SUSTAINABLE INFRASTRUCTURE

BUILDING BAHIR DAR

b.is

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TEAM

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ABSTRACT

The population growth in Ethiopia is one of the highest worldwide. More and more of these people exchange traditional lives in rural areas for the improved living conditions they can find in big cities. To avoid an uncontrollable growth of the capital Addis Ababa, it is necessary to provide decent living conditions in the secondary towns.

In this project architects and engineers worked together to design a settlement for about 4000 people in the outskirts of Bahar Dar, a secondary town in the Amhara region. While the architects focused on urban layout and detailed construction plans of the dwellings, the engineers developed the underlying infrastructure system. The close cooperation from the start enabled us to link both parts to mutual benefit.

The final concept includes elaborated proposals for rainwater management, water supply, waste water treatment, sanitation and waste management. Instead of copying western standard approaches we focused on techniques adapted to the local climatic, economic and social conditions. The chosen infrastructure system relies on manual labour, locally available materials and the cooperation of the users themselves.

By involving the findings of new alternative sanitation systems we do not simply try to get rid of human waste, but understand it as a resource. This way we can not only reduce costs but even generate a value high enough to finance the operation of the infrastructure system and contribute to environmental sustainability.

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List of Abbreviations

a	Year
AAU	Addis Ababa University
BDU	Bahar Dar University
B.is	Bauhaus-institute of advanced infrastructure systems
BUW	Bauhaus Universität Weimar
d	Day
C	Carbon
CHP	Combined heat and power
comp	Compound
CLUES	Community-Led Urban Environmental Sanitation Planning
DN	Diametre Nominal
EiABC	Ethiopian Institute of Architecture, Building Construction and City Developm.
Fig	Figure
h	Hour
ha	Hectare
InfAR	Planning systems in architecture
ISWM	Integrated Solid Waste Management
l	Litre
m	Meter
MSE	Micro and Small Enterprises
MSW	Municipal Solid Waste
N	Nitrogen
org.	Organic
p	Person
P	Phosphorus
PE	Poly Ethylene
PEHD	Poly Ethylene High Density
ROSA	Resource-Oriented Sanitation concepts for peri-urban areas in Africa
RW	Rainwater
s	Second
UDDT	Urine Diverting Dry Toilet
UNDP	United Nations Development Programme
VIP	Ventilated Improved Pit (latrine)
w	Week

1 INTRODUCTION

Emerging countries in the entire world are not only facing high population growth rates but also a rapid urbanization. Together this leads to uncontrollable megacities with large informal settlements where no planned infrastructure exists and people struggle to find appropriate shelter. Previous semester projects tried to address these problems by providing decent housing to the people in such settlements based on experimental building techniques.

The aim of this year's project was to find ways to strengthen the secondary towns in order to give incentives for the rural population to stay in their home town rather than abandoning it in favour of the capital. We focused on the capital of the Amhara Region, Barhar Dar. While students from Barhar Dar University and EiABC developed strategies for the progress of the inner city areas, our project site was located in the outskirts of the city, about five kilometre to the south of the centre. In total the strategies generated by architects and engineers shall provide a holistic concept how the city can grow in an economic, environmental and social sustainable way.

The supposed future scenario for our project site predicted a 1000% growth of a 10 house road-settlement. Living space for about 4000 people had to be designed. To guarantee the functionality of the settlement infrastructural planning had not only to be included in the architectural planning process but to lay the foundation of it.

In a first step we had the chance to identify the current situation, the problem space and chances on the site. It had to be determined what technical infrastructure like roads, waste management, sanitary facilities etc. already exist, how they work and whether improvement is necessary or even possible. A basic understanding of the local lifestyle and perception of infrastructure was the ground on which we could decide which general systems are suitable. Then the overall system had to be linked to people on a household scale. Further level of detail included construction aspects as the choice of building materials and techniques. To ensure sustainability, the maintenance and expandability of the system had to be discussed. While the feasibility of all measures was always a key element of our considerations, the financing of the investment could not be regarded in the way we intended to do, as the project team shrank during the process.

ETHIOPIA

The Federal Democratic Republic of Ethiopia is Africa's oldest independent country and with a population of about 99 million people the second largest in terms of population [1]. Ethiopia as part of the "Horn of Africa" is a landlocked country and bounded by Kenya, Djibouti, Somalia, Sudan, South Sudan and Eritrea.

