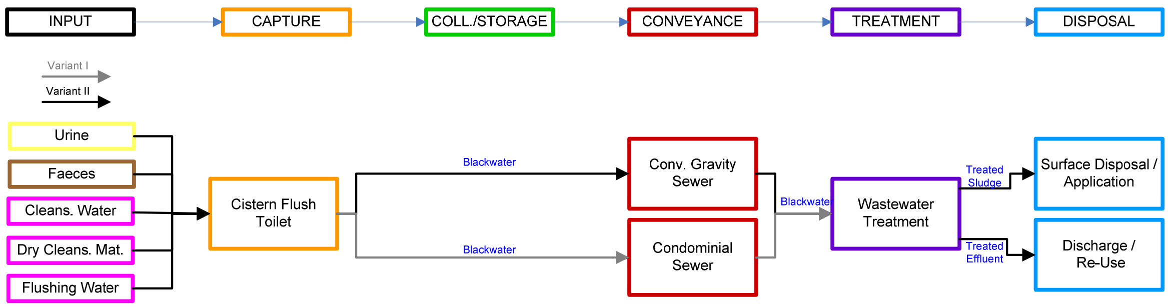

Fig. 22 Schematic overview of Semi-/Centralized Water-based Systems

3.5.1 Capture: Cistern Flush Toilet

Typical user interfaces are Cistern Flush toilets, where both excreta and cleansing materials can be dropped. Beside anal cleansing water, dry cleansing material can be processed, provided it does not tend to build up blockages[5] in the pipes. Looking at the system inputs it is of crucial importance to consider that greywater is co-transported and consequently co-treated. Conveying greywater together with Blackwater, minimizes the accumulation of solids within the sewer. A generated water seal prevents both odours and vectors from evolving back from the collection unit. Different from other facilities mentioned before, this user interface is commonly mass-produced and factory made. More details of this user interface can be found in chapter 3.4.1.

3.5.2 Conveyance: Conventional Gravity Sewer, Condominial and Settled Sewer

Conventional Gravity Sewer

This conveyance system is a very common option for transferring Blackwater. It consists of sewer lines along main roads (primary network), networks within neighbourhoods (secondary) and networks at household level (tertiary networks) (TILLEY et al., 2008). Large collector mains,

[5] “Traditional” dry cleansing material such as leaves, rags, stones and newspaper or also materials used for pot cleansing such as sand or ash, can harm the system as it can cause or exacerbate blockages (BUTLER & DAVIES, 2000).

which are mostly located below the middle of a road, are regularly flushed pipe networks and therefore characterised as water-borne. In order to achieve a constant through-flow of the wastewater within the pipes, they are usually laid with relatively large gradients (VEST & BOSCH, 2002). Manholes are placed at set intervals, at pipe interactions and at changes in pipeline direction - in order to access the sewer network for maintenance activities. Material entering the sewer is not pre-treated and therefore prone to cause particle accumulation. Due to that fact, it is of crucial importance to maintain self-cleansing velocity – a flow that will not allow an accumulation of particles (TILLEY et al., 2008). Since conditions in a Gravity sewer are extremely variable, flow rates and the amounts and character of sediment entering a system can vary considerably with time and location. Therefore, designing a sewer for keeping a "self-cleaning" velocity under normal conditions, does not prevent the occurrence of sediment depositions during periods of low flow and/or high sediment load (BUTLER & DAVIES, 2000). In general, maintaining a specific flow should be made possible by guaranteeing a constant downhill gradient along the length of the sewer. At places where this is impossible, the use of a pump station is required. As pump stations increase costs due to their energy demand, topographies with varying gradients (e.g. hilly landscape) are rather inappropriate for gravity sewers (BUTLER & DAVIES, 2000 and TILLEY et al., 2008).

Digging depths vary – depending on the position of the sewer. As Primary sewers for example are laid beneath roads, the depth should be sufficient to avoid damages caused by traffic loads. Besides, in areas with cold temperatures during winter, digging depth should be deep enough to avoid freezing of the sewer lines.

Wastewater & Stormwater Drainage

As mentioned before, a very significant feature of Conventional Sewer Systems is its close relation to stormwater management. However, this relation is a complex one and its consequences and limits have been reassessed during its long-lasting development. As water flows significantly increase during storm events and so can exceed transport and treatment capacity of the system "excess flows" have to be relieved into the rivers during storm events. Even though these flows show a reasonable dilution of pollutants, it is still an introduction of wastewater contaminants into receiving water courses. Therefore, in order to avoid potential contaminations caused by a combined piping of stormwater and wastewater, separate systems were developed. In the following a short overview of these two approaches will be given.

Combined

As already mentioned. the essential feature of combined sewers is their potential to carry both wastewater and stormwater in the same pipe. However, usually, this pipe is not designed to carry the full combined flow to treatment at all times. Therefore, at high flow-rates (as is the case during rain storms) it is necessary for some flow to be discharged directly into a watercourse instead of being transported to the WWTP first. This diversion is undertaken at a Combined Sewer Overflow (CSO) (Fig. 23).

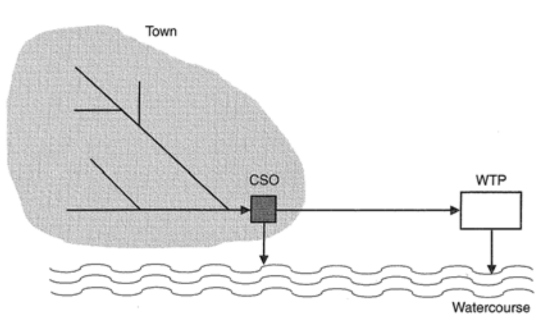

Fig. 23 Scheme of a Combined Sewer System

Upstream of the CSO, the pipe carries both wastewater and stormwater from the upstream catchment. If the flow does not exceed the CSO setting, all continues to the WWTP. In the case the flow does exceed the CSO setting, there will be an overflow to the watercourse. The CSO setting hence determines the flow that is retained in the system and gets treated even during storm events. Therefore, especially during storm conditions the rate and composition of the flow therefore can vary significantly at different points throughout the system in storm

(BUTLER & DAVIES, 2000) conditions (BUTLER & DAVIS, 2000).

Qualitative combined system: Less polluted streams of stormwater (eg. water evolving from roofs) are separately drained or locally swept away.

Separate

The basis of this system isthe assumption that rainwater is widely unpolluted and therefore can be drained directly to the water courses without being previously treated (see Fig. 24). Stormwater and wastewater streams are separately piped, whereas the stormwater pipe is characterized by a larger diameter (due to the occurrence of high peak flows) and a direct discharge into receiving waters. As the wastewater flow on the other hand generally remains stable, the wastewater sewer usually has a relatively small diameter. It is buried at a depth of >2,5m and has to be connected to a treatment plant (BUTLER & DAVIES, 2000).

Since Conventional Gravity Sewers carry large wastewater volumes, they require a connection to a treatment facility capable of processing these huge amounts of wastewater. Therefore, they are often connected to an intensive treatment unit (more details see chapter 3.5.3). Characteristic for this conveyance variant, are their application and management levels. Different from other options described above, Conventional Sewer Systems are applied for whole cities – not for single households. Thus, also management of its operation and management is undertaken by a public authority (TILLEY et al., 2008).

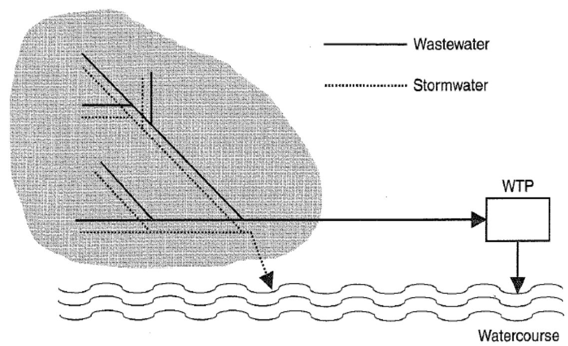

Fig. 24 Scheme of a Separate Sewer System (BUTLER & DAVIES, 2000)

Condominial sewer

In order to find solutions for improving sanitation in (pour) peri-urban areas, a new approach for water supply and sewerage networks was developed in Brazil during the 1980s – termed simplified (or Condominial) sewerage. Compared to Conventional Sewerage the "unit" service is provided to, was redefined: Whereas Conventional systems provide service to each housing unit, in the Condominial sewerage concepts service is provided for whole housing blocks. Consequently, public sewer no longer need to run through every plot of land, but merely provide a single connection point to each city block (see Fig. 25). Required network lengths are therefore significantly shorter (MELO, 2005).

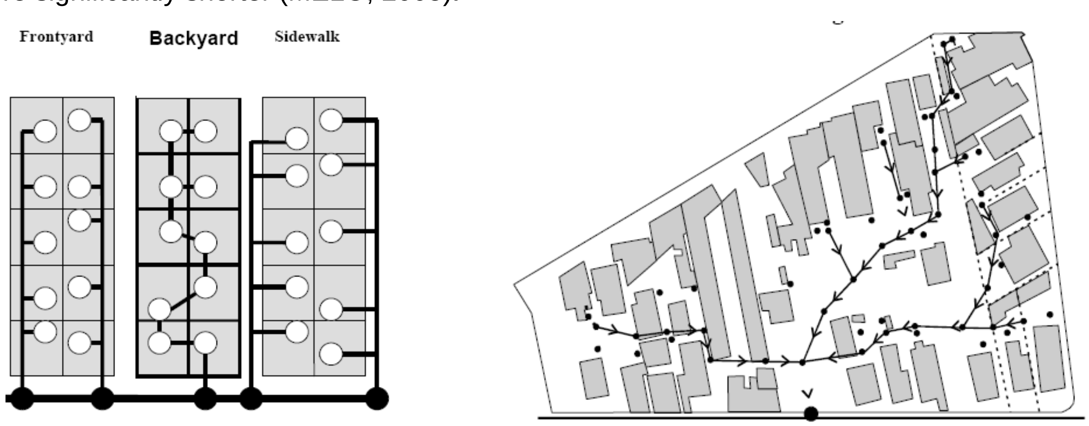

Fig. 25 Design schemes for two design options of Condominial sewerage in planned (left) and unplanned (right) peri-urban areas (CAESB, n.a)

Condominial sewers are similar to Conventional foul sewerages, but designed simpler in terms of reduced basic and less-conservative design assumptions. Characteristic are small-diameter pipe works, shallow excavation depths and shallow gradients (e.g.: 100-150mm diameter; gradient of 1 in 167m). Besides, in contrast to Conventional sewers, no large manholes but simple inspection units are used for maintenance as well as access point spacing is increased (MARA, 1997 and TILLEY et al., 2008) which is illustrated in Fig. 26.

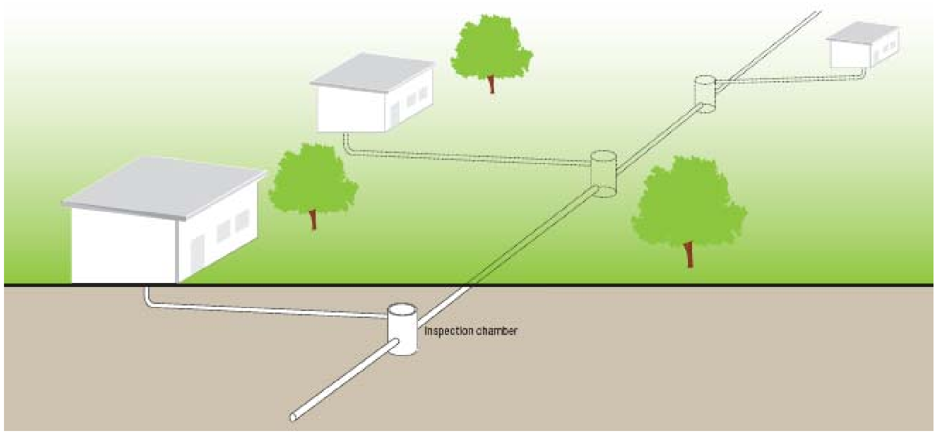

Fig. 26 Scheme of Condominial Sewers with inspection chambers (TILLEY et al., 2008)

Condominial sewers are mostly laid within property boundaries – instead of below central roads – what takes a reasonable impact on installation costs. Different from conventional household connections, which are running perpendicular to the network, Condominial branches are running parallel to the housing blocks which encourages an installation in the most convenient part of the block (e.g. under sidewalks or backyards). Besides, in contrast to Conventional Sewer systems, no collector mains are needed (VEST & BOSCH, 2002). The network therefore can easily be adapted to local conditions and different urbanization patterns (MELO, 2005). In the case they are laid outside of the block, they are usually laid below the pavement on both sides of the road (MARA, 1997 and TILLEY et al., 2008). For sewers laid inside housing blocks "back-of-property" collectors are used in order to minimize sewer lengths (BUTLER & DAVIES, 2000). In general, connection distances are kept as short as possible, as a large number of households discharges into the same pipe (VEST & BOSCH, 2002).

In upper reaches of the network the flow can be intermittent and solids progress in a sequence of "deposition-transport-deposition-transport". In "lower" reaches, which collect drainage water streams from several reaches, the flow is more constant. This flow pattern works well for this system, as it is generally more efficient for small-diameter pipes than for large-diameter sewers (MARA, 1997). However, a certain amount of water is needed in order to move the wastewater through the pipes - which requires a water supply connection within the households. VEST & BOSCH (2002) suggest a flow velocity of at least 0,5m/s in order to assure sufficient self-cleaning.

An integral baseline of the Condominial approach is the *decentralization* of sewerage service in order to prevent problems arising from a concentration of fluids at a single geographical point (as it is emphasized by Conventional sewerage). In this context, MELO (2005) notes that the processes used for effluent treatment are combining anaerobic reactors and waste stabilization ponds as well as small-scale treatment plants. Thus, the decentralization of treatment facilities can be of interest in order to minimize the transport distances. However, TILLEY et al. (2008) also mention the possibility of routing the effluent from Condominial sewers to a Conventional main sewer (what implies Centralized Treatment).

Besides, a significant difference to Conventional Sewerage is the institutional organization of sewerage services. There is a close relationship between service providers and users - as users directly participate in the construction and maintenance process. Members of a

"Condominium" must select appropriate design of the sewer service in order to adapt it to local needs and constraints (MELO, 2005). In general, Condominial Sewers do not conform to a hard set of technical standards, instead they are rather designed in accordance with the means and preferences of the target group (UNESC, 2004). As a large proportion of the network runs on private properties, either the municipality (or any other official operator) or the users themselves have to agree about who takes over the responsibility. TILLEY et al. (2008), however, suggest that management of operation and maintenance should be carried out by a public authority. Due to the fact that many households are connected to one and the same pipe, a lack of maintenance in one household can negatively affect the whole block. In respect to this aspect, VEST & BOSCH (2002) are stating that a high level of user participation is necessary implying support and participation of each individual household connected.

Even if only rarely, blockages still tend to occur more often than in the case of Conventional sewers (MARA, 1997 and TILLEY et al., 2008).

Settled Sewer

This low-cost sewerage variant, which is also referred to as "Small Bore Sewerage", is designed to receive only liquid portions of wastewater. Therefore, wastewater is settled in an inceptor tank before it can be discharged to the sewer (HOPHMAYER-TOKICH, 2006 and AVESTÉGUI, 2005). Inceptor tanks are normally designed as Septic tanks. Removing solids already as part of the household connection poses a significant difference to Conventional Gravity Sewerage, where no pre-treatment is undertaken at household level (see Fig. 27). Settling-out heavier material makes the system's design independent from maintaining high self-cleansing velocities. VEST & BOSCH (2002) suggest a flow velocity of 0,3m/s as guiding value for the dimensioning of a Settled Sewer. Even if there is the need of lift stations - e.g.: due to insufficient gradient for gravity flow - simple pumping structures are sufficient as no solids have to be pumped (TILLEY et al., 2008 and AVESTÉGUI, 2005).

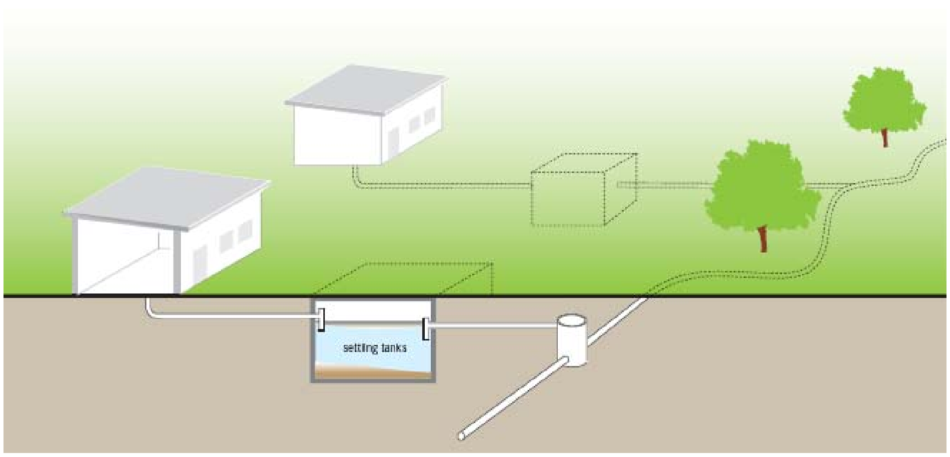

Fig. 27 Scheme of Settled Sewers with inceptor tanks ("setting tanks") (TILLEY et al., 2008)

As removal of grease and scum reduces the risk of blockage, they have to be settled out. The consequently clarified effluent flows by gravity into the sewer. The Settled Sewers are designed as gravity fluid conduit following the superficial ground contour. Therefore, there must be a positive height difference between household-connection and sewer outflow (AVESTÈGUI, 2005 and MARA, 1997). The flow in the sewers varies along the sewer length (normal gravity open-channel flow → full-bore pressure flow → open-channel flow). In sections with pressure-flow, potential re-fluence from the sewer to the inceptor tank must be avoided (AVESTEGUI, 2005). The attenuation of the individual flow inputs, reduces the peak flows (MARA, 1997 and BUTLER & DAVIES, 2000).

Shallow excavation depths and small-diameter pipe work characterizes its design. Instead of large manholes, simple inspection boxes are used for maintenance. Similar as in the case of

Condominial sewers, there is the possibility to install the pipes on rear parts of properties instead of below roads (TILLEY et al., 2008 and AVESTÉGUI, 2005).

Similar as Condominial Sewer, Settled Sewer are most appropriate for an application on neighbourhood level, rather than for a whole city. However, the management of operation and maintenance, should be carried out or organized on behalf of a public authority.

It is of importance to realize that both Condominial sewer and Settled Sewer are only processing *domestic* wastewater streams and therefore require a separate system for stormwater management. This obviously poses a huge difference to Conventional Sewer systems.

Thus, when comparing the two alternative conveyance approaches (Condominial Sewer and Settled Sewer) with Conventional Gravity sewer, the following (see Tab. 3) differences in terms of "water consumption", "pipe diameter" and "gradient" requirements can be observed.

Tab. 3 Characteristic attributes for different sewer systems (adapted from VEST & BOSCH, 2002)

Type	**Water consumption**	**Pipe diameter**	**Gradient needed**
Conv. Gravity sewer	high	large	high
Condominial sewer	moderate	small	low
Settled sewer	low	small	low

3.5.3 Treatment: Intensive and Extensive Wastewater Treatment Facilities

Second integral part of this system represents an according treatment facility. Depending on the quantity and quality of the wastewater/faecal sludge that is treated, there is a variety of specific technologies and systems available. These technologies not only have different functions, but also varying treatment performances. Therefore, the decision which technology is preferably applied, strongly depends on the legal requirements concerning the required output quality. In general, when considering variants and approaches of treatment technologies, it is of crucial importance to take into account the final "fate" of the output products.

For choosing a technology, therefore, the ultimate "decision" must be made, whether the effluent/sludge has to be re-used (or can be disposed of) (XANTHOULIS et al., 2008). Some aspects relevant when considering options for disposal or re-use are discussed in chapter 3.5.4 and 3.5.5.

Neglecting appropriate treatment only dislocates sanitation problems and accumulates them at the outlet of the sewer system (TILLEY et al., 2008 and BUTLER & DAVIES, 2000) or at the point of discharge of motorized sludge transport.

Centralized & Semi-centralized

It is important to consider that treatment facilities can be dimensioned for different scales. Beside wastewater and sludge treatment facilities dimensioned to handle very large volumes - up to several million population equivalents[6], there are also small scaled "decentralized" solutions, which are applied at settlement or neighbourhood level. These options are especially relevant for communities, where no central treatment facility exists or where a connection to a central treatment is too expensive and technically challenging (VEST & BOSCH, 2002).

Within this thesis, following XANTHOULIS et al. (2008) and HOPHMAYER-TOKICH (2006), the terms "centralized" and "semi-centralized" wastewater management are understood as follows:

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[6] One population equivalent corresponds to the organic biodegradable load having a five-day biochemical oxygen demand (BOD5) of 60 g of oxygen per day (EUROPEAN COMMISSION, 2010)

- Managing wastewater **centralized**, includes Conventional wastewater conveyance systems (sewers), a centralized wastewater treatment plant, and a disposal/re-use of the treated effluent and sludge. Usually, there is a large distance between the point of waste generation and the point waste disposal – what can be seen as significant characteristic for this approach.
- A **semi-centralized** organisation of wastewater management includes the collection, treatment and disposal/re-use of wastewater at or near the point of waste generation. This can involve wastewater (or faecal sludge) from individual homes, clusters of homes, isolated communities or institutional facilities, as well as from portions of existing communities. For transportation not only motorized means, but also Non-conventional sewerage systems, such as Settled sewerage or Condominial sewerage can be applied.

Primary objective for the decision, whether a treatment facility is designed for a centralized or semi-centralized wastewater management pattern, should be the minimization of the overall costs for collection, conveyance (that does not only refer to sewer-based conveyance, but also motorized transport) and treatment while guaranteeing a safe handling and disposal of the processed materials(WSP & BNWP, 2008).

As referred to in previous sections, semi-/centralized treatment facilities not only provide treatment for wastewater evolving from sewer networks, but also for faecal sludge collected in “on-site” sanitation units such as Pit latrines or Septic Tanks.

After clarifying the terms “centralized” and “semi-centralized”, in the following an overview of some common technological approaches and their functional characteristics is provided.

Wastewater Treatment Facilities

Receiving a mixture of urine, faeces and originally fresh water, primary goal of a wastewater treatment facility is the removal of solids and organic substances and nutrients from the wastewater – in order to separate the contaminants from the transport media “water”. This cleaning process involves several different technologies and steps. As illustrated in Tab. 4, there are different treatment levels, with each removing different materials and contaminants from the wastewater.

Tab. 4 Levels of treatment and systems used (XANTHOULIS et al., 2008)

Treatment level	Definition	Systems
Preliminary	First stage of collective waste water treatment which removes large particles, oil and grease, and other material that may disrupt or affect the performance of downstream operations and processes.	Screening, grit removal, comminution, oil and grease removal, etc.
Primary	Removal of a portion of settleable solids, floatable solids and organic matter from the wastewater.	Primary sedimentation, septic tanks, anaerobic stabilisation ponds, etc.
Secondary	Removal of biodegradable organic matter, suspended solids mainly by biologic processes. Secondary treatment is also called biological treatment.	Facultative stabilization ponds, trickling filters, anaerobic biological treatment, activated sludge, constructed wetlands, , etc.
Tertiary	Removal of dissolved and suspended materials remaining in order to polish the final effluent. Implies the removal of pathogen and nutrients such as nitrate and phosphorus.	Maturation ponds, sand filters, Epuvalisation, etc.

Depending on the inflow characteristics and required outflow quality, there are various possible combinations and designs of technological solutions. A detailed discussion of these technologies and their specific functional pattern is not undertaken in this thesis. However, in order to discuss the most characteristic functional aspects, in the following it will be distinguished between “intensive” and “extensive” treatment. There are various technologies available for treating wastewater covering both very modern and technical highly sophisticated approaches (“intensive”) as well as simple variants, which are strongly orientated on natural processes (“extensive”). The chosen categorization allows the summarization of those technological approaches, which have some reasonable characteristics in common in terms of their functional requirements.

Considering the previously mentioned differentiation of centralized and semi-centralized management, VEST & BOSCH (2002) are noting that Intensive Treatment is rather associated to big “intensive” plants (“central treatment”), whereas semi-centralized organized treatment often relies on extensive approaches.