The total area is estimated at 1.104.300 km^2. Compared to Germany the total area of Ethiopia is three times the size. By far the largest Ethiopian city is Addis Ababa, which is also the capital and the economic and social heart. [2]

Ethiopia is often called Africa's water tower because 14 of the main rivers are pouring out of the Ethiopian Highlands including the Blue Nile River. All these reserves represent a high potential for irrigation and hydropower, which are underused at the time. [3]

In Economic terms, there is a large expansion and a steady growth whereby Ethiopia is one of the fastest growing countries worldwide. Ethiopia's main exports are coffee and gold, whereas the import mostly consists of fertilizers, petroleum products and capital goods [Wondifraw, 2015]. Nevertheless the Ethiopian Gross National Income is one of the lowest worldwide. As seen on the graph the

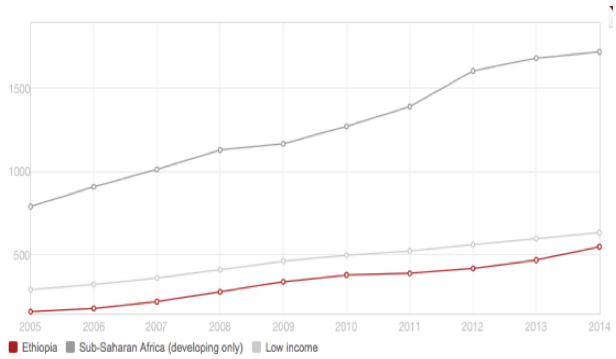


Fig. 1: GNI Ethiopia [4]

Ethiopian GNI is lower than the average Sub-Saharan GNI and even lower than the value of low income. [4] Over the last three decades Ethiopia's population has increased extremely fast due to the fact that improvements were carried out in the sector of healthcare. [5] Numbers of the UNDP show a population explosion. By doubling todays population compared to 1990, this is particularly evident. The population in rural areas has risen from about 42 million in 1990 to nearly 80 million. Based on the numbers, the urbanization will be appreciated. While the urban population amounted to 6 million people in 1990, now there are about 20 million people living in urban centers. Particularly striking is the population increase in the capital Addis Ababa, which will be further enhanced in the future. [10] By 2025, today's population will double [Donath, 2013].

However, according to Human Developing Index Ethiopia is still one of the countries with the poorest development worldwide. In a ranking of 187 countries Ethiopia ranked number 173, which shows that drastic improvement in term of living conditions of the population are inevitable. [6]

The predominant climate type is tropical wet climate, which is characterized by wet and dry season. Temperatures vary from 15-20°C in high altitude regions to 25-30°C in the lowlands. Also rain is highly dependent on the region. Generally there is one main wet season and a secondary wet season, which is comparatively weak. [McSweeney et al., 2013]

In general the climate situation in Ethiopia represents a major challenge in terms of agriculture and food security. On the one hand, there are heavy rainfalls during the wet season, which can lead to flooding. On the other hand, the lack of rainwater and water scarcity related during dry season remains a critical challenge for people and farmers. Another significant point is that due to the missing infrastructure and outdated techniques and equipment the overall productivity and effectiveness are on a very low level. However, there already are governmental initiatives, which attempt to improve the agricultural sector though promoting modern technologies, production of high value crops, encouraging micro irrigation schemes, and improving marketing institutions and infrastructure. [Wondifraw. 2015]

With the steady increase of the population in Ethiopia, the demand for food will grow, which is impossible to cope with, using the current practices in agriculture. The loss of nutrients in the soil is too heavy to be covered by the import of chemical fertilizers. Cooperation between agriculture and sanitation systems can help to close the loop and recycle nutrients. [Drewko, 2013]

Although Ethiopia has a high potential for energy production from renewable energy sources it is one of the countries with the lowest energy consumption worldwide. Ethiopia's power supply system covers a small part of the country whereby only 16% of the population has electricity in their households. The situation in rural areas is much more drastic since only 2% of the rural population has easy access to electricity. [7]

Also in terms of the sanitation coverage Ethiopia is facing major challenges. WHO/ Unicef Joint Monitoring Program's estimates show how inadequate the current situation of sanitation is. Currently 28% of all Ethiopians are using improved facilities, 14% shared facilities, 29% other unimproved facilities and still 29% are practicing open defecation. However, the difference between the rural and the urban population is significantly. While only 6% of the urban population practice open defecation, 34% of the rural population still has no access to sanitation.

In 2015 Ethiopia met the Millenium Developing target for drinking water supply. Now 57% of Ethiopia's total population has access to safe drinking water. Compared to 1990 the number of people without access to safe drinking water was halved. [8]

Fig. 2: Ethiopia

BAHAR DAR

Bahar Dar is located in the northwest of Ethiopia and is approximately 578 km north-northwest of Addis Ababa. As one of the most populated Ethiopian cities it is the capital of the Amhara region. Current estimates put the total number of inhabitants on 220.000. Compared to the first population census in 1984 (55.000 inhabitants) the enormously demographic explosion is obvious. However, it should be noted that the number of the rural population is 40.000. Currently the city records steadily growing population numbers, which are due to a high birth rate and migration rate. The city has a flat topography and an elevation of 1.800 m above sea level. Furthermore it is situated at the southeast of Ethiopia's largest Lake Tana, which is the source for the River Blue Nil. [Shiferaw, 2015]

Since Bahar Dar is a well-planned and safe city, it is above the average in many standards compared to other African cities. It was also awarded the UNESCO Cities for Peace Prize for managing to address the challenges of rapid social economic developments. [9]

2 METHODOLOGY

The project "Adaptable structures in emerging countries - Building Bahar Dar" was the fifth core module of the institute "Planning systems in architecture" (InfAR) and represented the main part of the architectural design studio of the summer semester 2015 at Bauhaus-University Weimar. This project appealed to bachelor students of architecture and master students of environmental sciences.

The course was internationally and interdisciplinary organized and managed. It was a close co-operation between Ethiopian students form Addis Ababa and Bahar Dar and German students under the supervision of teachers and specialists of different institutes [Studio Reader, 2015]

The supporting institutions were:

Ethiopian Institute of Architecture, Building Construction and City Development

Addis Ababa University
Chair of Building Architecture and Science
Dipl.-Ing. Dr. techn. Petra Gruber

University of Bahar Dar

bauhaus.ifex
Bauhaus-institute of experimental architecture

Prof. Dr.-Ing. Dirk Donath
Dipl.-Ing. Lukas Veltrusky
Dipl.-Ing Nicole Baron

B.is
Bauhaus-institute of advanced infrastructure systems

Prof. Dr.-Ing. Jörg Londong
Dipl.-Ing. Jürgen Städel

The project was introduced to the environmental engineers in February 2015 by Prof. Dr.-Ing. Dirk Donath and Dipl.-Ing. Nicole Baron. After a short application and acceptance, a first meeting between architects and environmental engineers from Bauhaus-University Weimar took place. The project was explicitly explained and information about Ethiopia was mediated. A few weeks later, in April 2015, the excursion to Addis Ababa and Bahar Dar took place. Back in Germany, the architects and engineers were divided in several groups to exchange and bring together their ideas and strategies. Besides weekly meetings and feedbacks, two series of lectures ensured a wide knowledge transfer: "Ethiopian Affairs" by members of BUW and EiABC and "Sanitation Systems" by Dipl.-Ing. Jürgen Städel. The final presentations and the final critique of all participants were on 7th July 2015 in the main building of Bauhaus-University in Weimar.

EXCURSION

Following the tradition of previous projects, the excursion to Ethiopia represented an integral and essential part of the project. The core time of the excursion was from 20th April 2015 to 26th April 2015, but a few students decided for a longer self-organized stay in Ethiopia till the end of April 2015. The journey firstly lead us to the capital of Ethiopia, Addis Ababa, and later on to the city of Bahar Dar where the project site was located. The complete excursion schedule and three detailed reports can be found in the annex.

ADDIS ABABA

After we arrived at Addis Ababa Bole International Airport, we were picked up by minibus and brought to Taitu Hotel in the district of Piazza. During the drive, we got first impressions of this big city and the rapidly growing immigration in situ. We did not only pass wide roads and multi-level buildings, but also dirt roads and informal settlements. The streets were lined with all kind of people: traders, business men, kids, beggars, police men and workers. There was a heavy traffic composed of cars, taxis, minibuses, trucks and motor scooters, although the travel ways were not in a good condition. We quickly learned that the infrastructure was badly developed. Water supply was insufficient and characterized by shortages because of faulty technologies and facilities. Waste water was mainly drained in open channels or open earth channels. Open defecation under bridges, in side streets or directly into the channels was a common view. Nevertheless, our task was an accurate analyzing of these living and infrastructural conditions. We also paid a visit to Addis Ababa University (AAU) and attended the mid-term critique of the master course of the EiABC. Furthermore, we could look at the completed "InfAR-EiABC trilogy" of experimental, technology driven building prototypes (SECU/SICU/MACU) on the campus of AAU. Other highlights were guided visitations of the Flintstone Warehouse building site, the Addis Ababa Mercato and the condominiums.