Intensive Treatment

The term “intensive treatment”, which is especially applied for urban wastewater treatment, mainly refers to intensive biological processes. These processes are carried out in so-called “wastewater treatment plants”, which accommodate several treatment steps (as shown in Tab. 4). Therefore, the type of treatment plant is basically determined by the form of biological treatment involved. In general, following treatment steps are commonly found in wastewater treatment plants:

(1) **Mechanical treatment** with screens, grit chambers and grease separators as well as the primary clarifier for settlement (NEUNTEUFEL, 2008).

(2) **Biological treatment**: during this step, transformation and destruction of organic matter is undertaken using intensified natural processes (EUROPEAN COMMISSION, 1991). Treatment is processed in relatively short time and confined space, which characterizes this approach as “intensive” (HOPHMAYER-TOKICH, 2006). Technologies associated with this approach are designed to deal with huge wastewater volumes and are able to provide a comparably high level of nutrient-, organic- & pathogen removal (XANTHOULIS et al., 2008). Besides the biological reactor (where these intensified treatment processes are carried out), a secondary clarifier as well as a return sludge compound can be part of the biological treatment step (NEUNTEUFEL, 2008).

According to the European Commission (1991), following main types of processes are used in biological reactors:

Fixed bed processes such as Biological Filters and Rotating Biological Contactors: Biological Filter, which are also referred to as “Trickling Filters”. In this case, wastewater is running through a bed of porous material that serves as support medium for purifying micro-organisms (forming a “biofilm”). The biofilm involves both aerobic bacteria on the surface and anaerobic bacteria near the support media. In order to maintain appropriate conditions for the aerobic bacteria, aeration has to be carried out - either by natural aspiration or by forced ventilation. In the case of Rotating Biological contactors, the rotating disks are used as supporters for the purifying biofilm, allowing oxygenation due to the rotation of the partially immersed disks.

Suspended growth biological treatment using Activated Sludge: in this case, raw sewage is mixed with recycled sludge, which is biologically active. Aerobic degradation is achieved by thoroughly mixing the micro-organisms with the influent, in order to use the organism’s “self-purification” potential. “Purified” water is then separated from the “purifying” sludge and can be discharged to final treatment. This process represents the most common approach for treatment of domestic and industrial wastewater.

Beside these processes, there are also several other technological options associated to intensive treatment thesis such as enhanced Biological Filtering or Biofiltering Techniques, which are not described in this. However, the two approaches presented above are assumed to be the most commonly used approaches (HOPHMAYER-TOKICH, 2006).

(3) **Advanced Treatment***:* As illustrated in Tab. 4, during tertiary treatment, wastewater is polished in terms of nutrients. Thus, characteristic processes are nitrogen and phosphorus removal.

(4) **Sludge Treatment***:* As primary aim of wastewater treatment is the removal of solids, organic substances and nutrients from wastewater, sludge is formed (during different treatment steps) which has to be further treated. In general, faecal sludge is not a uniform product and therefore has to be treated according to its specific quality.

One can distinguish sludge evolving from mechanical pre-treatment, biological treatment or advanced treatment, whereas volumes, dry substance contents and contents in general are varying. As already described in section 3.2.4 (faecal sludge treatment facilities), sludge has to stabilized, dried/dewatered and sanitized before being finally disposed of.

Stabilization*:* major issue of this process is the reduction of organic carbon contents (BOD). This can be carried out under aerobic or anaerobic conditions. *Aerobic stabilization* can be carried out within an Aeration Tank (or as well during an "Activated Sludge" Process). Moreover, it can also be part of a composting process. Composting can than either be carried out in a specifically built composter or - more less sophisticated - in windrows (UNEP, 2010). *Anaerobic stabilization* is a bacterial decomposition process ("digestion") for stabilizing organic wastes while producing a mixture of methane and carbon dioxide gas. It is usually carried out in specially built "digesters". Besides, it also can be carried out in a slower rate by using an unmixed tank or pond. Important when considering anaerobic digestion, is the production of biogas, which can be collected and subsequently used (UNEP, 2010 and HABERL et al., 2008).

Thickening, Dewatering and Drying: Depending on its origin, sludge can have a high water content. Therefore, several steps are necessary to minimize its water content. Increased solid contents are more adequate for composting. (Optionally, other dry materials can be added) Besides, due to the associated reduction in volume, further transport is facilitated (UNEP, 2010 and TILLEY et al., 2008).

Sanitation: In order to remove residual pathogens, very high temperatures, as well as pH adjustments and ionic radiation can be applied (HABERL et al, 2008)

Extensive Treatment

This treatment approach sums up diverse "technological" options, which are relying on self-purification processes in the water bodies and other natural biological processes for pollutant removal, oxidization of organic matter and destruction of pathogens. Extensive treatment facilities can be both naturally developed or artificially built (HOPHMAYER-TOKICH, 2006). Natural dissolution is stimulated, using natural elements such as sunlight, heat, sedimentation, UV radiation and acidity. Purification is carried out by using fixed bed cultures on small media or suspended growth cultures, which are using solar energy for producing oxygen by photosynthesis. The heterogeneity and diversity of plants, soils and types of water flow applied/used cause a variety of available approaches (EUROPEAN COMMISSION, 1991). HABERL (2009) mentions the following systems as examples for Extensive Treatment approaches:

- Constructed Wetlands
- (Wastewater) Ponds and Lagoons

As in the case of Intensive Treatment facilities, there are physical, chemical and biological mechanisms involved in the purification process. Thus, different forms of wetlands, ponds and lagoons fullfil varying treatment levels and are combined accordingly in order to achieve a required treatment level. According to the EUROPEAN COMMISSION (1991), the following treatment mechanisms can be identified, which are accommodated by different components.

(1) **Physical mechanisms**

- filtering through porous areas and root systems
- sedimentation of suspended solids and colloids in lagoons

(2) Chemical mechanisms

- precipitation of insoluble compounds or co-presipitation with insoluble compounds (N,P)
- adsorption on the substrate (N, P, metals)
- decomposition by UV radiation (virus and bacteria elimination), oxidation and reduction (metals)

(3) Biological mechanisms

- degradation of organic matter due to bacterial development
- nitrification (aerobic zones)
- denitrification (anaerobic zones)

A more detailed description of the particular approaches used, is not undertaken within this thesis. It is assumed that for the interest of this thesis, the identification of the basic functional requirements and limitations, a general consideration of the systems' characteristics is sufficient. Following HABERL et al. (2009), Extensive Systems are characterized by their simplicity, low control engineering requirements, low machine use as well as low operation and maintenance needs and a high buffering capacity. Their treatment performance is stable - with a comparable low excess sludge production. However, although there is only low need for maintenance, operating staff has to consider operational parameters such as wastewater volume, treatment time and oxygen supply (eventually ventilation). Besides, seasonal climatic conditions such as droughts, heavy rainfalls but also heats and frosts have to be monitored. Thus, personal operating such facilities, has to be educated at a sufficient level.

When comparing the two presented treatment approaches, the following (Tab. 5) characteristics can be identified, amongst other things:

Tab. 5 Characteristic attributes for Extensive and Intensive Systems (according to HABERL, 2009)

Attribute	**Extensive Systems**	**Intensive Systems**
Hydraulic loading	low	high
Oxygenation & oxidation rate	low	high
Maintenance	low	high
Area, volume	high	low

Especially in areas with arid or semi-arid climatic conditions, Extensive systems not only fulfil the function of treating wastewater but also of supplying water for irrigation. Due to their design and dimensioning, they can be used as storage facility. This aspect is of importance, because effluent demand can have significant seasonal variations, whereas effluent production during wastewater treatment stays comparable stable (HOPHMAYER-TOKICH, 2006).

3.5.4 Disposal: Discharge of Effluent and Disposal of (treated) Sludge

In general, the following two different output products evolving from (intensive and extensive) treatment processes can be distinguished:

- (treated) effluent
- (treated) sludge

Quality and quantity of effluent and sludge are strongly varying with the treatment technology they evolve from and of course with the amount and characteristic of the wastewater that was treated. Considering these two output products, the following interdependency is observable: The more "successful" the treatment – in terms of a high quality ("clean") effluent – the higher concentrated are problematic compounds in the sludge and therefore, the more difficult and complex becomes its further handling. Hence, further "Sludge Treatment" is necessary in order to biologically stabilize it. How many steps of treatment (and which technologies) are applied, finally depends on the ultimate use/disposal of the output product and related legal and socio-economic requirements.

Effluent Discharge

Generally, there are as well the options of "disposing" as also of "re-using" the effluent. In the case no re-use is planned, the treated effluent can be discharged in a receiving surface water body (i.e. rivers or lakes) or into the groundwater body (by discharging on land). It is substantial to ensure that the assimilation capacity of the particular water body is sufficient to recieve the evolving nutrients without being overloaded. Therefore, when considering the treatment steps previous to a discharge, main objective of the treatment activities is the avoidance of "eutrophication", which is caused by pollutant overloading (XANTHOULIS et al., 2008).

The decision of what is seen as overload, is strongly dependent on legal regulations applied in the particular region. Therefore, the adequacy of a water body for being used as recipient is not only determined by the natural conditions but also by the legal requirements (TILLEY et al., 2008). According to TILLEY et al. (2008), effluent discharge is especially appropriate for areas which are at risk of salt water intrusion or for aquifers with a long retention time.

Sludge Disposal

After being treated in several steps, the treated sludge can either be disposed of at disposal sites such as landfills or become incinerated. In every case, the sludge has to be prepared and stabilized in respect of its pathogenic compounds and chemical stability in order to achieve safe disposal.

The stockpiling of sludge at landfills (which is mostly done together with other unusable materials), has to be undertaken with care. Due to the risk of unwanted percolation, storage should not take place in areas with high groundwater levels. If not stored correctly, there is a risk of pollutant accumulation in the soil and consequently pollution of the groundwater body (TILLEY et al., 2008). Incineration of sludge is of special relevance in case the sludge is heavily contaminated with heavy metals or other specific pollutants (XANTHOULIS et al., 2008).

The disposal of sludge is most appropriate for a city-wide application, which obviously requires a public authority taking over the responsibility (TILLEY et al., 2008).

However, besides disposal, there is also the option of using stabilized sludge, which is described underneath.

3.5.5 Re-Use of (treated) effluent and sludge

Especially in the context of the recent challenges such a growing world population, increasing urbanization and rapid extension of economic activities, the re-use (instead of disposal) of wastewater treatment products gets of increasing importance (HOPHMAYER-TOKICH, 2006). Substantial pressure is put on the world's fresh water and agricultural resources. Therefore, both the effluent and the sludge are relevant for being re-used. Similar, as in the case of applying stored urine and dried faeces (described in relation with the Re-use oriented Systems), the problem of micropollutants has to be mentioned. More details to this topic can therefore be found in section 3.3.

Re-use of Effluent

In respect to water scarcity and progressive water resources pollution, XANTHOULIS et al. (2008) state "wastewater reclamation and re-use (…) is an excellent way to preserve and extend existing water supplies and is becoming more and more frequent throughout the world (p.226)." McDONALD (2004), who is discussing economic aspects of wastewater re-use in Australia, identifies several potential drivers for enhancing and establishing wastewater re-use.

- There is the need for reducing the volume of effluent being released to bodies of water in terms of protecting environmental resources, and
- a shortage of water for irrigation purposes or industrial purposes.

Following XANTHOULIS et al. (2008), in agricultural zones and particularly in semi-arid or arid countries, irrigation can be identified as main objective for wastewater treatment and (consequently) its re-use. Considering this issue, treatment activities are therefore designed to eliminate pathogens in order to minimize health risks when re-using the effluent in agriculture. Besides, there is a focus on sludge elimination in order to reduce the risk of pipe clogging. Furthermore, not only irrigation but also other agricultural activities such as aquaculture can be a purpose for re-using wastewater, which is related to very specific issues (WHO, 2006). In addition to these aspects, re-use can also be applied as part of an overall water demand management strategy, including innovative approaches for solving modern issues in the water sector (McDONALD, 2004). It is important to realize that there is a reasonable range of applications for re-using treated wastewater, which are all related to very specific parameters determining required treatment activities. Generally, parameters of concern and therefore relevant for designing the treatment options, are either health oriented or specified for the particular application (e.g. agriculture: protection of plant and crop yield, trace elements management, etc.; irrigation: salinity management; industrial re-use: avoidance of scaling, corrosion, biological growth,…) (XANTHOULIS, 2008).

Use of (treated) Sludge

The second major wastewater treatment product relevant for re-use, is sludge. On the one hand, the sludge can be a significant supplier for nutrients and trace elements for agricultural purposes. On the other hand re-using sludge is a comparable in-expensive option for "disposing" it (XANTHOULIS et al., 2008). Generally, there is both the option of using stabilized sludge in agricultural and in industrial processes.

Sludge provides nitrogen, phosphorus and microelements important for plant growth and therefore poses an attractive substitution for commercial fertilizers. Furthermore, the organic content of the sludge can be very relevant for increasing the organic content of devastated soils. Sludge characteristics are strongly dependent on the treatment process and on the place of origin during the treatment process. It makes a difference, whether the sludge is received from small treatment units processing material from pits, or whether the sludge is arising from large-scale treatment plants, where the sludge tends to contain chemical or heavy metal pollutants. This is also due to the fact that these treatment facilities often not only receive domestic but also industrial wastewater and stormwater.

Especially in terms of an agricultural re-use, heavy metal concentrations, pathogens, vector attraction and contents of toxic organic compounds can be significant limiting factors (XANTHOULIS et al., 2008). Therefore, stabilization based on long-term storage or/and the addition of lime are common practices for minimizing the risks evolving from sludge re-use. The application of treated sludge can be undertaken on both private and public land. Agricultural purposes as well as landscaping are typical fields of application, whereas the sludge's quality is a distinctive factor. TILLEY et al. (2008) describe stabilized sludge as bio-solids, which can be spread on the ground surface using different technical means. Moreover, the more liquid the stabilized sludge, spraying onto or even injection into the ground are possible options. The application rates and usage purposes, however, should take into account not only the presence of residual pathogens and contaminants, but also a sustainable and agronomic rate in terms of the contained nutrients (TILLEY et al., 2008).

Re-use of sludge can be applied city-wide, whereas its management can be organized by households as well as co-operatives of households or public authorities (TILLEY et al., 2008). In general, the application of sludge is highly dependent on the acceptance and willingness of the community to use the product. Therefore, there are big and long-lasting discussions dealing with this topic (often in relation to the problem of “Micropollutants”, for more details see 3.3.2.4).

4. Functional Requirements of Sanitation Systems

"The type of wastewater system should be chosen and adapted in the context with the density of the population, climatic conditions and the technical/socio-economical ability of the responsible body to implement it, operate it and maintain it (ISO/CD 24511, viii)"

In the following section, those factors should be discussed, which are determining the basic conditions for the feasibility of the presented system components. These factors should be understood as knockout-criteria deciding whether a technological component and consequently a system in general can be installed or not. It is essential to be aware that criteria discussed in this thesis are not decision criteria applicable at actual planning or project level. In the project-specific planning phase for a sanitation system a much bigger variety of factors have to be considered. Interest of this thesis is much more the characterization of over-all criteria – "functional requirements" – relevant for identifying general fields of applications for the discussed systems.

Within the following chapter, functional requirements of all components presented in the previous chapter are discussed. Similar as for describing the Functional Pattern, the requirements will be organized according to the functional groups "Capture", "Collection/Storage", "Conveyance", "Treatment" and "Disposal".

A short summary of the most characteristic identified requirements is provided in Annex II.

4.1 Functional Requirements of a Pit-latrine based System

"[Pit latrines can be applied] in settlements with insufficient or irregular water supply provisions and with suitable soil conditions (VEST and BOSCH, 2002, p.75)."

4.1.1 Captures: Pour Flush and Water-less Toilet

Looking at factors distinctive in terms of the applicability of those captures discussed in relation with pit-latrine based systems, there is a major difference between the two options "Pour Flush Toilet" and "Water-less Toilet". Whereas the former relies on a constant water supply, the latter works without water. As Pour-Flush Toilets, however, can also be operated with greywater and rainwater, the required level of water supply is comparable low (TILLEY et al., 2008).

In general, both presented components do have low capital costs. Operational costs, however, can be higher for Pour Flush Toilets - depending on the price of water.

Also in terms of the components' availability, there is a difference between Water-less and a Pour Flush Toilets. The former are relatively easy to construct (provided that sand and cement are available) and are mostly repairable with locally available materials and skills. The latter, however, in most cases have to be purchased as a whole - which limits their local availability. This obviously is also relevant in terms of potentially necessary repairs. However, as both systems do not involve any mechanical parts, repair works should be comparably rare.

Considering the components' maintenance, Pour Flush Toilets might require more maintenance - due to their tendency to build up blockages. For both options, regular cleaning is necessary in order to prevent pathogen / disease transmission. However, as cleaning is necessary for all kinds of user interfaces, needed user commitment is not assumed to be outstanding.

4.1.2 Collection & Storage: Single Pit/VIP, Twin Pit, Alborloo Pit

In the previous chapter about the "Functional Patterns" of diverse sanitation systems, different options for Collection & Storage in a Pit-latrine based system were presented. However, when looking at their functional requirements, they do have some requirements in common.

Firstly, there is a considerable dependency from the prevailing soil structure. Thus, normal Single Pits as also VIPs or Alborloo Pit and Twin Pits are dependent on the surrounding soil in twofold ways: On the one hand, the soil has to be appropriate for digging – which excludes areas with rocky soil or high groundwater levels. On the other hand, soil conditions should be adequate for absorbing the effluent evolving from the pit (TILLEY et al., 2008 and BRIKKÉ & BREDERO, 2003). Thus, the presence of bedrock (in less than 2m below surface) can hinder infiltration and therefore should be avoided. Besides, coarse or medium sand do provide insufficient filtration and are hence also inappropriate (except for variants with less effluent development - e.g. water-less capture) (LOETSCHER & KELLER, 2002). According to WINBLAD and HÉRBERT (2004) seepage from unconsolidated or unlined pits is frequently identified as source of well or even groundwater pollution resulting in a deteriorated drinking water quality (e.g. in terms of measured NO_3 concentrations). This sensitive interconnection of drinking water supply and wastewater disposal has therefore to be taken into account. A complex interaction of soil profile, hydraulic conductivity parameters, temperature, soil pH and moisture retention capacity influences the movement of viruses and bacteria (evolving from infiltrations from the pit) in the soil. Thus, the exact determination and identification of the appropriateness of a soil in terms of its retention and filtration capacity is a very difficult task (SAYWELL & SHAW, n.a.). Generally, for providing some reference or guideline, a distance of 30m between pit latrines and water sources is suggested (TILLEY et al., 2008, LOETSCHER & KELLER, 2002, etc.).

Moreover, due to infiltration activities related to these systems, an installation in areas with high groundwater levels should be avoided (GTZ, 2000, TILLEY et al., 2008, etc.). According to LOETSCHER & KELLER (2003), the groundwater table should be at least 2m away from infiltrating facilities, if the water supply is piped. In the case wells or boreholes are used for water supply, a minimum distance of 5m has to be calculated. The over-all target is the minimization of the risk of so-called “short-circuits” to surrounding water bodies. Soil which is not permeable enough, can also be problematic, as the effluent then tends to come up to ground level (HOPHMAYER-TOKICH, 2006). VEST and BOSCH (2002) also mention the inappropriateness of locations with low-lying land and/or depressions, as there is an increased risk of pollutant accumulation.

As an overflow of pits can cause serious contamination of the surrounding area, this system is very vulnerable to floods and heavy rain falls. An installation of pits in areas prone to such weather conditions may therefore be done with caution (TILLEY et al., 2008 and HOPHMAYER-TOKICH, 2006). Thus, constructional design has to be appropriate for taking into account local precipitation conditions.

The ability of soil to absorb effluent and retain pollutions is, strongly related to the settlement density. Obviously, the risk of pollutions depends on the population density, since frequency and pollution load correspondingly rises with an increasing population density. Therefore, special care has to be taken to this issue for population densities exceeding 150-200 inhabitants per hectare. Thus, theoretically, the use of pit latrines is limited to areas with less than 250-300 inhabitants per hectare (GTZ, 2000 and VEST & BOSCH, 2002). PATERSON et al. (2007) strengthen the role of the settlement density in terms of the technical feasibility of on-site solutions such as pit latrines as follows: “In peri-urban areas, the ground conditions often make on-site sanitation infeasible, with poor drainage and risk of contaminating drinking water sources (p.903)“.

Characteristic for pit latrines are their low construction costs. However, depending on excavation depth and used materials, costs can vary. Compared to other technologies, only low technical skills and know-how are needed, which is again related to (low) costs. VIP latrines can be slightly more expensive in construction than normal pits - due to their more sophisticated design. In general, all of these options can be built and repaired locally (TILLEY et al., 2008). According to TILLEY et al. (2008), management of operation and maintenance of these variants is mostly done by individual households or by self-organized cooperatives of households.

Therefore, compared to variants managed by public authorities, users must be aware of the components' function. Thus, a certain extent of user commitment is required.

When considering efforts needed for maintaining these facilities, there are some differences between Single pits (or also VIPs), Arborloo or Twin Pits. Compared to the other two options, both the Arborloo concept and Twin Pits are considerably more dependent on an appropriate operation and maintenance through the users. The users must be aware of the idea and function of these technologies, implying a certain level of understanding of the system. Otherwise, the system's function is at risk (TILLEY et al., 2008).

4.1.3 Conveyance: Human Powered and Motorized Emptying and Transport

The settlement pattern is a crucial factor influencing the functionality of the conveyance steps in a Pit-latrine based system. Aspects correlated to that are the availability of space, the accessibility to the facilities and the available emptying capacities. In the case new pits are dug instead of emptying the "old" ones (Arborloo), enough space has to be available. This also comprises excavations for disposal procedures (as it is the case for Twin Pits). Therefore, the option of disposing sludge directly after removal is only feasible in low- to medium densely populated areas (GTZ, 2000). For Single Pits or VIPs, moreover, accessibility to and sufficiency of emptying procedures become very important, as they have to be emptied frequently - mostly involving motorized vehicles (LOETSCHER & KELLER, 2002). Therefore, pits are commonly classified as sanitation option best suited to rural and peri-urban areas (BRIKKÉ & BREDERO, 2003 and TILLEY et al., 2008).

Transport by motorized means is associated to several of requirements. On the one hand, transport infrastructure like roads, vehicles or fuel are needed. On the other hand, used vehicles are equipped with special features as vacuum pumps, which can limit their local availability.

Twin Pits, whose output material has undergone more degradation than that of Single Pits or VIPs, emptying can proceeded manually. Sustainable success and usefulness of manual emptying depends on the distance to the point of sludge disposal (TILLEY et al., 2008). Manual transport for distances of more than 0,5 - 1km is not manageable with purely manual means. Thus, requirements in terms of materials and tools needed for emptying are varying for manual and motorized procedures. Depending on the level of manual emptying, special material (e.g. MAPET) may be required (PEAN and THYE, 2009). Personal carrying out the emptying have to be skilled - however, the level of these skills are comparable low (TILLEY et al., 2008).

In general, costs for emptying and transport can be significant compared to the capital costs for construction of the storage facility (BRIKKÉ & BREDERO, 2003).

When looking at the management of operation and maintenance, there is a difference for human powered and emptying and transport relying on motorized means. Whereas the first can be organized at neighbourhood or even household level involving small enterprises for emptying and treatment activities, the latter rather requires management at a sophisticated institutional basis (VEST and BOSCH, 2002, BRIKKÉ & BREDERO, 2003 and TILLEY et al., 2008). Thus, whereas manual emptying requires a much higher level of user commitments in terms of operation and maintenance, motorized emptying relies on the user's ability to pay for the service. Generally, workers who are in contact with offensive material (untreated / non-degraded faecal sludge) need to be skilled appropriately. However, the level of these skills is comparable low.

4.1.4 Treatment: Faecal Sludge Treatment Facility

Different from Arborloo or Twin Pits, sludge evolving from Single Pits or VIPs, requires treatment in an according facility. There is a range of technological variants available, which do have some characteristic functional requirements in common:

A very prominent aspect is their large space area demand (except for the Anaerobic Biogas Reactor) conditioning their appropriateness for rural and peri-urban communities. Due to that fact, as also due to potential inconveniences (i.e. smells or vector breeding), they obviously require a minimum distance to other settlement structures and should therefore always be located on the edge of a community. Besides, accessibility of the treatment units with vehicles is necessary in order to operate and maintain the facility (TILLEY et al., 2008).

According to TILLEY et al., (2008), Faecal sludge treatment facilities tend to have low to moderate capital costs and low operational costs. Material necessary for construction but also for operation and maintenance should mostly be locally available. However, their design, as also their operation and maintenance requires trained personal, which has to be specifically educated for appropriately supervising the facility. Thus, for managing operation and maintenance a considerable level of institutional organization is required (TILLEY et al., 2008).

4.1.5 Disposal: Arborloo concept, Disposal of (treated) Sludge

In general, depending on the particular storage/collection facility applied, there are different options for disposal procedures, which are again linked to different functional requirements.

In the case of Twin Pits, degraded material can be used as soil conditioner which implies that there is space for applying it. Hence, this form of disposal is limited to areas with sufficient land area available, which is mostly found in rural to peri-urban environments. In general, management of the material’s application is undertaken at household or even neighbourhood level. The required skills are comparable low. Nevertheless, the users must be educated in order to maximize their acceptance for using the material.

For Single Pits or VIPs, whose sludge is treated in Faecal Sludge Treatment facilities, there are different approaches for final material disposal. As these procedures are similar for sludge evolving from (Semi-)Centralized water-based systems, their functional requirements are described in chapter 4.4.4.

4.2 Functional Requirements for Systems focussing on Re-use

In contrast to the previously described Single Pit based or VIP based variants, both presented systems focussing on re-use neither require (semi-)centralized treatment nor associated conveyance technologies.

4.2.1 Functional Requirements of a Water-less System with Alternating Pits

4.2.1.1 Capture: Water-less Toilet

In terms of the technology's material needs, this user interface is relatively easy to construct. Provided that sand and cement are available, it can be built and repaired easily with locally available material. There are no mechanical parts involved, which again proves the system to be easy maintainable. In terms of maintenance, the users must be aware of the appropriateness of diverse input materials. Besides, after defecation a constant source of soil, ash and leaves is necessary. Like for all user interfaces, regular cleaning is necessary in order to prevent pathogen / disease transmission (TILLEY et al., 2008).

4.2.1.2 Collection & Storage: Fossa Alterna

The material needed for construction and repairs of Fossa Alternas is mostly easily locally available. Depending on the particular design, capital costs are therefore comparable low. According to VEST & BOSCH (2002), also operational costs are low. This is due to the fact, that neither specific materials nor energy or water are needed for operating this collection and storage facility.

However, compared to other systems, users of Fossa Alternas should be more committed to the operation and maintenance – and have to "spend" more time and efforts than in the case of water-based systems. According to TILLEY et al. (2008), Fossa Alterna Pits are mostly used in the context of individual households or probably a cooperative of households (neighbourhood). Accordingly, the management of operation and maintenance is mostly undertaken at household or neighbourhood level. Additionally, for establishing a sufficient degradation process, the users must be informed about the idea and function of this system. Otherwise, inappropriate handling can highly risk the success of the decomposition process. However, this does not necessarily refer to a very high level of skills.

As in the case of other excavated, infiltrating storage units, prevailing soil conditions can be a limiting factor. Digging necessary for the installation of the vaults in rocky or highly compacted soils is very difficult or even impossible. Similarly, high ground water levels are problematic. The efficiency of the degradation process is sensible to the adding of water, which has to be taken into account during designing a facility.

Being oriented on the re-use of the components' output, this solution is especially interesting for areas with poor soil conditions. Since emptying is carried out manually, a vacuum truck access is not necessary, which encourages an application in rural and peri-urban areas (TILLEY et al., 2008).

4.2.1.3 Conveyance: Human Powered Emptying and Transport

Provided that the decomposition has been successful, the output material evolving from Fossa Alterna pits is broadly in-offensive. Besides, it is not as compact as normal faecal sludge. Thus, the emptying of the storage vaults is less hazardous than in case of Single Pits (or VIPs) and can be carried out manually by the users themselves. This avoids high requirements in terms of equipment (vehicles) and accessibility. However, in order to be sure that the emptying is done correctly, users must be informed about accurate handling procedures. Besides, manual emptying has a limited capacity in terms of the distance between the point the material is "generated" and the point of its final use.

In general, tools for manual emptying should be locally available (unless mechanical means are used, which can have a limited local availability).

4.2.1.4 Re-Use: Application on Land

When considering this step in the sanitation process, the most important requirement is that there is a need for using the material. This opinion is shared by LOETSCHER & KELLER (2003) who identify the demand for the output product of re-use systems as crucial basis for the system's function.A crucial factor that influences a successful implementation of output re-use, is that there are no culturally conditioned reservations against the application of (former) human excrements. According to a publication of the GTZ (2000), cultural reservations are dependent on adequate education and information. Besides, available land areas should be sufficient for the application of the produced material.

It is characteristic for the Fossa Alterna based system, that operation and maintenance can be carried out by the users – either organized at household or neighbourhood level - implying a sufficient understanding of the whole process (TILLEY et al., 2008). Therefore, the users must be aware of correct application procedures.

4.2.2 Requirements Urine-Diverting System focussing on Re-Use

4.2.2.1 Capture: Urine Diversion Dry Toilet (UDDT)

Depending on the particular design, the materials needed for construction are easily locally available. Beside variants built out of concrete or wire mesh, there is also the option of using plastic. According to TILLEY et al. (2008), UDDTs are characterized by low capital and operation costs.

In order to achieve good acceptance and appropriate handling, education and demonstration projects are necessary. Besides, cleaning requires more efforts than for in the case of the other presented captures, as water use is very limited. The proneness to clogging can cause an increased maintenance effort.

In contrast to other mentioned system components, this system is totally independent from any water source.

4.2.2.2 Collection & Storage: Double Dehydration Vaults, Single Dehydration Vaults, Composting Vaults

The presented storage units do have in common that the vaults must not be dug in the soil, but are built up within a super-structure. Whereas other systems are limited to soil conditions favourable for digging, dehydration vaults but also composting toilets can be built in rocky or sandy areas (TILLEY et al., 2008 and VEST & BOSCH, 2005). Due to that fact that the vaults are built above surface and are designed to be water tight, the risk of ground water pollution is low. Thus, high ground water levels are no real limitation – in contrast to other on-site options such as pit latrines. The water-tightness makes the system also useful for areas, which are frequently flooded (TILLEY et al., 2008)

Especially when using Double Dehydration Vaults (where no additional space for continued drying/composting is needed), the space requirements are little. As excreta are not mixed with water, the volumes handled during the collection and storage phase are comparable small. Additionally, due to the dehydration process, the volumes are even decreasing during storage. Besides, as there is the option of installing the toilet (+storage) indoors, the application is feasible in both rural and dense urban environments (TILLEY et al, 2008). However, regarding further steps for handling the output material, a dense urban environment appears problematic. Single Dehydration Vaults and Composting Vaults, mostly require a second step of drying or composting – which is related to slightly higher space requirements.

The materials needed for building and repairing the components should be locally available. In general, Dehydration Vaults are classified as low cost options. However, depending on the particular design, the capital costs can vary.

Using and operating a Urine Diversion Toilet in combination with Dehydration Vaults is not intuitively or immediately obvious to all users (TILLEY et al., 2008). Therefore, a reasonable amount of knowledge, sensitivity, discipline and acceptance on behalf of the users is required (BRIKKÉ & BREDERO, 2003). The necessity of education and demonstration projects therefore appears to a big issue. In this context, small-scale organization plays an important role. This can involve self-help initiatives as well as community based organisations or other specific associations (VEST & BOSCH, 2005 and ESREY et al., 2001). As it is the case for the Fossa Alterna pits, therefore, user commitment is a crucial factor for a well-operated system. In general, the maintenance is carried out by households or co-operations of households, mainly involving local workers (BRIKKÉ & BREDERO, 2003 and TILLEY et al., 2008).

4.2.2.3 Conveyance: Human Powered Emptying

Depending on the collection unit, further steps after collection and storage are varying. Whereas faeces evolving from Double Dehydration Vaults, are already fully dried before they are removed from the chambers, material evolving from Single Dehydration Vaults (or Composting Vaults) has to pass further treatment. Thus, emptying of Single Dehydration Vaults has do be done with more caution. However, for all options, requirements in terms of both accessibility and skilled labour are comparable low - as emptying and transport are carried out manually. However, as stated before, manual transport is only appropriate for a maximum distance of 1km between the point of sludge generation and the point of its final application.

Emptying is mostly undertaken on behalf of the users. Thus, they must be willed to take over this responsibility. In the case more households are using similar systems, conveyance and re-use can obviously be organized jointly – and may involve small enterprises.

4.2.2.4 Re-Use: Application on Land

Similar as for Fossa Alternas, the most obvious requirement in terms of this process step, is the need for and interest in using the output-materials. Besides, there must be sufficient land available for application of the material. In general, the materials' application can be organized by households themselves or at neighbourhood level. In the case of urine, there is also the option that a public authority organizes the transport and use.

TILLEY et al. (2008) characterize both application of urine and application of faeces as low cost option, relying on simple techniques. However, agricultural skills are necessary in order to achieve an optimal application efficiency.

The application of urine is most appropriate for rural to peri-urban areas, where the point of generation is not far from the point of application. Besides, considering the application of dried faeces, the requirement for sufficient space area has to be noted.

4.3 Functional Requirements of a Septic Tank based System

4.3.1 Captures: Cistern Flush Toilet and Pour Flush Toilet

Depending on the capture, a supply of water from 2-3l to up to 20l per flush is needed. Therefore, already at the user interface the whole system's dependency from water is determined, which characterizes this approach as "water-based". However, the required "level" of water supply is very different for a Pour Flush or a Cistern Flush Toilet. Whereas the former only needs a very basic supply level in terms of qualities but also quantities needed (recycled water or rain water can be used as well; or only one water supply connection per household), the latter requires a constant, piped water supply (TILLEY et al., 2008).

Due to the small amount of water needed, Pour Flush Toilets tend to clog easier than Cistern Flush Toilets and therefore require more maintenance. Repair works for Pour Flush Toilets on the other hand should be rarer as no mechanical parts are used.

Both toilet options are produced commercially, which means that they can hardly be built or repaired locally. Whereas Pour Flush Toilets are rather cheap to purchase (low capital costs), Cistern Flush Toilets can have high capital costs.

4.3.2 Collection & Storage: Traditional Septic Tank

A basic and significant requirement of a Septic Tank is its need for a constant and reliable water supply in order to maintain a sufficient through-flow.

Besides, the functionality of this system component strongly depends on the surrounding soil structure. This is on the one hand due to the need for conditions appropriate for digging, in order to install the storage unit. And on the other hand, in terms of the soil permeability as the effluent is infiltrated (e.g. by a soak pit). Thus, an installation in clay, hard packed or rocky soils is inappropriate (TILLEY et al., 2008). VEST & BOSCH (2002) site "sufficient space" and "permeable soil" as basic requirements for a properly working Septic Tank. In general, wastewater treated in Septic tanks is infiltrated into the soil, which requires minimum distances[7] to other buildings, infrastructure or topographic features. Especially in dense urban environments these conditions are often not fulfilled. Soil's absorption capacities are easy exhausted by large numbers of effluent infiltrating facilities. BRIKKÉ & BREDERO (2003) therefore suggest rural to peri-urban areas as appropriate settlement condition. Space demands for the facilities themselves, however, are comparable low, as the structure is located below the surface.

As both unwanted percolations and intended infiltrations (of the effluent) are prone to cause a transmission of contaminated streams, a Septic tank should not be installed in areas with high groundwater tables (TILLEY et al., 2008). BRIKKÉ & BREDERO (2003) therefore stress that it is crucial that communities are able to afford a safe construction.

Depending on the capture, initial costs can range from moderate to high. Variations in terms of the running costs, however, can be more significant. Whereas in the case a Pour Flush toilet is used as user interface, costs for operating and maintaining a Septic Tank can be low, those where a Cistern Flush Toilet is used as capture, can become comparable high (VEST & BOSCH, 2005). There is the possibility of constructing tanks designed to serve several households. Jointly using one larger tank for a group of households can reduce the costs per capita. Furthermore, construction can be easier undertaken self-helped with the mutual help of neighbours (TILLEY et al., 2008).

[7] depending on the soil's filtration capacity (VEST & BOSCH, 2005)

In general, the materials needed for construction and repairs are mostly locally available. Construction is not as simple as in the case of latrines, however, it does not require highly skilled labourers or designers (VEST & BOSCH, 2002).

According to TILLEY et al. (2008) cold climate can become a limiting factor, as treatment efficiencies are decreasing with decreasing temperatures.

Compared to other on-site options, the maintenance requirements of a Septic Tank are low. Thus, the system's function is not so very dependent on user commitments as in the case of i.e. re-use systems. In general, management can be carried out by the households themselves as well as by a public authority (TILLEY et al., 2008). Thus, a sophisticated institutional background is not obligatory for the storage component itself. However, when it comes to the conveyance (see underneath), requirements concerning the management structure might look different.

4.3.3 Conveyance: Motorized Emptying and Transport of Sludge

Due to an accumulation of faecal sludge inside the tank, regular desludging with motorized means is required. This form of conveyance depends on several factors. A crucial one is the facilities' accessibility for motorized emptying (TILLEY et al., 2008 and VEST & BOSCH, 2005). This is again related to the availability of transport infrastructure such as vehicles, roads and fuel.

Regularly emptying the tank(s), moreover, is related to costs. In order to bear these expenses, households using this system therefore require a certain minimum income level.

The desludging services are mostly organized on a neighbourhood or even city level (i.e. involving small local enterprises) (BRIKKÉ & BREDERO, 2003 and VEST & BOSCH, 2005). According to TILLEY et al. (2008), the management should therefore be carried out by a public authority – requiring a relatively high level of institutional organization as well as user's capable of paying for this service.

4.3.4 Treatment & Disposal: Effluent Infiltration and Faecal Sludge treatment

When considering the functional requirements for these two components, one can distinguish between procedures used for handling the effluent and the ones dealing with the sludge.

In the approach described within this work, the effluent is infiltrated on-site (via a soak pit). There are several requirements related to this step. However, as the effluent "disposal" is associated to the storage facility, they are described in the context of the storage facility. In general, these requirements are similar to the ones described in the context of the storage facility of Pit-latrine based systems.

In terms of the treatment and disposal of sludge, however, procedures and herewith requirements are different. As these steps are similar for sludge evolving from pit latrines, their Functional Requirements are described chapter 4.4.4.

4.4 Functional Requirements of Water-based Systems

4.4.1 Captures: Cistern Flush Toilet

Probably the most significant requirement linked to this capture method, is its dependency from a constant water supply. Up to 20l of water are needed per flush, implying a sophisticated and reliable piped water supply.

As the facility is built commercially and has to be purchased as a whole, capital costs are relatively high. Additionally, maintenance and repairs can hardly be undertaken locally. The constant use of water furthermore can cause significant operational costs.

Different from in the case of other systems described so far, the responsibilities of the users are comparable low. They don't need a high grade of commitment for accurate operation (except for basic knowledge about inappropriate input materials).

4.4.2 Conveyance: Conventional Gravity Sewer, Condominial Sewer

When looking at the functional requirements of conveyance options associated with (semi-) centralized water-based sanitation, it appears useful to distinguish between Conventional approaches and the two presented "alternatives".

Conventional Gravity Sewer

Basically, a constant supply of water is the most relevant and obvious technical condition determining this component's function. Since it is of crucial importance to avoid solids from accumulating in the sewers, a constant flow-through is needed. Blockages, which pose a major problem in terms of the system's functionality, can be exacerbated by low water use (BUTLER & DAVIES, 2000). To work effectively and efficiently, the operation of Conventional Sewer requires a reliable multiple-tap in-house water supply (PATERSON et al., 2007).

Beside an insufficient water supply, too few sewer connections can cause inappropriate flow conditions (BUTLER & DAVIES, 2000). Therefore, the denser the settlement structure of a community and the more houses are connected, the more appropriate is a gravity sewer. Due to that fact, this system is best suited for dense urban settlements. In rural areas, quantity and frequency of wastewater are too little and the sewers are imperilled to be blocked.

As described before, Conventional Gravity Sewer strongly depend on a constant downhill gradient between the point of wastewater generation and the point of treatment. Therefore, their function is substantially relying on the area's topography. The more the inclination changes on the wastewater's transport route, the more pumping devices are needed. Different from on-site devices, whose positioning can be easier adapted, sewer can hardly bypass topographical impediments.

Another factor that can impede the construction phase, are soil conditions inappropriate for digging (TILLEY et al., 2008).

Moreover, BUTLER & DAVIES (2000) refer to the negative effect of high temperatures as they accelerate the decomposition of the material within the sewer and the associated limitation of the amount of oxygen that can be dissolved in water, which finally leads to a rapid development of anaerobic conditions. Therefore, the system's function indeed can be influenced by the climate.

A significant aspect when looking at Conventional Sewers are their high capital and operational costs. In general, there are various factors determining these high financial burdens: The construction is laborious and material-intense, since a minimum depth for protection against traffic loads, a minimum slope to avoid sedimentation of solids, and a minimum diameter to avoid blockages are required. Additionally, the construction highly depends on expert knowledge and skilled labours which is also cost relevant. Additionally, there are an on-going running costs related to operation and maintenance due to the high demand in water and requirements for specific labour and material (HOPHMAYER-TOKICH, 2006). Thus, a professional management institution is needed (BUTLER & DAVIES, 2000 and TILLEY et al., 2008). This aspect is also supported by HOPHMAYER-TOKICH (2006), who note that institutional low performance and high costs are common problems in terms of a communities' inability to install and maintain such a system.

Following TILLEY et al. (2008), Conventional Sewers are only manageable on behalf of a public authority. Different from previously described components, the management at neighbourhood or even household level is inappropriate. Thus, a public authority has to take over the responsibility and the community needs to be able to pay for the high costs in terms of the system's construction but also operation and maintenance (BUTLER & DAVIES, 2000). BUTLER & DAVIES (2000) underline this aspect by stating that "Conventional sewerage (…) will only be appropriate where property values are high and occupiers can pay for the full costs involved (p.457)." PATERSON et al. (2007) are very similar opinion as they identify Conventional sewer systems as "anti-poor" technology. According to the authors, only very rich communities are able to afford all costs. HOPHMAYER-TOKICH (2006) notes that only few cities in the world are able to directly cover all costs (related to construction, operation and maintenance) through user charges. In as much of most of the cities, even in those countries where labour and materials are cheap, costs are high and can be prohibitive. Thus, households prefer not to use their scarce income to address wastewater problems and the communities can hardly finance the system in a sustainable manner. Economic aspects are also discussed by UNEP SSC (n.a.) in relation to urban sanitation developments in India. Although first sewer channels were already constructed more than a century ago, today only 5% of all towns in India do have operating sewer facilities. The discussed reasons for that are very similar to those mentioned by other authors: the high demand in water but also the high, recurring costs for construction, operation and maintenance. Thus, most city municipalities, even the big ones such as Mumbai, are not able to supply water in appropriate quantities.

It is therefore of significance to understand that conventional wastewater management infrastructure benefits from economies of scale. Per capita costs (e.g. for a sewer) are much higher in smaller (rural) communities, than in urban ones – e.g.: due to a longer sewer length per user (HOPHMAYER-TOKICH, 2006).

JENSSEN & KARAKOYUN (2005) investigate the dependency between infrastructural costs (with special emphasis on water-based (semi-)centralized sanitation systems) and settlement structures. For characterizing the settlement structure they considered areal types and settlement types:

Tab. 6 Overview over Areal Types and Settlement Types characterized by JENSSEN & KARAKOYUN (2005)

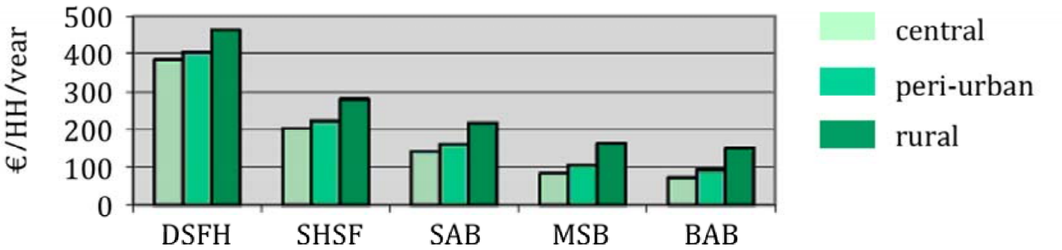
Areal Types	Settlement Types
	detached single-family house (DSFH)
central urban	serial house for single-families (SHSF)
peri-urban	small apartment building with low building density (SAB)
rural	mulit-storey building (MSB)
	big apartment building with high building density (BAB)

For determining these areal types both the local significance and the population density are considered. Moreover, a determination is also possible based on the summarization of areas with approximately the same building density.

With settlement types, typical prevailing building patterns (for residential houses only) should be represented. The investigation of JENSSEN & KARAKOYUN (2005) focuses on the situation in

Germany. Thus, these settlement characterizations are describing the conditions commonly found in this context.

According to their study, as illustrated in Fig. 28, the costs per household and year for a conventional centralized water based wastewater management depend on the settlement type but also on the areal type. Thus, conveyance via a Conventional gravity sewer to a centralized treatment plant is most expensive for single-family houses in rural areas. A significant reason for that, are the relatively high connection costs for the direct household-connection, as they fundamentally take an impact on the required sewer length. The denser the building structure, the smaller are the costs per household.



(with *DSFH* - detached single-family house; *SHSF* - serial house for single-families; *SAB* - small apartment building with low building density; *MSB* - mulit-storey building; *BAB* - big apartment building with high building density)

Fig. 28 Mean annual costs for wastewater disposal (per household and year) depending on areal type and settlement type (adapted from JENSSEN & KARAKOYUN, 2005)

Looking at the requirements for managing such a system, it becomes obvious that conveyance (as well as centralized treatment) are completely different organized than in the case of other systems, where the users have to take over most of the responsibility. As described before, conventional centralized wastewater management is resource intensive in terms of the initial installation of the infrastructure (sewer system and treatment plant) but also in respect to their operation and maintenance. Therefore, in many countries centralized wastewater management is undertaken under the responsibility of a municipality – or an inter-municipal joint-venture (UNESC 2004). Users are only responsible for installing and maintaining their house connection. Installation and maintenance of the main network is mostly within the responsibility of the according legal authority - which must be capable of taking over this responsibility. Users are participating in terms of costs by paying a connection fee and by paying regular usage fees.

Condominial sewers

Within the chapter about the “Functional Patterns”, two different variants of “alternative” conveyance options were presented. Within this section - for describing major functional requirements of this functional group - the focus is on “Condominial sewers”.

Similar as Conventional Gravity Sewers, Condominial Sewer are dependent on a reliable water supply. However, due to their different design, the required level of water supply is significantly lower. Instead of a multi-tap in-house supply, an on-plot level of water supply such as a yard-tap (usually located outside the houses) is sufficient (MARA, 1997).

A high ground water level or rocky soil conditions can significantly impede the construction, which is related to reasonable extra costs. These factors therefore are indicating favourable fields of application especially (in terms of costs). As the required excavation depth is shallower than in the case of Conventional Sewers, Condominial sewers can be comparably cheaper even under unfavourable conditions (TILLEY et al., 2008 & MARA, 1997).

Condominial sewers are often characterized as “low-cost” sewerage options. However, their construction still requires a reasonable amount of capital (TILLEY et al., 2008 and MELO, 2005).

They can be installed in almost all types of settlements. However, dense urban settlements are appear most appropriate (TILLEY et al., 2008). MELO (2005) who describes examples from Condominial Sewerage in urban areas in Brazil, emphasizes this argument as he states that Condominial sewerage “has proved feasible on a large scale in major urban areas (…) and demonstrated their versatility in the most challenging peri-urban environments, where Conventional systems are simply no option (p.55).”

It is of significance to consider the close relation of service providers and users, which is part of the Condominial sewerage concept. These factors can reasonably take an impact on the system’s overall functional requirements. Condominial sewerage need users, who are committed to participation in terms of construction but also operation and maintenance. Condominial sewerage services are rather managed on basis of a “neighbourhood”, than on behalf of a centralized management institution (as it is the case for Conventional Sewerage). Nevertheless, a reasonable institutional stability is required (VEST & BOSCH, 2002 and TILLEY et al., 2008).