Fig. 3: Students of the Bahar Dar University and Bauhaus University Weimar [Infar]

BAHAR DAR

After half a week, the second part of the excursion lead us to the city of Bahar Dar in the Amhara region. In addition to extensive sightseeing tours, we had a consultation with the principal of the city administration of Bahar Dar. He told us that the infrastructure is old and needs to be upgraded, especially roads and water supply. Due to the fact that more people move into the city, Bahar Dar needs every additional water source. The current supply works instable. The sewer systems causes problems and needs to be modernized. We also noticed these circumstances on our own. Our stay at the NGG Hotel was branded by water shortages and power breakdowns for several days.

Anyway, Bahar Dar has still shown great determination in its efforts to tackle difficult issues – such as housing shortages, economic stagnation, and lack of electricity – by using local labour to find solutions, developing sanitation and transportation infrastructure, and generally providing adequate public services. Therefore, the city was awarded the UNESCO Cities for Peace Prize for addressing the challenges of rapid urbanization in the year 2002 [9].

For our essential work, we attended lectures and workshops at Bahar Dar University (BDU) together with the Ethiopian students and teachers. The core task was a joint investigation of the project site, a rural area to the south of Bahar Dar City [Figure 4].

After a short briefing, the students had to explore the terrain in mixed groups and to interview the local inhabitants about their living conditions, hopes and wishes for the future. As shown in Figure 5, our presence caused a sensation, especially with the children. The area was characterized by occasional settlements, dirt roads, cattle flocks and fields for agriculture. The living spaces of the families were almost too small. The income was mostly generated by men. Lots of them held down a job as daily workers. The main wishes of the people are better water supply, steady current supply within their houses in association with lights and street lights, markets, schools, a medic centre and more space for living.

Based on these facts and gained experiences, ideas and know-how could be shared among the students and strategies and concepts for this area could be discussed and developed.

Fig. 4: Meeting at the Planning Site

Fig. 5: Compounds near the Planning Site

PLANNING PROCESS

The following chapter gives a short overview of the planning process and the paradigms we followed. The planning process is divided in several steps which were executed in order during the project to reach our final task.

STEPS OF THE PLANNING PROCESS

I — Define Objectives
Task and aim of the project

II — Problem identification
Basic information
Excursion
Discussion with students and inhabitants

III — Analysis and first drafts
Evaluation of information and development of initial ideas

IV — Approaches and criteria for technical implementation
Technical alternatives and selection criteria

V — Technical solutions and conclusions
Decision on technical solutions
Overall concept

VI — Future Outlook
Next steps
Ideas for further improvements

I Define Objects

The objectives were given by the official description of the project "Adaptable structures in emerging countries - Building Bahar Dar" , as mentioned above.

II Problem identification

The second step focused on the local current situation in Ethiopia, especially on the infrastructural circumstances in the city of Bahar Dar and the rural area where the project site is located. Therefore, basic information were mediated and collected using data, case studies and experiences from other projects. During the excursion, the students from Germany worked hand-in-hand with Ethiopian students and specialists. They explored the project site and made contact with local inhabitants. As a result, knowledge and impressions were gained on-site.

III Analyses and first drafts

Still in Ethiopia and later on in Germany, the project members shared and analyzed the collected data and information. Priorities concerning the infrastructure were set. They included water supply, sanitation, rainwater management and waste management. In groups, the students built up first sketches and possible material flow systems.

IV Approaches and criteria for technical implementation

Based on the gained facts and first ideas, different scenarios for technical implementation of a suitable infrastructure were perused, depending on the local technical, social, climatical and economical conditions. We started with some simple brainstorming and mind mapping. Afterwards, we discussed advantages and disadvantages of possible technical solutions and straight followed important environmental aspects – economical, local, adaptable, sustainable, profitable, and understandable. Whenever it was possible, we tried to "close the loop" and find useful applications of every resource. With the help of simple assessment tables, we could make better decisions between the alternatives.