Even though a convincing proportion of the needed work-load can be covered by self-helped initiatives from users, expert knowledge is especially required during the design and construction phase (TILLEY et al., 2008).

4.4.3 Treatment: Intensive and Extensive Wastewater Treatment Facilities

There is a huge variety of technological variants available, which all require specific contexts. Therefore, in the case of the treatment component, technologies were categorized into two groups: intensive and extensive treatment (see 3.5.3). This categorization follows a common classification and facilitates the identification of some over-all functional requirements. A detailed consideration of each technological variant and its specific context is not undertaken within this thesis.

Intensive Treatment

„ ...conventional systems, and especially the conventional collection system and the intensive treatment technologies, require high skilled labour, large amounts of capital, and steady socio-economic conditions... (HOPHMAYER-TOKICH, 2006 p.14).“

Due to that fact that intensive systems are designed to work in confined space, these technologies require smaller space area than “extensive” systems. This makes them especially (financially) attractive for dense urban areas where land value is high (HOPHMAYER-TOKICH, 2006 and XANTHOULIS et al., 2008). Intensive systems can reach very high treatment efficiencies, which makes them able to handle comparable large wastewater volumes. Especially in the context of wastewater management of dense urban environments, this aspect becomes relevant.

However, it is of crucial importance to realize that these systems’ feasibilities highly depend on several factors. On the one hand, there are reasonable requirements in terms of materials and infrastructure in general. Mostly, technological solutions associated with Intensive Treatment require specific components, which are mostly hardly locally available. This concerns the construction phase as well as operation and maintenance. Moreover, during all phases, skilled, specified labourers are needed - starting with the design to the actual operation of the facility. Significant as well is the need for a constant and reliable energy supply, mainly caused by the aeration units.

Material and energy requirements as well as needed labourers characterize this approach as very cost intensive - both in terms of capital but also in terms of running costs (TILLEY et al., 2008). According to a publication of UNESC from 2005, wastewater treatment of sewer-based systems is a great challenge for developing countries due to the high costs and the technical skills required for design, operation and maintenance.

As intensive systems achieve substantial economies of scale, they are especially appropriate for high-density areas (HOPHMAYER-TOKICH, 2006). There are also small-scaled designs of intensive systems, however, especially in the context of Developing Countries, small-scale “intensive” systems are not considered as relevant option, due to their financial burdens.

As intensive treatment is mostly applied for a big neighbourhood or whole city, it is not appropriate for a user based “self-helped” organization and management. Rather, a public authority takes over the responsibility of safely handling the wastewater. Thus, users must be able to pay the service fees (TILLEY et al., 2008).

Extensive Treatment

In general, extensive systems, such as constructed wetlands and lagoons (or wastewater stabilization ponds), are applied where it is not economically feasible or even technically impossible to connect sewers to a large(r) centralized treatment plant. Of special relevance in this relation is the availability of space area.

Compared to intensive systems, extensive treatment requires substantially greater land area. Therefore, such systems are only an option for areas, where land is available and land prices are sufficiently low (HOPHMAYER-TOKICH, 2006 and VEST & BOSCH, 2002). Besides, in general treatment takes much more time – which characterizes these systems as suitable for low wastewater volumes (UNESC, 2004). Significant in terms of their feasibility, can also be climate. High evaporation due to hot and dry climates, can take a reasonable impact on the facilities efficiency. According to the UN ECONOMIC AND SOCIAL COUNCIL (2004) low-technology and low-cost waste-water treatment systems are most cost-effective in warm, humid climates.

As most extensive systems are cheaper in construction, operation and maintenance, they are also affordable for poorer communities (HOPHMAYER-TOKICH, 2006). However, according to VEST & BOSCH (2002), cost revenue can be high. TILLEY et al. (2008) on the other hand are classifying several “extensive” variants as low-cost options - both in terms of the construction and the operation & maintenance. As mostly neither special materials nor energy supply are required, this opinion appears plausible.

Depending on the particular system used, access with vehicles may be necessary for regular maintenance works such as the removal of the sludge (VEST & BOSCH, 2002).

Even if there are no or only a few technical components involved and operation and maintenance efforts needed are lower, the operating staff has to monitor operational parameters carefully and disciplined, which requires a certain and specialized level of education. According to VEST & BOSCH (2002), however, stable community organisations can possibly carry out operation and maintenance - provided that they are willing to acquire necessary skills. Nevertheless, construction and design need experts - which are highly educated and skilled. In general, however, the authors suggest an operation through official municipal or private operators. This opinion is shared by TILLEY et al. (2008) who note in the context of some extensive treatment approaches that management can also not only undertaken by a public authority as also by a cooperative of households. Thus, it is assumed that in general a high institution organization is required.

4.4.4 Disposal: Discharge of Effluent and Disposal of (treated) Sludge

When considering requirements linked to disposal/re-use of materials evolving from (semi-)centralized treatment, it appears useful to distinguish between the two streams – treated sludge and treated effluent.

(treated) effluent

Provided that its treatment has been efficient enough (which is mainly determined by legal requirements), the treated effluent can be discharged to a receiving water-body. Therefore, a major requirement is that the treatment facility is sited close to a water body capable of receiving the effluent.

Discharge of effluent in receiving waters has to be supervised accordingly with regular monitoring and sampling. In order to ensure that effluent quality and quantity is adapted to local conditions, therefore skilled personal is needed (TILLEY et al., 2008).

(treated) sludge

For both surface disposal and land application, an obvious requirement is the supply of land area the treated sludge can be applied on or disposed of. In both cases, the application should be undertaken with care, as - depending on the sludge quality and form of application/disposal - the sludge can pose a health risk.

Landfills are facilities, which have to be specifically built, operated and maintained. Therefore, skilled personal is required. Depending on the design, special material might be required as well (TILLEY et al., 2008). However, as a detailed consideration of requirements related to landfills would lie beyond the scope of this work, these aspects are broken down to the requirement that a facility such as a (well-working and safely operated and built) landfill has to be available and within an acceptable distance.

Sludge incineration on the other side, is not as space demanding as the other two variants, however there are considerable requirements concerning material and energy supply. Besides, skilled personal during construction but also operation of a facility are needed. It is therefore not characterized as low-cost variant.

4.4.5 Re-Use: Sludge Application on Land

When using sludge in agriculture, a basic requirement represents the social and cultural acceptance regarding the community. Besides, depending on the particular application approach applied, special spreading material may be required, whose local availability can be limited.

5. Context Dependencies

Subsequently, existent tendencies of the presented technologies in terms of their dependency from specific domains within and around a community will be examined. Thus, previously identified requirements are used for forming “context fields”, which should illustrate those domains of a community that are relevant in terms of an application of a sanitation system. In a further step, those requirements should be determined, which appear distinctive regarding conditions prevailing in developing countries - so-called “limitations”.

Once, the most concise limitations are worked out, a systematic appraisal (described more in detail in chapter 2) facilitates an investigation of existent differences in terms of “dependencies” of specific components or even whole systems from the determined limitation factors. Being aware of the “limiting” factors as also the grade of the dependency from these factors, should allow evaluating the appropriateness or even adaptability of a system in terms of potentially prevalent “local contexts”.

5.1 Context Fields

In the previous section, „functional criteria“ were identified which are relevant for the general feasibility of the discussed system components. As noted before, neither the mentioned requirements nor the now formed context fields should be seen as complete depiction of relevant factors in terms of an actual application of particular system in a specific project context.

However, the discussed factors should give an idea of

- what major aspects are potentially distinctive for a systems’ feasibility,
- what are significant differences between the systems in terms of their requirements concerning their application environment

By forming groups of linked aspects, these criteria should now build the basis for characterizing „Context Fields“. With these context fields it should be made clearer, which **domains** within or around a community can be relevant for the establishment of a system and therefore the characterization of its application field.

Not all systems depend on each factor and corresponding context field – which will be considered more in detail in chapter 5.

(1) Natural Environment

This context field incorporates different aspects associated with the natural environment. The “soil structure” can be cited as prominent factor in two respects: on the one hand, some components require soil suitable for digging and on the other hand, permeability and infiltration capacity are potentially relevant properties.

Besides, another repeatedly mentioned factor is the “groundwater level”, which can be decisive for systems involving an infiltration of contaminated streams. Thus, a high groundwater level can be a veto-criteria for those systems that are on a pit latrine based or septic tank based (combined with a soak pit for the effluent).

When considering the aspect of “topography” (e.g. inclination profile) and its relevance in terms of being a distinctive factor, it is significant to distinguish between small-scaled on-site system and big-scaled systems. Whereas small-scaled technologies can easier be adapted to topographical features by an adapted design, big-scaled technologies such as a centralized sewer system is much more affected by the topographical profile of a community.

Moreover, climatic conditions (e.g.: rainfall patterns), are not seen as directly applying “requirement”. Obviously, during actual project planning or implementation, local rainfall patterns are fundamental for the systems' designs and dimensionings. However, focusing on factors decisive whether a component can be established at all, climatic conditions are taken into account indirectly by the aspect "availability of receiving waters". However, other climate-related aspects such as temperature or humidity take an impact on several components, they do not appear as "distinctive" requirements.

(2) Settlement

Another context field is the settlement pattern, where the "density" can be taken as main indicator. The settlement density or also the population density can be of relevance for several reasons. On the one hand, in respect to required accessibility to the facilities. On the other hand, in terms of the space demands per unit, which can vary significantly. Moreover, necessary minimum distances to other settlement structures (e.g. drinking water well) are related to settlement density. Besides, the population density is obviously related to the aspect of capacity – the denser the population, the more capacity must have an applied system and vice versa.

(3) Infrastructure

A key-aspect that can be assigned to this context field, is the available water supply structure. Obviously, water supply and wastewater management are directly inter-connected, as they are conditioning each other. A prominent example is the relation of a sewer-based conveyance system and a sophisticated water supply. Considering the sewer system, a minimum flow is required – which is provided by the household's wastewater production. The wastewater production is depending on the water supply – the better the water supply, the more wastewater is generated. On the other hand, other systems are explicitly suitable for water-scarce areas with a simple water supply and rather little wastewater generation per household.

Moreover, associated with infrastructure, are arising necessities for energy or transport structures (including roads as well as vehicles or fuel). Whereas some components are relatively independent from other structures, others are dependent on the availability of i.e. a constant energy supply.

Another aspect of significance, are the required materials for both construction and operation & maintenance. The more specific the materials or components needed, the more difficult is the local availability and the more dependent is the system on the provision of an according supply.

(4) Community-specifics

This context field is encompassing a broad range of aspects dealing with the socio-economic conditions that should be provided by a community in order to ensure a system's feasibility.

The probably most obvious aspect is the availability of financial means. This not only refers to the solvency of a legal authority, but also to the ability of users to pay fees in a regular manner. Depending on the system, different stakeholders have to pay for construction but also operation and maintenance, whereas the particular costs can vary enormously. Therefore, the system has to be appropriate for the communities' abilities to cover arising financial costs. Here, a "community" implies a responsible legal authority as well as individual households.

Another issue of relevance is the differing management and institutional structure needed for installing but also running the systems. Whereas it is feasible to manage purely on-site systems (e.g Re-Use based on Urine Diversion) on a very simple institutional level - with mainly entrusting the users with responsibilities associated to construction but also operation and maintenance - a conventional water-based system requires a highly sophisticated institutional framework. Thus, users are indeed liable for paying the connection of the household to the municipal network and regularly arising fees, however, the main responsibility lies with the legal authority and the particular entity operating the conveyance and treatment facilities. Consequently, needed efforts and commitments from the users are varying significantly.

However, considering the cases, where the users have to be committed to run the system, an appropriate education or information of the users is a basic pre-requisite. Without understanding the basic function of a particular system, responsible “operators” won’t be able to run the system successfully. Thus, the lower the requirements for an institutional framework and legal bodies responsible for the operation of a system, the more system-specific education of the users is needed.

5.2 Limitations associated to the Context Fields

In the following, on basis of previously identified functional requirements and context fields, “limitations” should be worked out. It is assumed that (very) wealthy communities can rather defy functional requirements, since they can accept additional costs caused by an installation and operation of a system in an “inappropriate” environment. But especially in the case of poorer communities, where financial means are limited and economic efficiency should be of high priority, functional conditions are considered as critical – as the economic efficiency is strongly dependent on an installation under appropriate conditions - and therefore are identified as limitations. Limitations are characterized as factors which appear as percussive in terms of a sanitation system’s feasibility regarding developing countries.

Whereas limitations identified for the two Context Fields “Natural Environment” and “Settlement Structure” are rather covering factors relevant for describing the “technical feasibility” of an option, the decision about limitations associated with “Infrastructure” and especially “Community-specifics” is strongly influenced by the focus on Developing Countries.

(1) Natural Environment

- Soil structure:

  As described before, soil conditions can play a significant role in terms of a soil’s suitability for digging but also in terms of its permeability or infiltration capacity.

- Ground Water Level:

  Due to contaminated infiltration streams evolving from some components, their installation in areas with high ground water levels is highly problematic. Therefore, this factor can be deciding whether a component should be installed or not.

- Topographical Profile:

  Ground inclination – which is mainly conditioned through the topographical profile of an area – can play a very relevant role. (As explained in previous sections, this factor can be especially seen as distinctive for sewer-based systems.)

- Availability of receiving Waters

(2) Settlement Density and Structure

- Accessibility with vehicles:

  With this factor it is referred to the requirement of accessing some components with a vehicle in order to maintain and operate it – which can be especially problematic in very densely built settlements. Accessibility for manual operation and maintenance is not seen as distinctive, as it is assumed that this is not as sensible to building density as access with motorized means.

- Distance to other settlement structures:

  This aspect mainly concerns water supply structures and is mostly of relevance in the case there are infiltrating streams expected. Besides water supply, also other settlement structures can be adversely affected by a closely installed sanitation facility – e.g. due to the problem of vector breeding or strong smells.

- Load/capacity:

  This aspect should refer to required minimum or maximum loads (per unit) – which are linked to the population density. Whereas some system units are only designable for small numbers of users – and therefore would need numerous facilities in a densely populated area, other components tend to be insufficiently loaded in a less densely populated environment.

- Available space area:

  Another aspect related to the settlement structure but also settlement density, is the available space area. This factor can be crucial – as some components require significantly more space area as others and their feasibility is therefore very dependent on the availability of space area for their installation.

(3) Infrastructure

- Special Material:

  In the case construction, but also operation and maintenance can't be sufficiently undertaken with (easily) locally available materials, "special" materials and tools are required. Especially in the context of Developing Countries, options for provision of materials and goods can be quite limited and therefore this factor is categorized as distinctive.

- Constant Water Supply:

  Similar as the previous factor, the dependency from a constant, sophisticated water supply infrastructure can very critical regarding infrastructural conditions found in many communities of Developing Countries. It is similar with the next two aspects, which can be significant in terms of the ability of a community to provide sufficiently for a sanitation system.

- Constant Energy Supply
- Transport Structures (roads, vehicles, fuel)

(4) Community-Specifics

- Skilled Labour:

  With this factor, it should be referred to the requirement for highly trained and educated personal. This does not include workers, which are skilled on a low level (simple, executive activities), as it is assumed that this should not be a distinctive criteria.

- User Commitment / Education:

  As explained in previous sections, operation and maintenance of some components is significantly depending on their users. Therefore, these components do require users willing and able to assiduously taking over these responsibilities. As this is a question of eduction and information, this aspect is seen as determining.

- High grade of institutional organisation:

  Whereas some systems can be installed and run on a neighbourhood level or even on family level, others do require a complex framework of stakeholders – which are fulfilling different functions and do take over diverse responsibilities. Focussing on Developing countries, thus the requirement for a "high" level of institutional organisation is characterized as critical.

  It is important to note, that a high level of institutional organisation not only refers to a "physically" existing structure, but much more to an actually working organisation ("governance"). Insufficient governance is a frequently identified problem in the context of advancements in water and sanitation in developing countries. Unclear responsibilities and missing coordination between involved stakeholders - both horizontally and vertically - are often reason for inefficient channelling of resources as well as ill-planned and consequently badly implemented strategies and reforms (UNDP, n.a). Only, if both the physical structures and according working efficiencies and qualities are provided, a "high level of institutional organisation" is given.

- High capacity to pay:

This aspect should refer to expected cost revenues - and corresponding requirements in terms of the communities' (implying both users and legal authorities) ability to cover these costs – their "capacity to pay". Whereas some components do normally rather have low capital costs and low operational costs, other components are very expensive in construction and/or operation and maintenance. Especially operation and maintenance cost structure can be significant as this refers to regularly arising costs. Depending on the organisational structure of the sanitation sector either the legal authority and/or the users have to cover these costs. However, within this work it is not distinguished between them. Regarding the context of Developing Countries, the requirement for a "high" capacity to pay is seen as critical factor.

6. Evaluation of Context Dependencies

“Context fields” and “limitations” identified in the previous chapters are now used for formulating criteria (variables), that are building the basis for evaluating the grade of dependencies of the technologies/systems from the identified context fields. By considering how many factors are actually determinant for a technology/system, its “context dependency” should be characterized.

Subsequently, the context dependencies of both particular technologies and whole systems (considering the arising area) will be evaluated. That way, existent differences of the dependencies in the course of the sanitation process are clarified as well as varying dependency characteristics of the presented systems.

6.1 Component-specific Context dependencies

Within this section, context dependencies of each component will be presented - illustrated in radar charts involving areas in up to five colours (depending on which components are involved in the process). It is important to note that due to visual overlays, some component’s areas are not visible - as their area is smaller than that of another component in the process. However, additionally to the each radar charts, a summary of the actual evaluation values is provided. A more detailed explanation of the charts and tables can be found in 2.3.

6.1.1 Context Dependencies of Pit-latrine based systems

As there are several variants of component combinations involving pit latrines, their dependencies in terms of the context fields will be illustrated and discussed separately.

In Fig. 29, the result of the component-specific context dependency evaluation of a pit-latrine based variant involving a Single Pit is illustrated.

Variant I: Water-less Toilet → Single PIT / VIP → Motorized E & T → Faecal Sludge TM → Landfill Disp.

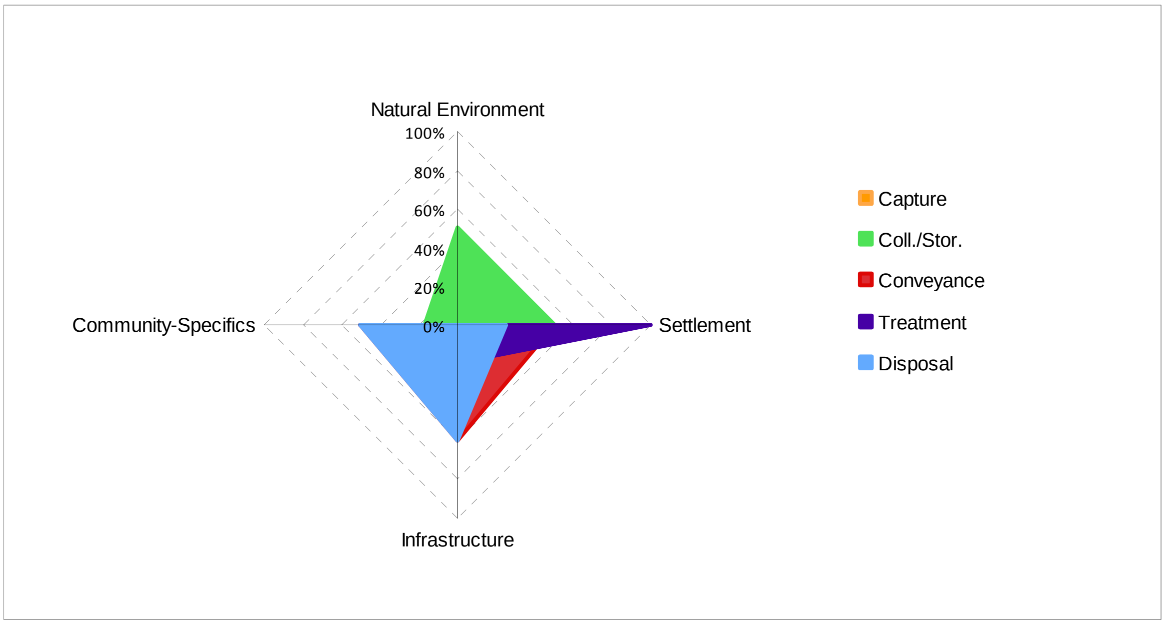


Fig. 29 Component-specific Context Dependencies of Variant I of a Pit-latrine based Sanitation System

Tab. 7 Evaluation Values of Component-specific Context Dependencies of Variant I of a Pit-latrine based Sanitation System

	Natural Environment	Settlement	Infrastructure	Community-Specifics	Sum Ind. Proportion Values (abs.)
Capture	0%	0%	0%	0%	0,00
Coll./Stor.	50%	50%	0%	17%	1,17
Conveyance	0%	50%	60%	50%	1,60
Treatment	0%	100%	20%	50%	1,70
Disposal	0%	25%	60%	50%	1,35

In terms of actual functional limitations, the User Interface appears widely independent from the defined context fields.

That is different for the Collection and Storage component, which exhibits a reasonable dependency from “Natural Environment” (50% of the criteria applied) and “Settlement Structure” (50% of the criteria applied). This is on the one hand based on the requirements concerning the soil structure/permeability but also due to its sensibility concerning high ground water levels. And on the other hand, in terms of the settlement, pit latrines require a minimum distance to water supply structures – which can be problematic in very dense built environments. Their capacity per facility moreover limits their application to less densely populated areas. Another aspect is the characteristic level of managing pit latrines – relying on self-organized neighbourhoods or single households. Thus, user commitment is a basic requirement.

The Conveyance – emptying and transport with motorized means – obviously depends on the “Settlement Structure” (50% of the criteria applied) due to the facilities’ need for the accessibility with vehicles as well as the limited capacities of motorized transport. Moreover, there is a considerable dependency from “Infrastructure” (60% of the criteria applied) - as infrastructural means such as vacuum trucks or other specific vehicles as also general transport infrastructure are required. Motorized Emptying moreover depends on Community-specifics (50% of the criteria applied), as there has to be an according organization and management of the transport – which also includes its costly establishment. Thus, either a public authority must take over the responsibility for emptying or at least a well organized neighbourhood. Therefore, users must be able to regularly pay for the service.

The treatment in a Faecal Sludge Treatment Facility is highly depending on the “Settlement structure” (100% of the criteria applied). Space demands are high and moreover, the facility has to be in a certain distance from the community and should be accessible with vehicles. Besides, these facilities do have a maximum design dimension limiting them for an application low to medium sludge volumes. Furthermore, in terms of the “Community-specifics”, a dependency of 50% is observable due to the requirements in relation to the worker’s skills as also the needed grade of institutional organization.

When looking at the Disposal (Landfill), dependencies are mainly observable in terms of “Community-specifics” (50% of the criteria applied) and “Infrastructure” (60% of the criteria applied). Regarding “Community-specifics”, limiting requirements such as sophisticated skills necessary for building but also operating a landfill condition such a high evaluation value. Besides, the organizational structure has to be capable of running the facility safely. Special materials needed for construction but also operation and maintenance are not easy locally available, causing a high dependency in terms of infrastructural resources (including transport).

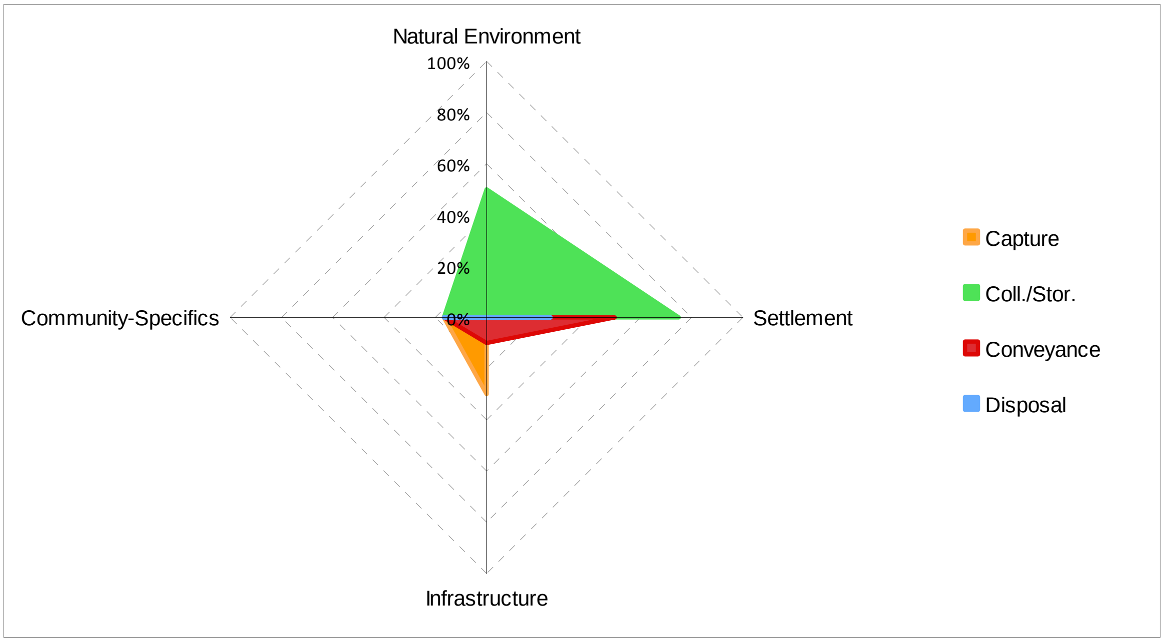


Fig. 30 Component-specific Context Dependencies of Variant II of a Pit-latrine based Sanitation System

Tab. 8 Evaluation Values of Component-specific Context Dependencies of Variant II of a Pit-latrine based Sanitation System

	Natural Environment	Settlement	Infrastructure	Community-Specifics	Sum Ind. Proportion Values (abs.)
Capture	0%	0%	30%	17%	0,47
Coll./Stor.	50%	75%	0%	17%	1,42
Conveyance	0%	50%	10%	17%	0,77
Treatment	0%	0%	0%	0%	0,00
Disposal	0%	25%	0%	17%	0,42

Considering the Capture and its limitations, there is on the one hand some dependency on "Infrastructure" (30% of the criteria applied), based on the need for a constant supply of flushing water as well as the difficult local availability for purchasing the toilet. However, the required level of supply is comparable low, as rainwater or greywater can be used for flushing. On the other hand, running a Pour Flush Toilet coupled with Twin pits, requires user commitment – as users must be informed about the appropriateness of diverse input products.

Especially relevant concerning the Collection & Storage unit are limitations associated with the context fields "Natural Environment" (50% of the criteria applied) and "Settlement" (75% of the criteria applied). Requirements concerning soil characteristics and restrictions in terms of the groundwater level determine a dependency from "Natural Environment". Linked to the "Settlement structure" are requirements such as: a minimum distance to other settlement structures is required due to the risk of infiltrations taking a negative impact on sensible water supply structures. Besides, they are limited in terms of load per facility as well as they have a higher space demand per unit as other structures. Each facility requires two vaults in an acceptable distance to each other. Thus, an application in densely populated areas appears very problematic. In terms of "Community-specifics", a relatively high level of user commitment is required, as users must understand the system's function and have to take over appropriate operation and maintenance. Otherwise, disturbing material input as well as too short resting times could inhibit the sanitation process.

When looking at the Conveyance step, which is carried out manually or with simple mechanical means, it is relevant to consider the limited capacity of this conveyance type. Depending on the particular tools used for emptying, special material might be required. As in the case of the previous components, also a considerable level of user commitment is required. This is due to the fact, that organization of or even emptying and transport itself is (often) undertaken by the users.

In relation to Disposal, which actually refers to an application on land in this case, there can be observed a dependency in terms of the "Settlement Structure" (25% of the criteria applied), since using degraded sludge as soil conditioner requires sufficient space area. As users not only take over the responsibility for operation and maintenance of the previous steps in the sanitation process, but also organize the disposal self-helped, needed user commitments are considerable.

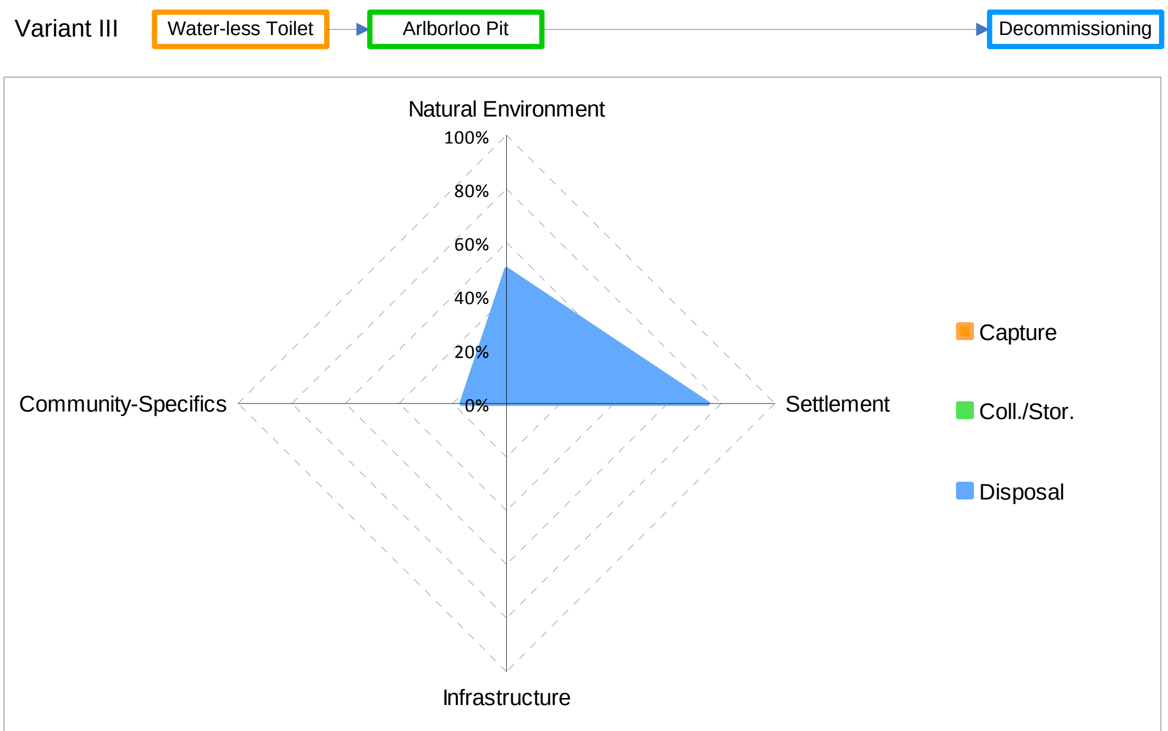


Fig. 31 Component-specific Context Dependencies of Variant III of a Pit-latrine based Sanitation System

Tab. 9 Evaluation Values of Component-specific Context Dependencies of Variant III of a Pit-latrine based Sanitation System

	Natural Environment	Settlement	Infrastructure	Community-Specifics	Sum Ind. Proportion Values (abs.)
Capture	0%	0%	0%	17%	0,17
Coll./Stor.	50%	75%	0%	17%	1,42
Conveyance	0%	0%	0%	0%	0,00
Treatment	0%	0%	0%	0%	0,00
Disposal	50%	75%	0%	17%	1,42

Due to the need of accurately using the user interface in order to support subsequent steps in the sanitation process, a certain level of user commitment is necessary.

Both, Collection & Storage and Disposal are mainly depending from "Natural Environment" (50% of the criteria applied) and "Settlement" (75% of the criteria applied) - due to their specific requirements concerning the soil structure, the soil absorption capacity and the ground water level, but also due to the extraordinary space demands.

Due to the simplicity of this system components in terms of materials and skills needed for installing but also maintaining it, dependencies in relation to the other context fields are comparable small.

6.1.2 Context Dependencies of Systems focussing on Re-use

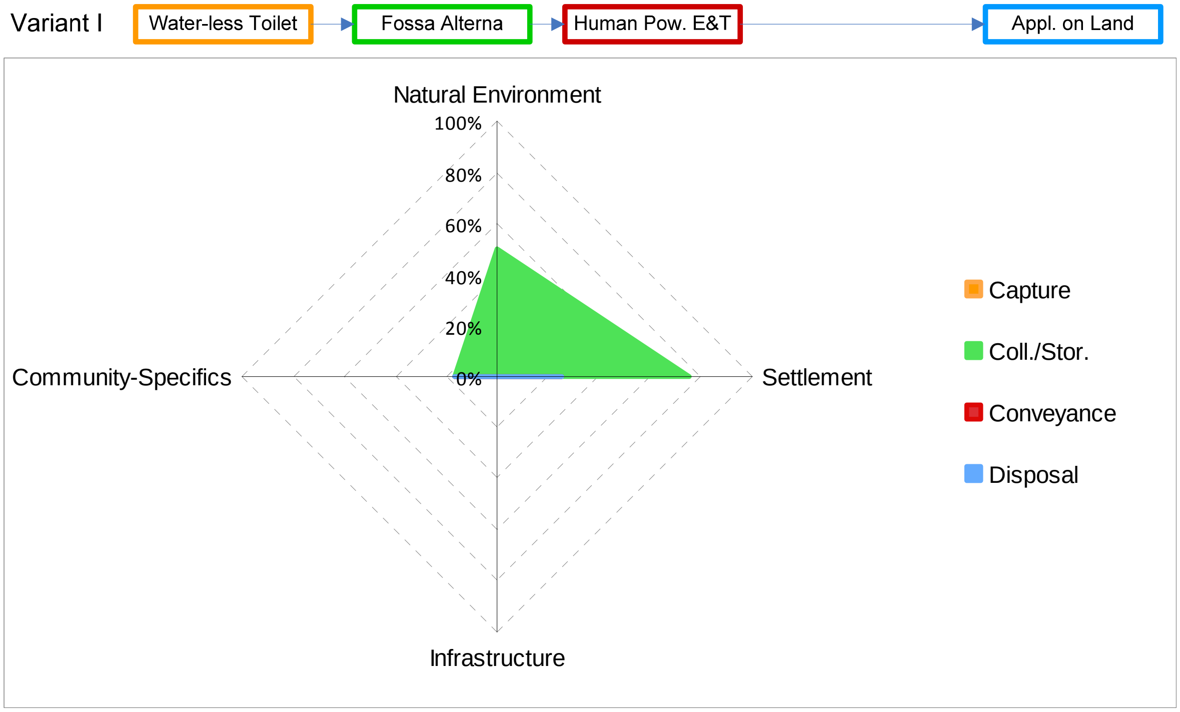


Fig. 32 Component-specific Context Dependencies of Variant I of a Sanitation System focussing on Re-use

Tab. 10 Evaluation Values Component-specific Context Dependencies of Variant I of a Sanitation System focussing on Re-use

	Natural Environment	Settlement	Infrastructure	Community-Specifics	Sum Ind. Proportion Values (abs.)
Capture	0%	0%	0%	17%	0,17
Coll./Stor.	50%	75%	0%	17%	1,42
Conveyance	0%	25%	0%	17%	0,42
Treatment	0%	0%	0%	0%	0,00
Disposal	0%	25%	0%	17%	0,42

In terms of the Capture, there is a need for users being committed to running the system properly. They have to be informed about appropriate input materials and should be willing to consider this aspect.

When considering this system, the most obvious dependency from the context fields, however, exhibits the Collection & Storage unit. Similar as other pit-latrine based systems, the unit depends on both the “Natural Environment” (due to the soil characteristics and the ground water level) (50% of the criteria applied) and “Settlement structure” (75% of the criteria applied). As storage periods have to be monitored, the users have to take over this responsibility.

The material can be emptied and transported manually – provided that the users are educated to undertake this work. Besides, the conveyance depends on “Settlement Structure” (25% of the criteria applied), as manual transports are limited in their capacities.

Successful Disposal/Re-use depends on available space area as also on sufficient user commitment. This starts with correct inputs to the system and ends with the cultural acceptance of the users for applying the output product on land (in an according manner).

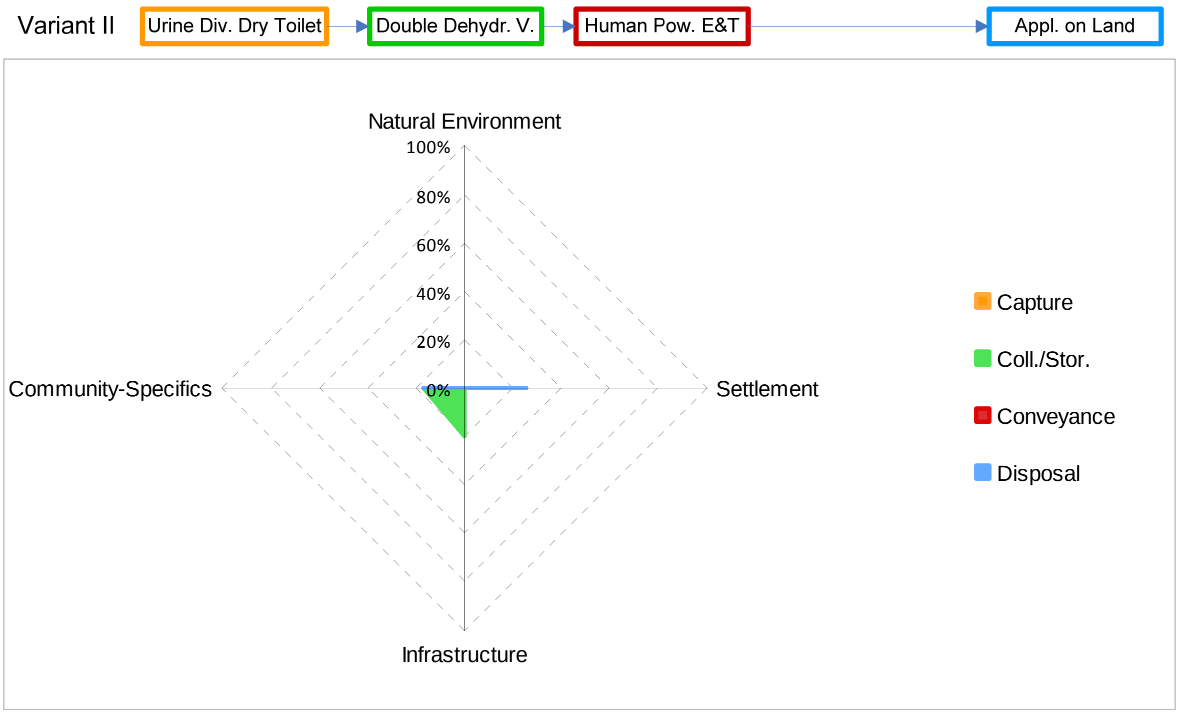


Fig. 33 Component-specific Context Dependencies of Variant II of a Sanitation System focussing on Re-use

Tab. 11 Evaluation Values of Component-specific Context Dependencies of Variant II of a Sanitation System focussing on Re-use

	Natural Environment	Settlement	Infrastructure	Community-Specifics	Sum Ind. Proportion Values (abs.)
Capture	0%	0%	0%	17%	0,17
Coll./Stor.	0%	0%	20%	17%	0,37
Conveyance	0%	25%	0%	17%	0,42
Treatment	0%	0%	0%	0%	0,00
Disposal	0%	25%	0%	17%	0,42

Looking at the capture's functionality, user commitment conditions a slight dependency in terms of “Community-specifics”.

Depending on design of the Collection and Storage Unit there is some dependency observable in terms of infrastructural requirements (20% of the criteria applied) (supply of material which is hardly locally available). Besides, user commitment must be provided – similar as in the case of the previously described system. As users are mostly responsible for running the storage units, they have to be educated accordingly.

Looking at the step of manually removing the material out of the vaults, it has to be assured that the users are educated and willed to undertake this work (causing 17% of the criteria applied for “Community-specifics”) Besides, the conveyance depends on “Settlement density” (25% of the criteria applied), as manual transports are limited in their capacities.

Similar as in the case of the previously described system, successful Disposal/Re-use depends on available space area as also on sufficient user commitment (25% criteria applied in terms of “Settlement”, 17% in terms of “Community-specifics”). This starts with correct inputs to the system and ends with the cultural acceptance of the users for applying the output product on land (in an according manner).

6.1.3 Context Dependencies of Septic Tank based system

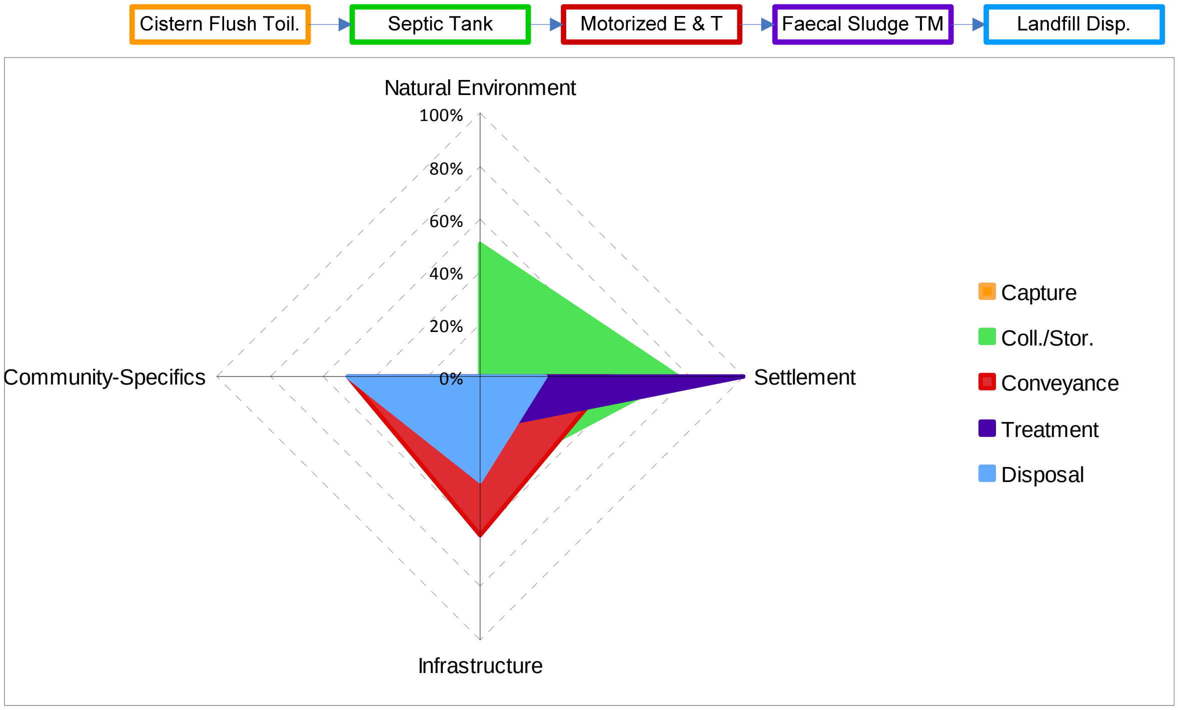


Fig. 34 Component-specific Dependencies of a Septic Tank based System with Infiltration

Tab. 12 Evaluation Values -specific Dependencies of a Septic Tank based System with Infiltration

	Natural Environment	Settlement	Infrastructure	Community-Specifics	Sum Ind. Proportion Values (abs.)
Capture	0%	0%	60%	33%	0,93
Coll./Stor.	50%	75%	40%	0%	1,65
Conveyance	0%	50%	60%	50%	1,60
Treatment	0%	100%	20%	50%	1,70
Disposal	0%	25%	40%	50%	1,15

Due to the requirements for a constant water supply as well as special materials for the Capture (Cistern Flush Toilet) (both in terms of installation and O&M), there is an obvious dependency, of the capture from the context field „Infrastructure" (60% of the criteria applied). As the toilet has to be purchased and huge amounts of water are used, also a relatively high capacity to pay for its "installation" as well as for its operation has to be assured (33% of the criteria in terms of "Community-specifics" applied).

Very significant are furthermore the requirements of the Collection & Storage unit concerning its "Natural Environment" (50% of the criteria applied) – due to the from the infiltration caused dependencies from groundwater level and soil structure. Besides, this component strongly depends on the "Settlement Structure" (75% of the criteria applied) (Space demand, max. load/capacity of the soil, distance to water supply structures). Moreover, as the capture, a constant water supply is needed for maintaining a sufficient through-flow. Materials for constructing the tank might not be easiliy locally available. Construction needs a certain level of skilled labourers and therefore causes moderate to high costs.

As sludge accumulating in the Collection and Ctorage facility has to be regularly emtied, motorized emptying and transportation is necessary, determining a dependency of the Conveyance facility from "Settlement" (50% of the criteria applied). Motorized conveyance is furthermore limited in its capacities. In general, a public authority manages sludge emptying and transport services. As specific vehicles as well as transport structures are required, as well establishment of this conveyance as also its operation and maintenance can be quite costly ("Community-specifics": 50% of the criteria applied).

The treatment in a Faecal Sludge Treatment Facility is highly depending on the "Settlement structure" (100% of the criteria applied) – as space demands are high as well as the facility has to be in a certain distance from the community and should be accessible with vehicles. Besides, these facilities do have a maximum design dimension limiting them for an application low to medium sludge volumes. Furthermore, in terms of "Community-specifics" (50% of the criteria applied), a dependency is observable due to the requirements in terms of skilled labourers as well as the needed grade of institutional organization.

When looking at the Disposal (Landfill), dependencies are mainly observable in terms of "Community-specifics"(50% of the criteria applied) and "Infrastructure" (40% of the criteria applied). Special materials needed for construction but also operation and maintenance are not easy locally available. Besides, transport structures must be provided. Regarding "Community-specifics", aspects such as sophisticated skills necessary for building but also operating a landfill are relevant. Besides, the organizational structure has to be capable of running the facility safely.

6.1.4 Context Dependencies of (Semi-/)Centralized Water-based system

Variant I: Cistern Flush Toil. → Conv. Gravity Sewer → Int. WWTP → Landfill Disp.

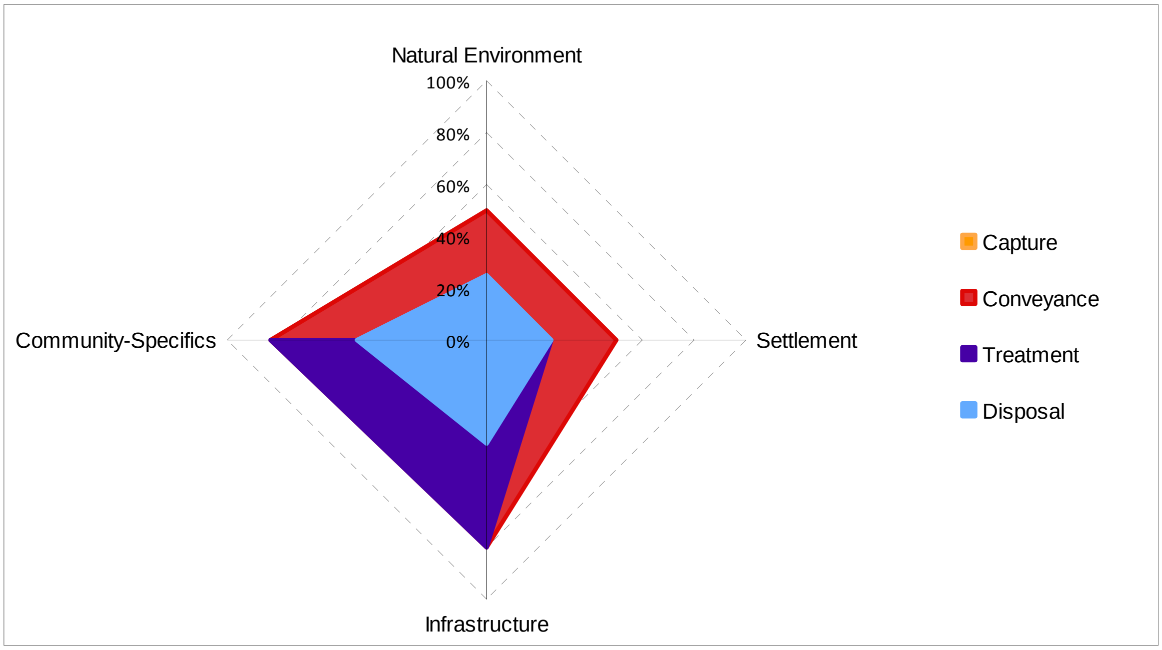


Fig. 35 Component-specific Dependencies of Variant I of a (Semi-)Centralized Water-Based System

Tab. 13 Evaluation Values Component-specific Dependencies of Variant I of a (Semi-)Centralized Water-Based System

	Natural Environment	Settlement	Infrastructure	Community-Specifics	Sum Ind. Proportion Values (abs.)
Capture	0%	0%	60%	33%	0,93
Coll./Stor.	0%	0%	0%	0%	0,00
Conveyance	50%	50%	80%	83%	2,63
Treatment	0%	25%	80%	83%	1,88
Disposal	25%	25%	40%	50%	1,40

Beginning with the Capture, there is a reasonable dependency of the system from "Infrastructure" (60% of the criteria applied) conditioned by the need for a constant and sophisticated water supply. This requirement is characteristic for all components (excluding the disposal). The industrially produced toilet is categorized as special material, as its local availability might be limited. This also concerns materials needed for operation and maintenance. Compared to other capture variants, Cistern Flush Toilets are expensive to purchase. Due to their water consumption, operation tends to be expensive as well (→ "Community-specifics": 33% of the criteria applied).