V Technical solutions and conclusions

After the comparison, we decided for one specific and suitable solution of every category in our infrastructure system. The technical execution is explained in a detailed way and an overall concept was established

VI Future Outlook

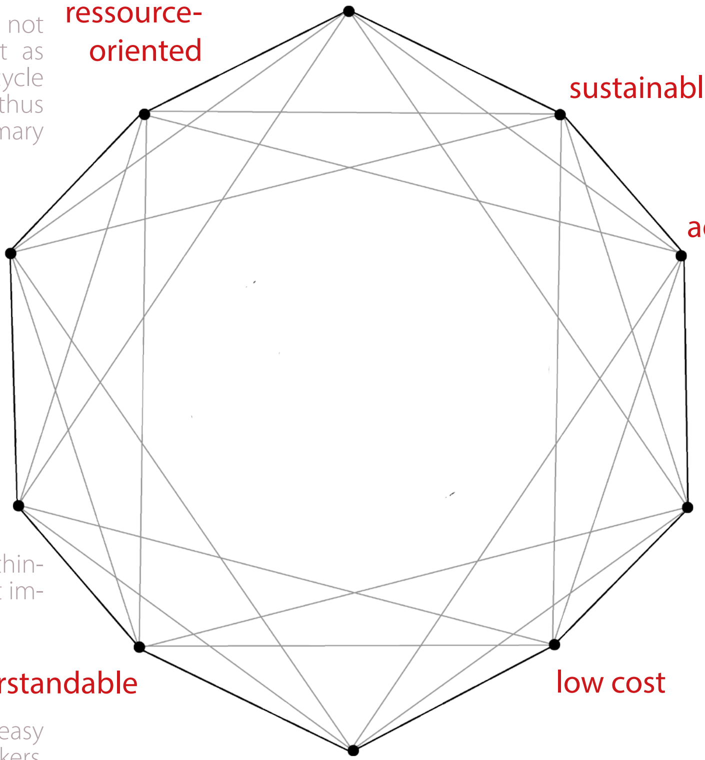
The last step should give a short look-out and how strategies for a specific implementation could be set up. Important points therefor would be user acceptance, participation and education of the users. It is also advisable to assess the future development of the concept, in particular how it can be improved and developed further. Furthermore, we introduced possible techniques.

PARADIGM

The 10 edges of the following Decagon symbolize the priorities of our planings.

integrated

We Integrated technical, environmental, economical and financial aspects. Following a holistic perspective to optimize the cooperation between all parts of the infrastructure was important to us.



sustainable

Meeting the needs of the present without compromising the ability of future generations to meet their own needs.

adapted

Our plannings are strongly oriented to the Ethiopian nation, in particular to the local economic, social and institutional circumstances in Bahar Dar.

flexible

All parts of our infrastructure concept should be easy to expand and adapted to the increasing population growth

low cost

We are not trying to implement western technical solutions, since they are by far too expensive. Our main focus is on low cost techniques and the use of manual labor. The use of mechanical devices is intended to be limited.

low maintannace

To guarantee consistent operation of the equipment, all parts have to be of good quality and in case of damage quickly and easily to repair.

understandable

All operations should be easy to understand for workers. Also residents should know what goals our concept is trying to reach.

local

In our project, the local thinking and acting is of great importance.

health / hygiene

We try to provide a healthy environment and improve the livelihood of every citizen of our planning site by minimizing the exposure to hazardous substances.

ressource-oriented

All material flows are not considered as waste but as a resource. We try to recycle every material and thus minimize the use of primary raw materials.

PARTICIPATORY PLANING

The work of engineers is always supposed to make the life of people easier. We work for people and with people. While we are trained in understanding the nature of things and know how to design technical processes, we cannot just as easily estimate people's wishes. Engineers tend to understand themselves as only responsible for the technical part. But often there is no one to link the engineers' ideas to the users' wishes. If engineers do not take care of that part themselves, it is likely that no one else will. In the end there is no other choice but to expand the own horizon and to play the role of both mediator and technical expert. Otherwise our work might not satisfy people's needs and cause additional problems instead of solving them. Guidelines that help with the participatory planning process have already been developed. One example that fits this project especially well is the Community-Led Urban Environmental Sanitation Planning (CLUES) [Lüthi et al. 2011]. Completely adapting our planning to this guideline would only have been possible, if the project had been intended to actually be realized. Yet we tried to include the key elements of this manual into our planning process. They shall here be described in short form.