Looking at the component used for Conveyance, a dependency from "Natural Environment" (50% of the criteria applied) is considerable, as both soil conditions are especially relevant during construction and topographical profile in terms of the operation. Besides, also in terms of the "Settlement Density" (50% of the criteria applied) some aspects have to be considered as vital for this component. Minimum loads are required (a constant flow through must be maintained), which is also depending on the distances between the connected households. But also in terms of "Infrastructure" (80% of the criteria applied) dependencies of Conventional Gravity Sewer are considerable. Thus, special materials for construction and operation & maintenance are as well required as a reliable supply of water and energy supply (in the case pumping stations are used). Moreover, "Community-specifics" (83% of the criteria applied) are noticeable determining whether Gravity Sewer can be installed and operated successfully. On the one hand, due to the needs for skilled labourers (for design, construction, operation & maintenance) and on the other hand due to the requirements concerning institutional organization as well as due to the high costs for construction and operation.

When looking at the treatment phase – in this case “Intensive Treatment” – “Settlement Structure” is (50% of the criteria applied) relevant in terms of minimum loads of these facilities in order to use their economies of scale. More significant, however, are the dependencies in terms of “Infrastructure” (80% of the criteria applied) and “Community-specifics” (83% of the criteria applied). Thus, high requirements concerning the materials for construction and O&M as also the needed water and energy supply are causing a dependency. Moreover, workers involved in the design, construction but also operation and maintenance of the treatment facility have to be highly skilled. Besides. a sophisticated institutional background as also a high solvency (either on behalf of the local authority or on behalf of the users) must be ensured.

Looking at the Disposal – surface discharge of the effluent and disposal of treated sludge at a Landfill – “Settlement Structure” and “Natural Environment” (25% of the criteria applied) have to be considered as relevant as well as “Infrastructure” (40% of the criteria applied). Due to the need for an water body capable of receiving the effluent, moreover, a dependency from “Natural Environment” is observable. But especially “Community-specifics” (50% of the criteria applied) appear to be of crucial importance in terms of the components function.

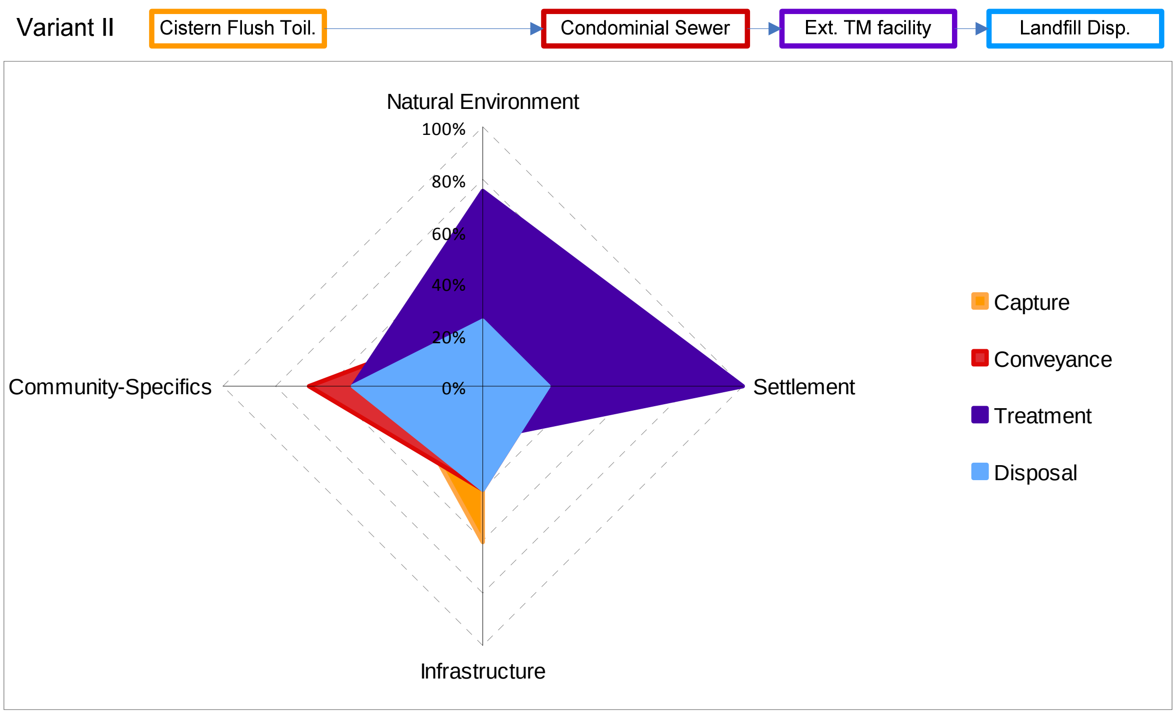


Fig. 36 Component-Dependencies of Variant II of a (Semi-)Centralized Water-Based System

Tab. 14 Evaluation Values of Component-Dependencies of Variant II of a (Semi-)Centralized Water-Based System

	Natural Environment	Settlement	Infrastructure	Community-Specifics	Sum Ind. Proportion Values (abs.)
Capture	0%	0%	60%	33%	0,93
Coll./Stor.	0%	0%	0%	0%	0,00
Conveyance	25%	25%	40%	67%	1,57
Treatment	75%	100%	20%	50%	2,45
Disposal	25%	25%	40%	50%	1,40

Due to the requirements for a constant water supply as well as special materials for the Capture (Cistern Flush Toilet) (both in terms of installation and O&M), there is an obvious dependency, of the Capture from the context field „Infrastructure“ (60% of the criteria applied). As the toilet has to be purchased and huge amounts of water are used, also a relatively high capacity to pay for its installation as well as for its operation has to be assured - which is associated with “Community-specifics (33% of the criteria applied).

Looking at the Conveyance in Simplified Sewers, “Natural Environment” (25% of the criteria applied) can be of relevance due to the need for a constant inclination (“Topographical Profile”). The sewer’s simplified design (shorter lengths, shallower depths) makes this option less vulnerable to inappropriate soil or ground water table conditions. Even if flow-through requirements are not as high as in the case of a Conventional Sewer, still a minimum load should be maintained. Special material needs for construction as well as the fact that water is used as transport media, causes a noticeable dependency in terms of “Infrastructure” (40% of the criteria applied). Even more significant is the Conveyance’s dependency from “Community-specifics” (67% of the criteria applied) as skills labourers for design and construction are needed. Besides, both user commitment and a stable institutional organization are required (even if not as complex as in the case of Conventional Sewer). As mainly construction is costly (operation is comparable cheap), a community must be able to afford the construction phase.

When looking at the treatment component – Extensive Treatment – “Natural Environment” (75% of the criteria applied) plays a considerable role in terms of soil characteristics, ground water level but also topographical profile. “Settlement Structure” (100% of the criteria applied) is an especially relevant context field. Beginning with the accessibility of a facility with vehicles (which is required for most extensive systems for reasons of O&M), over the needed minimum distance from other settlement structures, as also the required available space area. Besides, most extensive systems do have a limited capacity in terms of the density of population they are serving. In terms of “Community-specifics” (50% of the criteria applied) skilled labourers are needed for both construction and O&M (however, the skills needed for operation might be less sophisticated than in the case of operation & maintenance of an intensive treatment plant). As an extensive treatment facility deals with wastewater arising from a heighbourhood or even whole city, management has to be capable of taking over this responsibility.

Looking at the Disposal – surface discharge of the effluent and disposal of treated sludge at a Landfill – “Settlement” and “Natural Environment” (where 25% of the criteria applied) have to be considered as relevant as well as “Infrastructure” (40% of the criteria applied). Due to the need for a water body appropriate for receiving the effluent. Moreover, a dependency from “Natural Environment” is observable. But especially “Community-specifics” (50% of the criteria applied) appear to be of crucial importance in terms of the components function

6.2 Context dependencies regarding the Systems

After presenting dependency profiles of individual components, now existent differences between the whole systems are examined. Merging the individual areas to one big "dependency profile", should allow to clarify general differences in the dependency tendencies of the presented systems.

However, when considering the radar charts provided below (see Fig. 37-Fig. 44), it is important to realize that they illustrate those dependencies which resulted in the highest[8] values - thus, superimpositions of values are not taken into account. It is assumed that due to linearity of process, a summation of the individual values concerning context fields, is not useful.

Single-Pit based System: With a value of 100% the most significant dependency value is observable concerning "Settlement". Results in terms of "Infrastructure" (60%), "Natural Environment" (50%) and "Community-Specifics" (50%) are, however, also noticeable.

Twin Pits based System: As in the case of the previous mentioned system, the highest value can also be observed in relation to "Settlement" (75%). Followed by "Natural Environment" (50%) and "Infrastructure" (30%). Dependencies in terms of "Community-Specifics" are comparable small (17%).

Arborloo based System: Also in the case of this system, "Settlement" (75%) and "Natural Environment" (50%) play a significant role as for the systems relevant contexts. What is especially noticeable is the independency from "Infrastructure". "Community-specifics" are of relevance - with a comparable small value of 17%.

Re-use oriented System based on Fossa Alterna: As it gets obvious in the charts (see Fig. 39 and Fig. 40), system-specific values for this system are very similar to those of the Arborloo-based system. Therefore, to get more informations about existing differences for these systems, it appears useful to look at the component-specific breakdown of values provided in the previous chapter.

Re-use oriented System based on Urine Diversion: It is highly remarkable that this system appears widely independent from its "Natural Environment". Also the other dependency values are comparable small, with "25% in terms of "Settlement", 20% in terms of "Infrastructure" and 17% in terms of Community-specifics.

Septic Tank based System: This system shows a very high dependency in terms of "Settlement" (100%). Results in terms of "Infrastructure" (60%), "Natural Environment" (50%) and "Community-Specifics" (50%) are, however, also noticeable. Values are similar to the results of a Single-Pit based system. However, when considering the charts as well as the component-specific values, existing differences become more obvious.

Conventional Water-based System: The highest level of dependency can be observed in terms of "Community-Specifics" (83%), followed by "Infrastructure" (80%). But also "Natural Environment" and "Settlement" show reasonable values with each 50%.

Alternative Water-based System: The most significant dependency value can be observed in terms of "Settlement" (100%). "Natural Environment" with 75% is appears also as significant context field, as well as "Community-Specifics" (67%). With a value of 40%, the importance of "Infrastructure" is however not neglectable.

[8] A value of e.g.: 60% refers to that at least for one component during the process had 60%of the criteria applied.

Now considering the results in terms of the Context Fields, the following values are noticeable:

“Settlement Structure”: In relation to this Context Field by far the highest value can be observed in the case of the “Single-Pit based System”, the “Septic Tank based System” and the “Alternative Water-based System”.

“Community-specifics”: the most recognizable dependencies from this Context Field can be found in the case of the two water-based systems. Whereas the Conventional Water-based System proves to be the system with the most obvious dependencies (83%). With a value of 67% the “Alternative Water-based System’s” dependency is slightly smaller, but still remarkable distinctive.

“**Natural Environment**”: This context field appears for all systems of importance (excluding the “Re-use oriented System based on Urine Diversion”), however, the most noticeable value can be observed in the case of the “Alternative Water-based System” (75%).

“Infrastructure”: Obviously the biggest dependency from infrastructural resources appears to have the “Conventional Water-based System” (80%), followed by the “Septic tank based System” and “Single Pit based System” with each 60%. The Re-use oriented System based on Urine Diversion” (20%) as well as the “Twin Pit based System” (30%) have comparable smaller levels of dependencies in terms of this Context Field. Remarkable, however, is the observed independency from “Infrastructure” in the case of Arborloo and Fossa Alterna based systems.

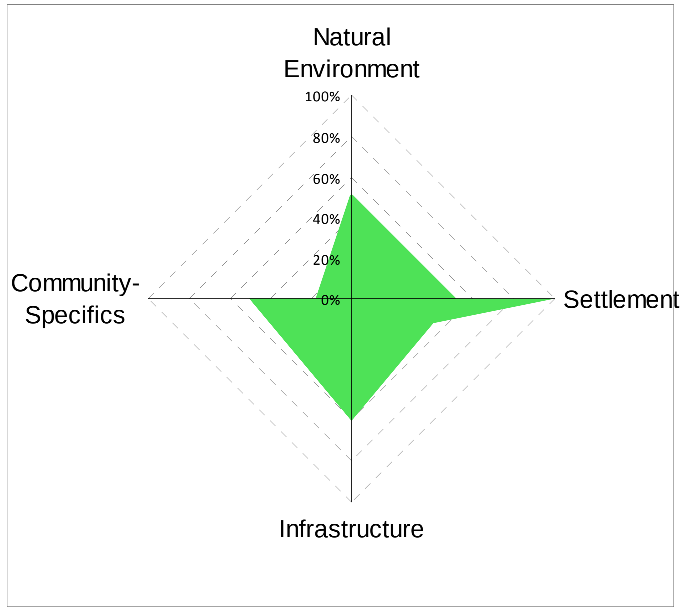


Fig. 37 Pit-latrine based System Variant 1:

System involving a Water-less Toilet as Capture, Coll.&Stor. in a Single pit, Infiltration of liquids on-site; Motorized Transport & Emptying, Treatment in a Faecal Sludge Treatment Facility. Disposal of outputs on a Landfill

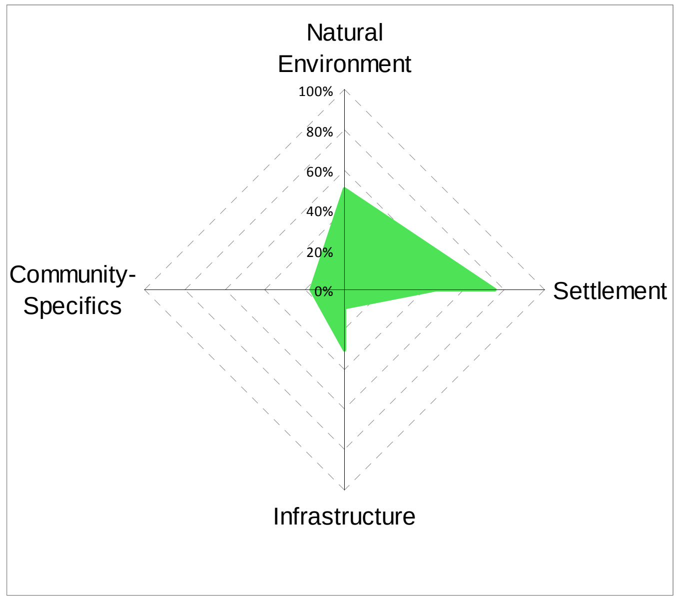


Fig. 38 Pit-latrine based System Variant 2:

System involving a Pour Flush Toilet as Capture, Coll.&Stor. in Twin Pits, Infiltration of liquids on-site; Human Powered Emptying and Transport, no extra Treatment; Disposal at a Landfill

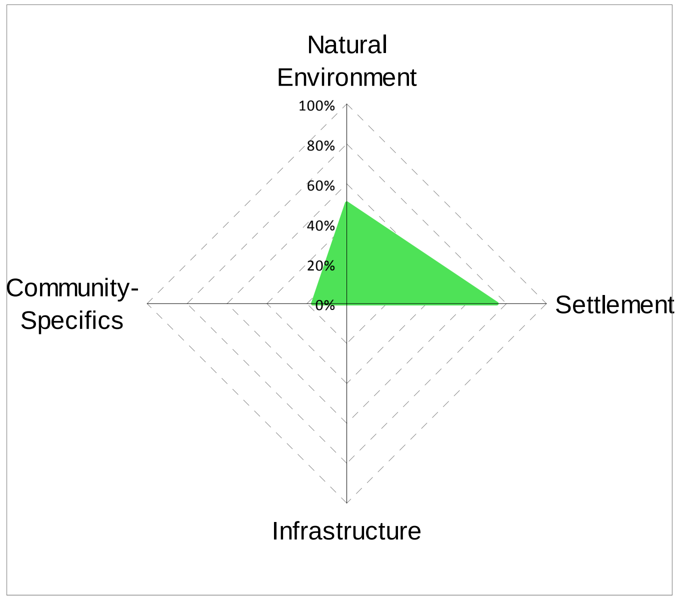


Fig. 39 Pit-latrine based System Variant 3:

System involving a Water-less Toilet as Capture, Coll.&Stor. in “Arborloo” Pits; Infiltration of liquids on-site, no Emptying & Transport; “Decommissioning” of the Pit instead of Disposal

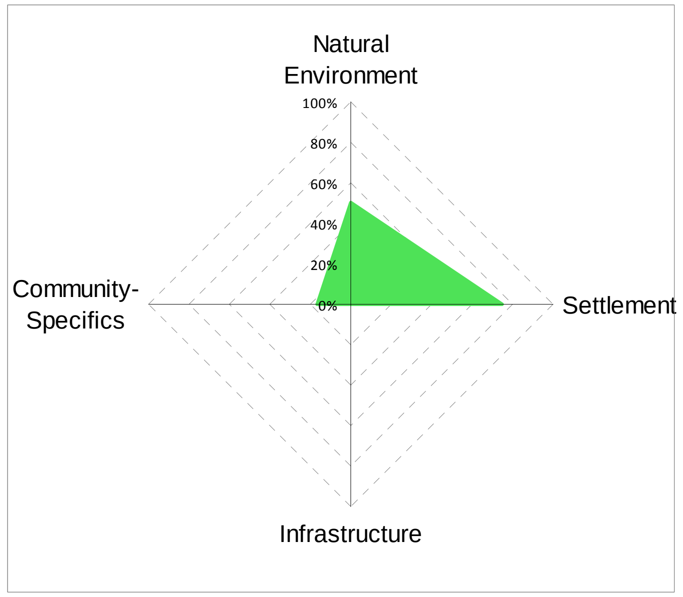


Fig. 40 Re-use oriented System Variant 1 (Fossa Alterna)

System involving a Water-less Toilet as Capture, Coll.&Stor. in a Fossa Alterna; Infiltration of liquids on-site; Human Powered Emptying and Transport; Application of the solid output on land.

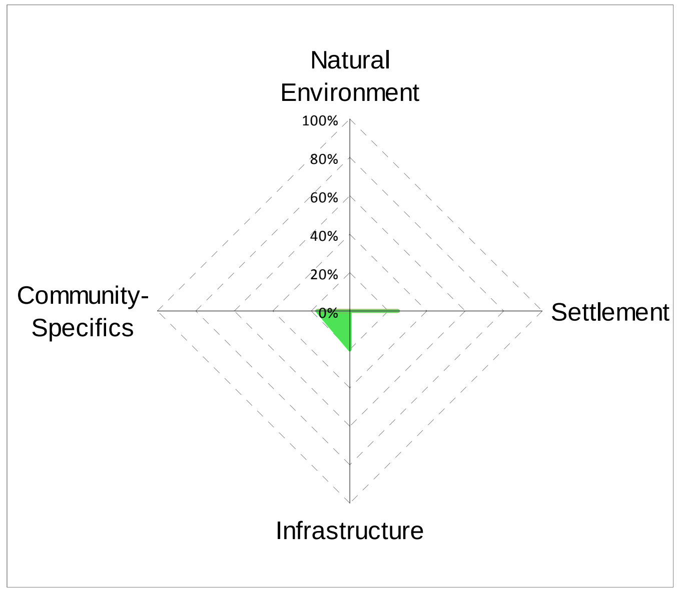


Fig. 41 Re-use oriented System Variant 2 (Urine Diversion)

System involving a Urine Diversion Dry Toilet as Capture, Coll.&Stor. in Double Dehydration Vaults, Human Powered Emptying and Transport, no extra Treatment; Re-use of the dried faeces and stored Urine on land .

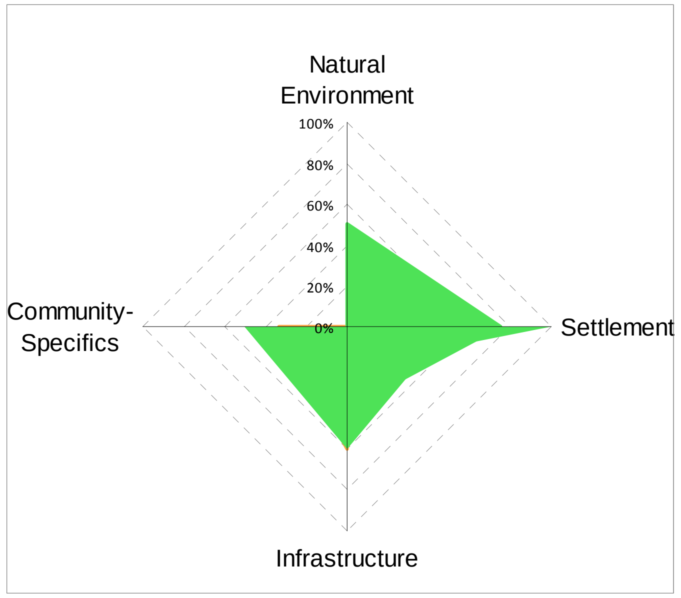


Fig. 42 Septic-Tank based System with Infiltration

System involving a Cistern Flush Toilet as Capture, Coll./Stor. in a Septic Tank, Infiltration of liquids on-site; Motorized Empyting and Transport, Treatment in a Faecal Sludge Treatment Facility; Disposal at a Landfill

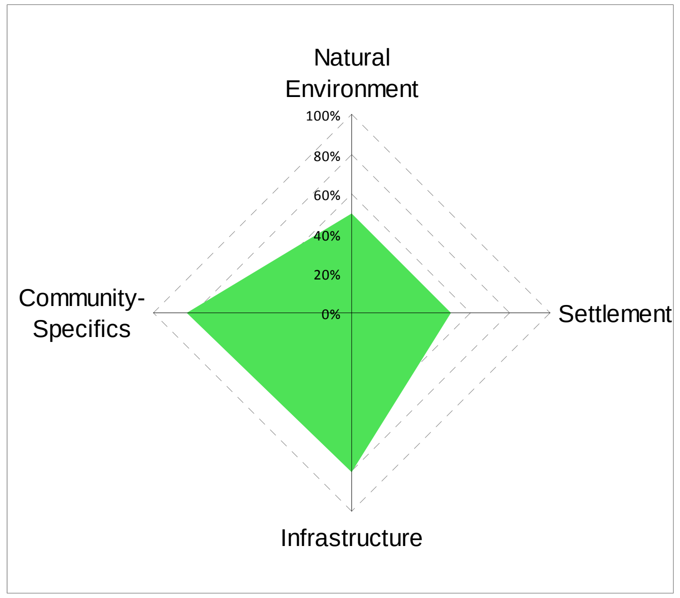


Fig. 43 Centralized Water-based System Variant 1:

System involving a Cistern Flush Toilet as Capture, no on-site Storage; Conveyance via a Conventional Gravity Sewer, Treatment in a Centralized (intensive) Wastewater Treatment Plant

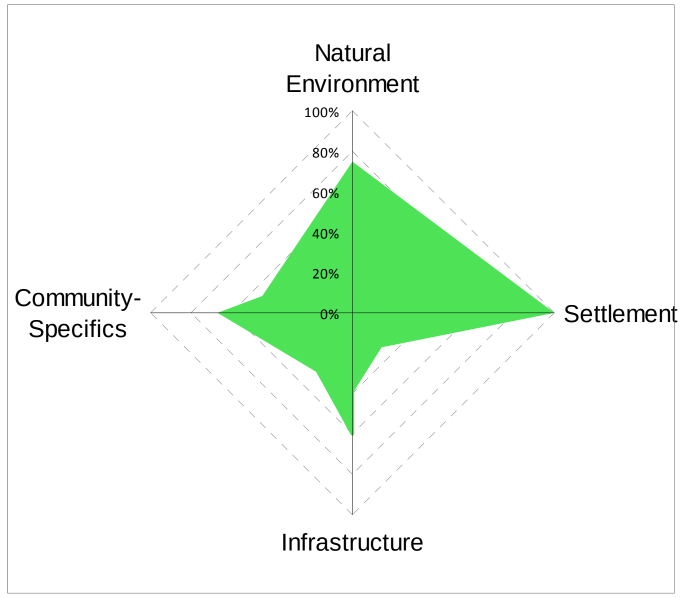


Fig. 44 (Semi-)Centralized Water-based System Variant 2:

System involving a Cistern Flush Toilet as Capture, no on-site Storage; Conveyance via Condominial Sewer, Treatment in a decentralized (extensive) Treatment facility

Fig. 45 System-specific Context Dependencies

7. Discussion & Main Findings

Sanitation as "*Infra-structure*" - Context Specific Sanitation strategy planning

Facing the target of developing regional and functional adapted sanitation approaches, a differentiated consideration of sanitation-relevant contexts is necessary. Thus, discussions and strategies should take into account two sides of contexts - the "user-specific context" and the "technology-specific context".

The user-specific context should illustrate characteristics (relevant in terms of sanitation) which are representative for the community a system is applied in. Typically, for the user-specific context in terms of sanitation, current conditions (settlement pattern, natural environment, climatic conditions, population, available infrastructures, socio-cultural approach towards sanitation, involved stakeholder structures,…) as well as expected developments are of interest.

With the technology-specific context, on the other hand, those factors should be recognized, which are representing "points of contacts" from a technical perspective between a community, its and a particular technology that should be applied in this community. It was content of this thesis and the presented approach to investigate which domains are of relevance in terms of different sanitation approaches. Being aware of these domains, can facilitate to answer the questions

- Whether a community can provide the context required for a specific technology/system or
- whether a technology/system fits to the context prevalent in a community
- What are potential adoptions possible within the community in order to provide a more appropriate context

System approach and Functional Patterns in Sanitation

It was proven that in order to investigate the technology-specific contexts, available technologies have to be considered in a systematic and differentiated manner. There is a range of technologies available, comprising different functions. Thus, it is necessary to take into account which functions are fulfilled by which component and which streams are actually processed.

Neglecting the range of available technological solutions and missing a differentiated consideration of their functional characteristics, as it has been the case in many previous discussions in the sanitation sector, is problematic in several respects:

It appears necessary to establish clear definitions of what process steps and compounds are actually necessary in a complete sanitation process - as basis for discussing available technologies. Lacking a function-specific basis, can result in comparisons or evaluations of technologies which actually fulfil different functions. Analyses and comparisons in terms of economic (or also other characteristics) are obviously only expressive when done for technologies (or technology combinations) of equal functions.

Taking into account the linear characteristic of sanitation, allows to well-understand existing functional linkages between the components - activities during one sanitation step can take a crucial impact on a subsequent step (e.g.: Minimizing water input at the user interface of water-based systems - in order to minimize the water consume - can cause an extra-demand of water during conveyance, due to the sewer's dependency from a steady flow through. Looking at "Drop & Store" approache: Settlement conditions for the collection and storage unit are also of importance in terms of subsequent conveyance steps; etc.)

Looking at on-going debates about the establishment of "ecosan" or other alternative approaches on large scale in order to prefer it over "conventional water-based" approach, it is questionable whether the technology's (associated to these approaches) basic functional characteristics have been recognized. Instead of concentrating on finding a solution applicable on large-scale, more efforts have to be made to examine and clarify the technology's actual preferable fields of application.

Functional Requirements and Context Fields

Within this thesis, it was therefore tried to approach technologies and their fields of application through identifying some of their major functional requirements. Being aware of these pre-conditions, facilitates to understand where a system's appropriateness is more likely and where not. Using main functional requirements for characterizing sanitation-relevant context fields, makes obvious that there is a range of factors directly relevant for the function of a technology/system.

Within this thesis, the fields “Natural Environment”, “Settlement Structure”, “Infrastructure” and “Community-specifics” were identified as domains in and around a community related to the technical functionality of the presented systems. Hence, necessities concerning particular “groundwater levels” or “soil characteristics” can be as well of relevance as the need for a community capable of covering high operation costs or providing specific (other) infrastructures. Hence, it becomes evident that a “single-dimensional” discussion of sanitation systems only considering one single fragment of this range of factors (e.g.: costs), neglects the complexity of aspects relevant in relation with sanitation infrastructure. Single-dimensional viewing moreover impedes the possibility of being aware of existing links between the domains. An example for such a link is the development of capital needs for establishing and running a system in the case other aspects are neglected (and the system gets applied in an inappropriate context). But also looking at the “basic” technical requirements linkages can be observed: requirements for soil characteristics such as infiltration capacity are highly influenced by the settlement density. There is also a relation of needs concerning other infrastructures (e.g.: energy supply, transport infrastructure) and requirements in terms of the level of skills of the labourers constructing and operating a facility. Thus, discussions have to follow a more multi-dimensional view - in order to include as many directly relevant aspects.

The approach elaborated in this thesis aims to consider sanitation technologies associated to systems (vertically) which are embedded in a framework of context fields (horizontally).

Limitations regarding Developing Countries

Considering the factors that were selected as “Limitation” criteria associated to the four context fields, those describing socio-economics and infrastructural aspects are considered of special relevance in terms of developing countries.

Looking at the two fields “Infrastructure” and “Community-specifics”, requirements dealing with operation and maintenance (“special material operation and maintenance”, “skilled labourers O&M”, “constant water supply”, “constant energy supply” or “high capacity to pay for O&M”) appear to be especially critical in the context of developing countries. Whereas demands related to the establishment/construction of a system can be met by donor-organisations (such as the World Bank or other international co-operations), long-term arising requirements rather have to be fulfilled by the particular community herself.

Moreover, it has to be realized that when speaking of a high grade of institutional organisation, special focus should be set on the aspect of “governance” (described more in detail in section 5.2).

Context Dependencies

Considering the evaluation results of the component-specific as well as the system-specific dependencies, the following findings can be summed up:

Single-Pit based System: As most critical steps in this process appear Treatment and Conveyance. These two steps are causing the biggest dependencies, mainly in terms of the fields “Infrastructure” and “Community-specifics”. But also “Settlement” plays a reasonable role - especially when considering the treatment in a Faecal Sludge Treatment Facility. Thus, when looking at the development and allocation of dependencies within the sanitation process, it becomes obvious that the capture is widely independent, Collection & Storage mainly depends on factors determining the technical feasibility (such as “Natural Environment” & “Settlement”), Conveyance and Treatment, however, are much more dependent on the Socio-Economic context in the community. Therefore, it is assumed that for a successful implementation of such a system in the context of a developing country, one should be aware of the resources needed for establishing emptying, transport to and treatment in an off-site facility.

In general, when considering the system as a whole, it gets obvious, that its function highly depends on the settlement conditions, but also reasonable relies on the other context fields. Thus, for applying the system, all four fields (and applied requirements) have to be considered - however, it should looked in detail which factors do exactly apply.

Twin Pits based System (Variant II): The aspect that Treatment and Conveyance have the most significant requirements concerning their context, can be strengthened when looking at the dependencies evaluated for this system - which does not include an off-site treatment. Therefore, Collection and Storage are causing the biggest part of dependencies (mainly concerning the fields “Natural Environment” and “Settlement”). Being independent from Motorized Emptying & Transport as well as from extra treatment off-site, minimizes needed resources in terms of infrastructure, education and financial means.

When considering this system as a whole, it is noticeable, though there were dependencies observed in terms of all the context fields, however, dimensions of these dependencies were considerably different. Thus, settlement specifics appear much more important as community-specifics.

Arborloo system: Within this sanitation process of an, Collection & Storage as well as the “Disposal” step are most obviously dependent on the system’s context. Due to their requirements concerning infiltration capacity of the soil or groundwater level (etc.), the appropriateness of both steps is mainly determined by the “Natural Environment” and the “Settlement structure”.

Applying Arborloo systems therefore mainly depends on prevalent Settlement and “Natural” conditions. On the other hand, the system is widely independent from other infrastructures or requirements in terms of the community, which makes an application especially attractive in areas with weak infrastructures and sophisticated institutional structures.

Fossa Alterna based system: Considering the most critical phases in terms of dependencies, the largest dependency is related to Collection & Storage. Here, factors concerning the Natural Environment and Settlement are of most importance.

As in the case of Arborloo systems, when looking at Fossa Alterna systems, prevalent conditions in terms of “Settlement” and “Natural Environment” are therefore in general most destinctive. On the other hand, the system is widely independent from other infrastructures or requirements in terms of the community, which makes an application especially attractive in areas with weak infrastructures and sophisticated institutional structures.

Urine Diversion based system: this re-use oriented approach exhibits a quite balanced dependency from its context during the process. Hence, Conveyance and Disposal appear equally dependent on “Settlement” and “Community-specifics”.

In general, observed dimensions of these dependencies are comparable little. Due to possible constructional design options - compared to the other systems - this system is widely independent of its Natural Environment. However, requirements concerning educated and committed users (“Community-specifics”) on the one hand, and limits due to manual emptying and transport but also disposal, which reasonable depends on the Settlement structure, have to be considered carefully.

Septic tank based system: considering this system, following can be noted: as Collection and Storage are more complex as in the case of a Single Pit-latrine based system (which is in general comparable to this system in terms of its functional pattern), the dimension of dependency of this step is very similar to those of the Conveyance and Treatment steps. Thus, already the Collection and Storage unit has more specific requirements concerning "Settlement" and "Infrastructure". Emptying & Transport to and treatment in an according (off-site) facility, however, are also causing dependencies - in terms of the Settlement as well as concerning the communities' socio-econonomic conditions ("Infrastructure" and "Community-specifics"). Interesting is also the importance of the Cistern Flush Toilet in terms of requirements concerning Infrastructure.

Generally, therefore, this system is highly dependent on its settlement specific context. Importance of the other context fields, however, is also remarkable. Thus, as in the case of a Single-Pit based system, one should be aware of all four context fields (and applied requirements).

Conventional Water-based System: Considering the development and allocation of dependencies within this system, Conveyance and Treatment appear as the most critical steps within the process. They exhibit significant dependencies in relation to "Infrastructure" and "Community-Specifics" (besides, "Natural Environment" is of special relevance for Conveyance). Also noticeable are occurring dependencies in terms of the Disposal (Discharge of Effluent and Landfill disposal of Sludge) - which is related to requirements concerning all context fields. As already mentioned above, the Cistern Flush Toilet can cause a reasonable dependency in terms of Infrastructure. However, looking at the dependency dimension of the subsequent steps, the Captures' dependency is comparable small. It is therefore of importance to realize that this system has reasonable dependencies in terms of its context during all process steps.

When looking at this system as a whole, it is noticeable that occurring dependencies are significant in terms of all context fields. This system has by far the highest dependency in terms of "Infrastructure" and "Community-specifics" of all presented systems.

Semi-centralized water-based system: Within this sanitation process, also Conveyance, Treatment and Disposal are causing significant dependencies. The components, however, depend on different context fields. Whereas, Condominial Sewer appear reasonable dependent on "Community-specifics", for the Treatment "Natural Environment" and "Settlement" become more distinctive. Disposal is noticeable dependent on the "Infrastructural" and "Community-specific" context. However, the importance of "Natural Environment" and "Settlement" should not be neglected.

Applying a semi-centralized water-based system as presented in this work, is significantly dependent on all context fields. Requirements in terms of "Settlement" and "Natural Environment" however are most distinctive. Compared to the other systems, also available resources in terms of community-specifics are reasonable, as also concerning available infrastructures.

Generally spoken, therefore, the following findings can be noted:

- The presented systems proved to have very different dependency profiles.
- In the course of the sanitation process, relevancies of the presented context fields (and associated requirements or limitations) range significantly.
- Looking at the peculiarity of the occurring dependencies, different process steps appear to be critical: E.g. Even if pit latrines (as Collection & Storage Unit) are easy and relatively cheap to construct (provided the discussed requirements are fulfilled), Conveyance, Treatment and Disposal of the sludge has significant requirements in terms of infrastructure, financial & organizational means ("Infrastructure", "Community-specifcs").

Conclusions concerning Field of application

The context distinctive in terms of function and therefore appropriateness of available approaches in sanitation is involving different domains in and around a community. Thus, considering or even evaluating a technology or a system separated from these required contexts, is inadequate.

When discussing the potential of specific systems (or approaches) to be established on large scale, one must be aware of the fact that each system operates in specific contexts and that these contexts have to be regarded in a differentiated manner.

It is insufficient to lump available approaches together in order to evaluate them single-dimensional (e.g. economic efficiency) without recognizing severe differences in terms of their function and context profile.

8. Summary

Ever since the UN Millennium Development Goals were published in 2000, the importance of sanitation in terms of the human kind's development became more and more recognized. However, facing the alarming numbers of people, who are still without adequate access to safe drinking water and basic sanitation supply in 2010, the progress appears limited. The transfer and applicability of sanitation systems commonly used in wealthy, industrialized countries to those areas where the situation is particularly serious - the informal settlements of poor urban and rural areas in developing countries, is problematic.

Available technological options are often not considered in a differentiated manner taking into account their actual functions and functionalities. Instead, a lot of discussions and debates in the sanitation sector are motivated by the idea that there is a single technological concept or solution which could be established efficiently on a large scale - independently from the context it is applied in. In many cases, economic efficiency - often contemplated trough costs - appears to be a leading interest in the decision making and development process towards sanitation. It is a matter of fact that sanitation "infra-structure" is highly linked to several domains within and around a community. Thus, a one-dimensional approach - only involving an economic point of view - seems insufficient.

Regional and functional adapted sanitation approaches are needed - requiring a more informed, multi-dimensional strategy planning of sanitation. Thus, in this thesis, technologies as well as technology-specific contexts were discussed systematically.

It is assumed that the presented technologies - and consequently their logical combinations to systems - are showing quite significant differences in terms of their field of application and corrsponding contexts they can and should be applied in.

According to the "System approach" presented by TILLEY et al. (2008), following systems have been selected - being built up through logically combining individual technologies appropriate to their functions within the sanitation process :

- Three variants of simple "Drop and Store" systems ("Pit-latrine based systems")
- Two variants of cyclic systems ("Re-use oriented systems")
- One system variant involving an improved on-site storage ("Septic Tank based system")
- One variant of a conventional water-based as well as one variant of an "alternative" water-based system ("semi-/centralized water-based systems")

Distinguishing five functional steps in the sanitation process (Capture, Collection & Storage, Conveyance, (Semi-) Centralized Treatment and Re-Use/Disposal), built the basis for examining the technology's (and consequently systems') general technical functionality.

Based on the description of the component's functionalities ("Functional Patterns"), associated functional requirements were identified. Identified requirements were then used for forming "Context fields", which should illustrate those domains of a community that are most relevant in terms of an application of a sanitation system. With regards to developing countries, it was tried to especially focus on requirements, which appear distinctive - so-called "limitations". The following context fields and associated limitation factors finally were identified:

- Natural environment (Soil structure, Ground Water Level, Topographical Profile, Availability of receiving Waters)
- Settlement (Accessibility with vehicles, Distance to other settlement structures, Load/capacity, Available space area)

- Infrastructure (Special Material, Constant Water Supply, Constant Energy Supply, Transport Structures)
- Community-specifics (Skilled Labour, User Commitment / Education, High grade of institutional organization, High capacity to pay)

A systematic appraisal was used to investigate existing differences in terms of “dependencies” of specific components or even whole systems from these limitation factors. Existent ranges of dependencies in the course of the sanitation processes were clarified as also varying dependency characteristics of the presented systems.

Looking at the main findings of this thesis, it was strengthened that in order to investigate technology-specific contexts, available technologies have to be considered in a systematic and differentiated manner. There is a range of technologies available, comprising different functions. Thus, it is necessary to take into account which functions are fulfilled by which component and which streams are actually processed. Lacking a function-specific basis in strategic sanitation planning can result in comparisons or evaluations of technologies which actually fulfil different functions. Analyses and comparisons in terms of economic (or also other characteristics) are obviously only expressive if done for technologies (or technology combinations) of equal functions.

The technology-specific context distinctive in terms of function and the corresponding appropriateness of the presented systems involved different domains in and around a community. It became obvious that a “single-dimensional” discussion of sanitation systems only considering one single fragment of this range of factors (e.g.: costs), neglects the complexity of aspects relevant in relation to sanitation infrastructure. Discussing or even evaluating a technology or a system separated from these required contexts, therefore is considered as inadequate.

Moreover, the presented systems proved to have very different dependency profiles. Also looking at the allocation of dependencies within a system, ranging relevancies of presented context fields (and associated requirements or limitations) were observable. Different process steps appeared as critical - in terms of the peculiarity of their dependencies.

Therefore it is assumed, that when discussing the potential of specific systems (or approaches) to be established on large scale, one must be aware of the fact that each system operates in specific contexts and that these contexts have to be regarded in a differentiated manner. Being aware of percussive “limiting” factors relevant for a technology’s or system’s application as well as the grade of dependency from these factors, can facilitate to evaluate the appropriateness or even adaptability of a system.

9. Outlook

Considering the outcomes of this thesis, it can be stated that a refining of the presented logical framework appears promising. As this work is literature based, an improvement of the data input by the means of case studies investigating the actual context conditions in practice should be contemplated. It is important to note that the identified factors are reasonable simplified (e.g.: it was not determined how many users are served by a component; water availability is categorized as basic requirement for conventional water-based conveyance, without specifying the importance of frequency and dimension of this water input;…). Therefore they are rather representing the existent range of relevant factors. For specifying the elaborated factors as also for identifying more requirements and context fields of relevance, further efforts are needed. That should on the one hand allow a verification of the criteria and context fields identified so far. On the other hand, eventually, expansions in terms of additional significant context criteria or even context fields are facilitated. Investigations of case studies, moreover, could allow the weighting of criteria during the evaluation process, what obviously can take a crucial impact on the results.

So far it was focused on the processing of domestic waste(water). Thus, the inclusion of other types of wastewaters such as stormwater or industrial wastewater appears promising.

In the context of strategic planning and associated legal frameworks, it can be suggested to use (and expand) the elaborated logical framework in order to subsequently design an adequate planning “instrument”. Realizing the ideas presented in this work in international standards in the sanitation sector, may allow to increase the awareness of the importance of a more multi-dimensional planning perspective as also the need for a more transparent and comprehensible technology choice and application.

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11. Annex

Annex I The Concept of “Ecological Sanitation”

In the following, an overview of background and development as well as associated technologies of the often used notation “Ecosan” should be provided. “Ecosan” or also called “Sustainable Sanitation” is often discussed as potentially competitive alternative to “Conventional water-based sanitation”. However, it is important to note that the term „Ecosan“ nowadays describes several approaches and perception as well as understanding can vary significantly. Thus, this short comment should allow a more differentiated consideration of these notations giving a short chronological overview of development and accessions to this “concept”.

Background of the concept

In the following primal motivation for the development and propagation of the “ecosan concept” should be discussed.

In his Final Report about the SanRes programme [more details see the box below], WINBLAD (2002) is explaining the background motivating the establishment of the “ecosan” (ecological sanitation) approach as follows:

In the early 1990s one realized that previous sanitation development approaches faced some fundamental problems:

- An increasing number of households in emerging and development without access to safe and adequate sanitation and hence a multiplicity of people suffering from related adverse effects
- Approaches advocated by development aid agencies were considered to be unsustainable and non-replicable.
- Successful application of available options (Pit toilet, VIP toilet, pour-flush toilet or WC connected to septic tank or sewers) was remarkably limited due to difficult conditions such as high water tables, seasonal flooding, unpickable soil, lack of space, lack of flushing-water or lack of money.
- Environmental sustainability of available options therefore was highly questionable.

The SanRes Programme

In order to answer the challenges cited above the Swedish International Development Cooperation Agency (SIDA) funded the research and development undertaking “SanRes” which was carried out in the years 1992 to 2001.

The SanRes programme aimed to investigate the potential of designing and testing an innovative sanitation approach that was

- affordable and replicable for the poorest of the urban and rural households in the third world,
- applicable under difficult conditions,
- protecting the environment – particularly groundwater & other water resources – against pollution,
- preventing vector breeding,
- using human excreta as resource, and
- mobilizing community participation and focusing on health education.

An important basis should build the principle of “**Don’t mix**” – meaning neither a mixing of urine with faeces, nor human excreta with flushing water or grey-water. It was hypothesized that keeping the *streams separated* should

- Minimize problems with odours and fly-breeding,
- facilitate storage, transport and sanitation of the output material,
- save water and herewith preserve the environment,
- reduce the needs for investments in infrastructure and
- make it possible to use relatively simple on-site methods for grey-water treatment.

In order to investigate this hypothesis, the SanRes programme carried out and analysed pilot projects where so-called “**eco-san designs**” were developed and tested (WINBLAD, 2002). Further interest of the project was the establishment of local capacities for research and development on sanitation as well as the facilitation of applied sanitation research in South-South collaborations (ECOSANRES, 2009).

ESREY et al. who were publishing “Ecological Sanitation” in 1998 are strengthening WINBLAD’s statements about the state of sanitation development in the early nineties. They are mentioning that in 1998 the majority of the sewage in cities in developing countries was discharged untreated causing pollution of rivers, lakes and coastal areas. Beside that, they are explicitly warning of severe risks, such as pathogen and nutrient seeping, evolving from pit toilets used in densely populated areas. In general, decreasing water quality and quantity are seen as overall problems describing the results from a weak sanitation development.

Beside the “pollution” problem, the loss of nutrients contained in human excreta was always and still is a central topic in the ecosan discussion. In 1998. Johan Holmberg for instance, from the Department for Natural Resources and Environment from SIDA, argued

“*In a situation of food insecurity, decreasing soil fertility and escalating prices for fertilizers in world markets, there is a need to utilize the nutrients, especially in human urine […] for agricultural purposes, thereby increasing productivity and reducing the needs for fertilizers* (ESREY et al., 1998, p.4).”

Ecosan as answer to challenges

Realizing all these challenges, the need for rethinking previous sanitation practices and approaches got obvious. Based on that, research and development of alternatives to conventional water-based sanitation was intensified. The Swedish International Development Cooperation Agency (SIDA) is one prominent organization working at this field. SIDA used the term “ecological sanitation” for describing a concept aiming to face the issues mentioned before. In the following its main characteristics and principles should be discussed. Considering the ecosan concept, it is important to realize the multiplicity of stakeholders using this term. SIDA is only one organization promoting “ecosan” and there are many other authors and organizations as well working on conceptual innovations in the sanitation sector entitling it "ecological sanitation".

The following three fundamental precepts

- preventing of pollution rather than attempting to control it afterwards,
- rendering human excreta safe, and
- recycling safe products for agricultural purposes

were identified and used as basis for achieving the targets of

- preventing diseases,
- recovering and recycling of nutrients contained in human excreta,
- reducing the need for, as well as, the contamination of water and
- minimizing adverse environmental impacts

The closure of material flow cycles and the consideration of human excreta as resource rather than as waste product should build the basis for this concept (ESREY et al., 2001; WINBLAD, 2002 and WINBLAD and SIMPSON-HÉBERT, 2004; GTZ, 2010).

With the upcoming and promotion of the idea of "Sustainable Development" the discussion about misleading developments in the sanitation sector was intensified. The announcement of the UN Millennium Development Goals (MDGs), which were aiming to achieve poverty reduction and sustainable development, reaffirmed the role of a well working sanitation sector and the need for more viable and *sustainable* solutions.

The eight goals, worked out during the UN Millennium Summit in 2000 and the Sustainable Development Summit in 2002, can be broken down in 21 targets measured by 60 indicators. In general, the reduction of poverty, the rapid increase in access to basic requirements such as primary education, health care, food security, and the protection of the environment were major aims of the ambitious goal-synthesis. In particular regard to water and sanitation provision the halving of the proportion of people without sustainable access to safe drinking water and basic sanitation has to by 2015 is targeted (UNDP, 2010).

"Sanitation is a key determinant of both equity in society and society's ability to sustain itself."

(WINBLAD and SIMPSON-HÉBERT, 2004; p.12)

Considering the ambitious MDGs on sanitation, "new holistic sanitation concepts (WERNER et al., 2004 p.23)" were demanded. By now, it is a common notion that ecosan does neither " …favour a specific sanitation technology" nor equate to a particular technology, but rather has to be understood as "a new philosophy in handling substances (PANESAR and WERNER, 2006 p.3.)" The concept is based on an overall-view of material flows as part of an ecologically and economically sustainable wastewater management system. Used technologies should be tailored to the needs of the users and to be respective to local conditions. Already ESREY et al. (1998) promoted the idea that technology was only one component that is involved in sanitation. Thus, Nature, Society, Process and Devices are all components of a sanitation system.

It is noticeable that the term "sustainability" got intimately connected with ecological sanitation within the last decade. The GTZ (German Assoziation for Technical Cooperation) for example, which is well established in promoting and developing "ecological sanitation" systems, even re-named their international "ecosan" program to "sustainable sanitation – ecosan" in 2009, emphasising the aspects of sustainability incorporated in the concept (GTZ, 2010).

According to the Stockholm Environment Institute, a sanitation system can be defined as "Sustainable Sanitation System" if it protects and promotes human health by balancing

- prevention of environment degradation

- protection of resource base
- technical and institutional viability
- social acceptability including individual and community preferences
- long term economic viability

Looking at these aspects, it gets clear that speaking of "Sustainable Sanitation" gives information about the performance or outcome in general of a sanitation system, rather than stating anything about technologies used.

It is important to note, that the notations "ecosan", "Resource-oriented Sanitation" but as well "Sustainable Sanitation" are remarkably overlapping. In the description of the IWA (International Water Association) Specialist Group on Ecological Sanitation for example "ecosan" for is equated with "Resource-Oriented-Sanitation". Furthermore, there are also publications using the terms "Sustainable Sanitation" for describing very similar approaches (ROSA, 2010)

Technologies in Ecological Sanitation

However, there are technological approaches characteristically assigned to "Ecological Sanitation" – such as the separation and separate treatment of different wastewater streams (WERNER et al., 2004). According to a paper describing the main features of Ecological Sanitation published by the STOCKHOLM ENVIRONMENT INSTITUTE (2008) ecosan can be viewed as a process dealing with human excreta in four steps: source-separation, containment, sanitization and recycling. The so-called "split-stream" approach for collection, treatment and re-use allows a distinguishing of faeces, urine and greywater and rainwater.

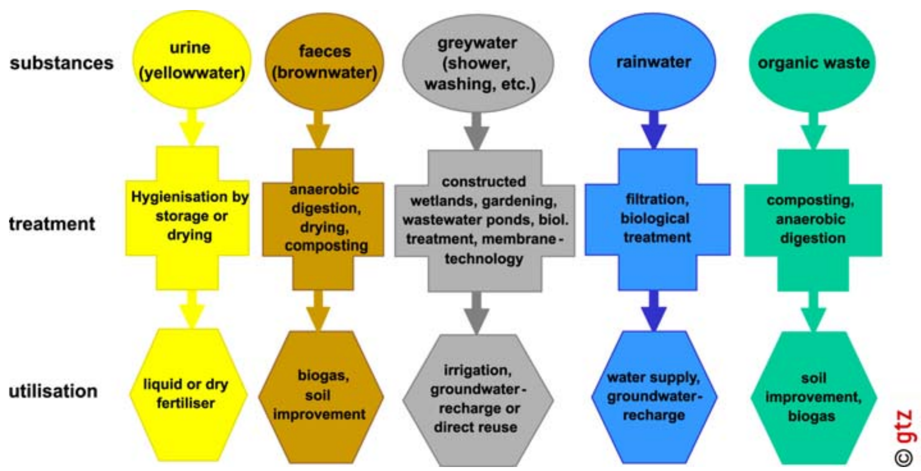

Fig. 46 Separation of Substances and examples of possible ecosan elements (WERNER et al., 2004)

Since the fractions have very different characteristics, their separation at source allows a more efficient treatment and finally disposal or re-use afterwards. In Fig. 46 an overview of the split streams, their specific characteristics as well as examples for their treatment and re-use/disposal are given.

Tab. 15 Differentiation of substance fractions, their treatment procedures and re-use/disposal; adapted from WERNER et al. 2004

Fraction	▪ Characteristics	▪ Treatment	▪ End-Product
Faeces	▪ hygienically critical ▪ consists of organics, nutrients and trace elements ▪ improves soil quality and increases water retainability	▪ dehydration ▪ composting ▪ stabilization ▪ soilisation	▪ dry fertilizer ▪ compost ▪ fluid fertilizer ▪ (energy usage from

		▪ fermentation	anaerobic digestion)
Urine	▪ less hygienically critical ▪ contains 90% of the total N, 55% of the total P and a substantial portion of the potassium contained in human excreta ▪ may contain hormones or medical residues		▪ fertilizer → directly applicable to plants
Greywater	▪ of no major hygienic concern ▪ volumetrically the largest portion of wastewater ▪ contains almost no nutrients (simplified treatment) ▪ my contain sprent washing powders etc.	▪ unventilated gravel filration ▪ biofilm procedures	▪ agricultural irrigation ▪ groundwater recharge ▪ discharge in surrounding water courses

ESREY et al., (2001) distinguish urine-diverting and non-urine-diverting toilets, where first may sanitize faeces through one or more processes such as dehydration, increasing pH or elevating temperatures. Non-Urine-Diverting storage on the other hand were relying on “moist” processes like composting or co-composting of human excreta. The authors are stating that urine-diverting would be the most commonly used ecological sanitation technological principle. A less commonly used system would be the compost-toilets, which “…do not divert urine, but [..] may work better if they did (ESREY et al., 2001 p.17)”. Most of ecological toilets would produce two separate products – urine on the one hand and a dry soil conditioner on the other.

This opinion is shared by WINBLAD and SIMPSON-HÉBERT (2004), by mentioning as well that ecosan systems are either based on dehydrating or composting (or soil composting) processes. Whereas dehydration would always require a strict diversion of urine and faeces, composting and soil composting could – in some cases – also process faeces together with urine. These “Non-Urine-Diversion” systems rely on “moist” processes as composting or co-composting (ESREY et al., 2001). Generally spoken, urine-diverting systems are using dehydration processes, while technologies which are treating faeces together with urine, are based on decomposition of material (WINBLAD and SIMPSON-HÉBERT, 2004). Depending on the specific technology Ecosan toilets hence are considered as place for primary treatment, which is occasionally completed by a treatment procedure outside the chamber (ESREY et al., 2001). This step - a so-called “secondary processing” - aims to make human faeces safe enough to return them to soil. It includes further treatment by high temperatures, composting, longer storage time or the addition of urea or lime in order to increase the pH. After an appropriate storage time[9] (and treatment) most bacterial pathogens will be eliminated and the number of viruses, protozoa and parasites should be reduced substantially. Without sanitizing the material, faeces must not be recycled or recovered (WINBLAD and SIMPSON-HÉBERT, 2004).

[9] In areas where ambient temperatures reach up to 20°C, a total storage time of 1,5 to 2 years is required. In areas with ambient temperatures of 35°C the same result should be achieved within 1 year of toal storage time (WINBLAD and SIMPSON-HÉBERT, 2004).

Annex II Overview of the most characteristic identified component-specific requirements

	Component	Characteristic Requirements
Capture	Water-less toilet	• Locally built, easily available building materials • Easy to build, operate and maintain, low skilled workers • Low capital costs, low operation costs
	Pour-flush toilet	• Component purchased; not (always) locally built • Water for flushing needed (rain water sufficient) • Maintenance in order to avoid blockages, no special skills • Low - Medium capital & operation costs
	Cistern Flush Toilet	• Constant water supply needed • Component purchased, not (always) locally built • Low-medium capital costs, depending on water prices medium to high operation costs
	UDDT	• Locally built or purchased • Low capital and operation costs • Users must be committed and educated
Collection & Storage	Single Pit/VIP/Twin Pits, Alborloo Pit	• Soil structure • Groundwater level • Settlement Structure / Density • Easy to build, operate and maintain, no special skills • Low capital costs, low (medium: VIP) operation costs
	Dehydration Vaults	• Locally built; easily available building material • Low - medium capital costs (depending on design); low operation costs • Committed and educated users
	Fossa Alterna	• Locally built, easily available building materials • Low capital and operational costs • Users must be committed and educated • Soil structure • Groundwater level
Conveyance	Motorized Emptying & Transport	• Settlement Structure / Density • Transport infrastructure • Availability of materials/tools problematic • Medium skilled workers • Organized on higher institutional level • Medium to high capital and operation costs
	Manual Emptying & Transport	• Settlement Structure / Density • Probably availability of materials/tools problematic • Low-medium skilled workers

		• Organized on household or neighborhood level • Low - medium capital and operation costs
	Conventional Sewer	• Constant (waste-)water supply needed (per household) • Settlement structure • Topography • High capital costs, high operational costs • Highly skilled workers • Components have to be purchased • Organized on a high institutional level
	Condominial Sewer	• Constant (waste-)water supply (per "yard") • Soil conditions • Topography • Medium (to high) capital costs • Settlement structure • Committed users are needed; medium institutional organization • Skilled workers
Treatment	Intensive Wastewater Treatment Facility	• Specific building materials needed • Highly skilled workers • High capital and operation costs • Constant energy supply needed • Settlement structure • High institutional organization
	Extensive Wastewater Treatment & (pure) Faecal Sludge Treatment Facilities	• Settlement Structure / Density • Low - medium capital and operation costs • Built with locally available material • Medium - high skilled workers (especially for design!)
Disposal	Alborloo	• Settlement Structure / Density
	Discharge of effluent	• Availability of adequate water body • Skilled labourers
	Disposal of sludge	• Landfill must be available → skilled labourers, high capital and operation costs • (and/or) Incineration site must be available → …
	Application of treated/degraded sludge or stored urine	• No cultural reservations • Agriculturally skilled workers • Low cost technology • Land/Crops adequate for use of material

Annex III Data Input for Evaluations

Input Data Dry Toilet - Single Pit - Empt. - Faecal Sludge TM - Landfill Disposal

Phase	Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Capture	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
	Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	0,00	5,00	0,00	6,00	0,00
Collection & Storage	Soil Characteristics	1,00	Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures	1,00	Special Material O&M		Skilled Labourers O&M	
	Ground Water Level	1,00	Load/Capacity	1,00	Constant Water Supply		User Committment/Education	1,00
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,50	4,00	0,50	5,00	0,00	6,00	0,17
Conveyance	Soil Characteristics		Accessibility with mot. Vehicles	1,00	Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M	1,00	Skilled Labourers O&M	
	Ground Water Level		Load/Capacity	1,00	Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	1,00
					Transport Structures (roads, vehicles, fuel)	1,00	High Capacity to Pay for Construction/Establishment	1,00
							High Capacity to Pay for O&M	1,00
	4,00	0,00	4,00	0,50	5,00	0,60	6,00	0,50
Treatment	Soil Characteristics		Accessibility with mot. Vehicles	1,00	Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	1,00
	Topographical Profile		Distance to other Settlement Structures	1,00	Special Material O&M		Skilled Labourers O&M	1,00
	Ground Water Level		Load/Capacity	1,00	Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands	1,00	Constant Energy Supply		High Grade of Institutional Organisation	1,00
					Transport Structures (roads, vehicles, fuel)	1,00	High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	1,00	5,00	0,20	6,00	0,50
Disposal	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	1,00
	Topographical Profile		Distance to other Settlement Structures	1,00	Special Material O&M	1,00	Skilled Labourers O&M	1,00
	Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	1,00
					Transport Structures (roads, vehicles, fuel)	1,00	High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	0,25	5,00	0,60	6,00	0,50

Input Data Dry Pour Flush - Twin Pits - Emptying - Disposal

Phase	Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Capture	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
	Ground Water Level		Load/Capacity		Constant Water Supply	0,50	User Committment/Education	1,00
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	0,00	5,00	0,30	6,00	0,17
Collection & Storage	Soil Characteristics	1,00	Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures	1,00	Special Material O&M		Skilled Labourers O&M	
	Ground Water Level	1,00	Load/Capacity	1,00	Constant Water Supply		User Committment/Education	1,00
	Availiability o Recieving Waters		Space Area Demands	1,00	Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,50	4,00	0,75	5,00	0,00	6,00	0,17
Conveyance	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures	1,00	Special Material O&M		Skilled Labourers O&M	
	Ground Water Level		Load/Capacity	1,00	Constant Water Supply		User Committment/Education	1,00
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	0,50	5,00	0,20	6,00	0,17
Treatment	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
	Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	0,00	5,00	0,00	6,00	0,00
Disposal	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
	Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	1,00
	Availiability o Recieving Waters		Space Area Demands	1,00	Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	0,25	5,00	0,00	6,00	0,17

Input Data Arborloo

Capture

Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	1,00
Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
				Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
						High Capacity to Pay for O&M	
	4,00 0,00		4,00 0,00		5,00 0,00		6,00 0,17

Collection & Storage

Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Soil Characteristics	1,00	Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
Topographical Profile		Distance to other Settlement Structures	1,00	Special Material O&M		Skilled Labourers O&M	
Ground Water Level	1,00	Load/Capacity	1,00	Constant Water Supply		User Committment/Education	1,00
Availiability o Recieving Waters		Space Area Demands	1,00	Constant Energy Supply		High Grade of Institutional Organisation	
				Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
						High Capacity to Pay for O&M	
	4,00 0,50		4,00 0,75		5,00 0,00		6,00 0,17

Conveyance

Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	
Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
				Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
						High Capacity to Pay for O&M	
	4,00 0,00		4,00 0,00		5,00 0,00		6,00 0,00

Treatment

Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	
Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
				Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
						High Capacity to Pay for O&M	
	4,00 0,00		4,00 0,00		5,00 0,00		6,00 0,00

Disposal

Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Soil Characteristics	1,00	Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
Topographical Profile		Distance to other Settlement Structures	1,00	Special Material O&M		Skilled Labourers O&M	
Ground Water Level	1,00	Load/Capacity	1,00	Constant Water Supply		User Committment/Education	1,00
Availiability o Recieving Waters		Space Area Demands	1,00	Constant Energy Supply		High Grade of Institutional Organisation	
				Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
						High Capacity to Pay for O&M	
	4,00 0,50		4,00 0,75		5,00 0,00		6,00 0,17

Input Data Fossa Alterna

Capture

Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	1,00
Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
				Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
						High Capacity to Pay for O&M	
	4,00 0,00		4,00 0,00		5,00 0,00		6,00 0,17

Collection & Storage

Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Soil Characteristics	1,00	Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
Topographical Profile		Distance to other Settlement Structures	1,00	Special Material O&M		Skilled Labourers O&M	
Ground Water Level	1,00	Load/Capacity	1,00	Constant Water Supply		User Committment/Education	1,00
Availiability o Recieving Waters		Space Area Demands	1,00	Constant Energy Supply		High Grade of Institutional Organisation	
				Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
						High Capacity to Pay for O&M	
	4,00 0,50		4,00 0,75		5,00 0,00		6,00 0,17

Conveyance

Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
Ground Water Level		Load/Capacity	1,00	Constant Water Supply		User Committment/Education	1,00
Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
				Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
						High Capacity to Pay for O&M	
	4,00 0,00		4,00 0,25		5,00 0,00		6,00 0,17

Treatment

Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	
Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
				Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
						High Capacity to Pay for O&M	
	4,00 0,00		4,00 0,00		5,00 0,00		6,00 0,00

Disposal

Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	1,00
Availiability o Recieving Waters		Space Area Demands	1,00	Constant Energy Supply		High Grade of Institutional Organisation	
				Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
						High Capacity to Pay for O&M	
	4,00 0,00		4,00 0,25		5,00 0,00		6,00 0,17

Input Data Urine Diversion

Stage	Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Capture	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
	Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	1,00
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	0,00	5,00	0,00	6,00	0,17
Collection & Storage	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
	Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	1,00
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	0,00	5,00	0,20	6,00	0,17
Conveyance	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
	Ground Water Level		Load/Capacity	1,00	Constant Water Supply		User Committment/Education	1,00
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	0,25	5,00	0,00	6,00	0,17
Treatment	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
	Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	0,00	5,00	0,00	6,00	0,00
Disposal	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
	Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	1,00
	Availiability o Recieving Waters		Space Area Demands	1,00	Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	0,25	5,00	0,00	6,00	0,17

Input Data Cistern Flush - Septic Tank

Stage	Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Capture	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M	1,00	Skilled Labourers O&M	
	Ground Water Level		Load/Capacity		Constant Water Supply	1,00	User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	1,00
							High Capacity to Pay for O&M	1,00
	4,00	0,00	4,00	0,00	5,00	0,60	6,00	0,33
Collection & Storage	Soil Characteristics	1,00	Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures	1,00	Special Material O&M		Skilled Labourers O&M	
	Ground Water Level	1,00	Load/Capacity	1,00	Constant Water Supply	1,00	User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands	1,00	Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,50	4,00	0,75	5,00	0,40	6,00	0,00
Conveyance	Soil Characteristics		Accessibility with mot. Vehicles	1,00	Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M	1,00	Skilled Labourers O&M	
	Ground Water Level		Load/Capacity	1,00	Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	1,00
					Transport Structures (roads, vehicles, fuel)	1,00	High Capacity to Pay for Construction/Establishment	1,00
							High Capacity to Pay for O&M	1,00
	4,00	0,00	4,00	0,50	5,00	0,60	6,00	0,50
Treatment	Soil Characteristics		Accessibility with mot. Vehicles	1,00	Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	1,00
	Topographical Profile		Distance to other Settlement Structures	1,00	Special Material O&M		Skilled Labourers O&M	1,00
	Ground Water Level		Load/Capacity	1,00	Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands	1,00	Constant Energy Supply		High Grade of Institutional Organisation	1,00
					Transport Structures (roads, vehicles, fuel)	1,00	High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	1,00	5,00	0,20	6,00	0,50
Disposal	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	1,00
	Topographical Profile		Distance to other Settlement Structures	1,00	Special Material O&M	1,00	Skilled Labourers O&M	1,00
	Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	1,00
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
	4,00	0,00	4,00	0,25	5,00	0,40	6,00	0,50

Input Data Cistern Flush Conv. Water-based

Stage	Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Capture	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M	1,00	Skilled Labourers O&M	
	Ground Water Level		Load/Capacity		Constant Water Supply	1,00	User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	1,00
							High Capacity to Pay for O&M	1,00
		4,00 0,00		4,00 0,00		5,00 0,60		6,00 0,33
Collection & Storage	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
	Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
		4,00 0,00		4,00 0,00		5,00 0,00		6,00 0,00
Conveyance	Soil Characteristics	1,00	Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	1,00
	Topographical Profile	1,00	Distance to other Settlement Structures	1,00	Special Material O&M	1,00	Skilled Labourers O&M	1,00
	Ground Water Level		Load/Capacity	1,00	Constant Water Supply	1,00	User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply	1,00	High Grade of Institutional Organisation	1,00
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	1,00
							High Capacity to Pay for O&M	1,00
		4,00 0,50		4,00 0,50		5,00 0,80		6,00 0,83
Treatment	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	1,00
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M	1,00	Skilled Labourers O&M	1,00
	Ground Water Level		Load/Capacity	1,00	Constant Water Supply	1,00	User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply	1,00	High Grade of Institutional Organisation	1,00
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	1,00
							High Capacity to Pay for O&M	1,00
		4,00 0,00		4,00 0,25		5,00 0,80		6,00 0,83
Disposal	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	1,00
	Topographical Profile		Distance to other Settlement Structures	1,00	Special Material O&M	1,00	Skilled Labourers O&M	1,00
	Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters	1,00	Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	1,00
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
		4,00 0,25		4,00 0,25		5,00 0,40		6,00 0,50

Input Data Cistern Flush Simplified Sewerage Extensive Treatment

Stage	Natural Environment		Settlement Density & -Structure		Infrastructure		Community-Specifics	
Capture	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M	1,00	Skilled Labourers O&M	
	Ground Water Level		Load/Capacity		Constant Water Supply	1,00	User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	1,00
							High Capacity to Pay for O&M	1,00
		4,00 0,00		4,00 0,00		5,00 0,60		6,00 0,33
Collection & Storage	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	
	Topographical Profile		Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
	Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
		4,00 0,00		4,00 0,00		5,00 0,00		6,00 0,00
Conveyance	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	1,00
	Topographical Profile	1,00	Distance to other Settlement Structures		Special Material O&M		Skilled Labourers O&M	
	Ground Water Level		Load/Capacity	1,00	Constant Water Supply		User Committment/Education	1,00
	Availiability o Recieving Waters		Space Area Demands		Constant Energy Supply	1,00	High Grade of Institutional Organisation	1,00
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	1,00
							High Capacity to Pay for O&M	
		4,00 0,25		4,00 0,25		5,00 0,40		6,00 0,67
Treatment	Soil Characteristics	1,00	Accessibility with mot. Vehicles	1,00	Special Material Construction/Establishment		Skilled Labourers Construction/Establishment	1,00
	Topographical Profile	1,00	Distance to other Settlement Structures	1,00	Special Material O&M		Skilled Labourers O&M	1,00
	Ground Water Level	1,00	Load/Capacity	1,00	Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters		Space Area Demands	1,00	Constant Energy Supply		High Grade of Institutional Organisation	1,00
					Transport Structures (roads, vehicles, fuel)	1,00	High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
		4,00 0,75		4,00 1,00		5,00 0,20		6,00 0,50
Disposal	Soil Characteristics		Accessibility with mot. Vehicles		Special Material Construction/Establishment	1,00	Skilled Labourers Construction/Establishment	1,00
	Topographical Profile		Distance to other Settlement Structures	1,00	Special Material O&M	1,00	Skilled Labourers O&M	1,00
	Ground Water Level		Load/Capacity		Constant Water Supply		User Committment/Education	
	Availiability o Recieving Waters	1,00	Space Area Demands		Constant Energy Supply		High Grade of Institutional Organisation	1,00
					Transport Structures (roads, vehicles, fuel)		High Capacity to Pay for Construction/Establishment	
							High Capacity to Pay for O&M	
		4,00 0,25		4,00 0,25		5,00 0,40		6,00 0,50

Curriculum Vitae

Sandra Nicolics

November 2010

Born in Vienna, 15/12/1986

Education

03/2008 - 11/2010	**BOKU, University of Natural Resources and Applied Life Sciences Vienna, Austria** International Master Program "Natural Resources Management and Ecological Engineering" in English as cooperation of BOKU Vienna and Lincoln University New Zealand Specialization Fields: Ecological Engineering & Risk Management Masterthesis „Context Dependencies of Sanitation Systems with regards to Developing Countries".
04.10. - 08.10.2010	**First CC Waters Training Course, Nyiregyhaza, Hungary** on "Water Supply in a Changing Environment"
04.07. - 09.07.2010	**DEX Summerschool, Rottenbach, Austria** on Advanced Wastewater Treatment
07/2008 - 11/2008	**Lincoln University, Christchurch, New Zealand** Exchange Semester as compulsory part of the Master Program
10/2004–02/2008	**BOKU, University of Natural Resources and Applied Life Sciences Vienna, Austria** Bachelor of Environment and Bio-Resources Management Specialization Fields: Regional Development and Sustainable Development
06/2004	**Akademisches Gymnasium, Vienna, Austria** Final examination ("Matura")

Professional Experience

08/2010-12/2010	**BOKU, University of Natural Resources and Applied Life Sciences; Institute of Sanitary Engineering and Water Pollution Control, Vienna, Austria** Student Project Assistance at the project „Großflächige Regenwasserspeicher, Energieerzeugung aus Biogas und Solarzellen, klimaneutrales Umweltgebäude an der Valley View University, Accra, Ghana";
since 10/2004	**AGTA, Arbeitsgemeinschaft für Thermoanalyse (Consortium for thermal analysis), Vienna, Austria** Team-Assistance
07/2007–09/2007	**myclimate – the climate protection partnership, Zürich, Switzerland** Internship on environmental education and scientific research in terms of climate protection.