7 STEPS OF PARTICIPATORY PLANNING Lüthi et al.

I Process Ignition and Demand Creation

Grievances that are obvious to us might not be perceived that way by the people who live with them. They might be living with a faulty situation for many years and be unaware that it can be changed. Thus, the first step is about promotional activities, e.g. raising awareness of sanitation and hygiene issues. In the outcome, the people should be demanding an improvement of the situation and a community task force should be formed.

Not only due the fact that we spent little time on the project site, could we not follow this step. As we had no means to actually realize the project, creating demands would only have ended in the people being less satisfied with their situation.

II Launch of the Planning Process

At the start of the actual planning process, all stakeholders come together to agree on what exactly the problems in the intervention area are and how they are to be addressed. Again, we could not do this in a project that was not intended to be realized. Instead we had to define the problem space ourselves.

III Detailed Assessment of the Current Situation

This step is about gathering information about the physical and socio-economic background of the intervention area, e.g. a stakeholder analysis and an assessment of the current levels of service provision. This information is needed in the following planning steps.

We spent the time we had on the project site to gather as much information as possible. Afterwards, we tried to cover the questions that remained by information we could gain from literature.

IV Prioritisation of the Community Problems and Validation

The findings of the steps before are now discussed in order to agree on a list of priority problems.
Since we could not do this with the people living in the intervention area, we had to prioritise the problems ourselves.

V Identification of Service Options

The technical experts now have to find appropriate infrastructure systems to address these problems. They should find a selection of possible solutions that can be studied in greater detail. The stakeholders and local authorities are informed about the systems and their implications and choose one.
Developing several proposals for infrastructure systems and elaborating the one that seemed best suited to us, was the main part of our work in this project. In the following chapters this planning process is described.

VI Development of an Action Plan

To realize the system agreed on, the stakeholders develop detailed action plans. The plans must present how the local community, authorities and private sector can fund, build and maintain the system.
The level of detail we could achieve in this project was limited. However, we considered the maintenance of the system.

VII Implementation of the Action Plan

After the actual planning process is completed, the action plan is implemented.
As mentioned before, an actual implementation was not the aim of this project.

Planning a project according to the CLUES approach requires intense communication between the planning team and the local community. Language barriers and cultural differences can make the communication highly complicated. The step mentioned first already includes finding community champions who can act as contact person for both planners and locals. If the planning team is not familiar with the conventions, finding the right people who could support the project can be difficult. In this case, help can possibly be found by organisations already working in the area. NGOs or governmental organisations can share experiences and give worthwhile advice. They can also counsel whether a top-down or bottom-up approach might be better in a specific case.

3 URBAN LAYOUT AND BUILDING TYPOLOGY

The project site is placed approximately 5 km from the city center of Bahar Dar. At present, the entire area is undeveloped and exclusively used for agriculture or animal husbandry. Overall, the rural area around Bahir Dar is very sparsely populated and only a few huts and barns can be found. The typical rural type of living in Ethiopia is the so-called compound, where several families live together on one property. Although every family has their own accommodation, it is usually to work and eat together and to help each other. The rural population is only low income and earns their livelihood through agricultural and craft activities.

Furthermore the planning area is near the Tiss Abay Road, which is a main route towards the south in spite of their poor condition. In addition, the River Blue Nile is very nearby. Moreover there is an unplanned garbage dump to find where the waste of the city Bahir Dar is deposited uncontrolled and unsorted. The thereby resulting environmental impacts are discussed in later chapters, since they have a decisive influence on the planning. The aim of the interdisciplinary work between engineers and architects is to develop an interface between urban and rural life in Bahar Dar, a combination of Ethiopian tradition with sustainable construction and practical infrastructure systems. In the following architectural considerations on household level and urban layout are presented. Since the total area was divided into three parts, which differ slightly. However, the objective is the same for all subterritory, but slightly vary interpreted in terms of building density, construction and utilization of space.

Urban scale

On the urban scale the attempt was made to find approaches to the idea of sustainable buildings, accommodating to historical circumstances, traditional Ethiopian lifestyles and affordable living concepts that are adapted to the fast-growing population. The top priority in this project is the integration of sustainable and adapted infrastructure concepts to profoundly changing the living conditions in the settlement. Following the central idea, “First look, then built”, the architectural considerations have to be guided by all necessary parts of the infrastructure. This should ensure that the settlement bases on a solid infrastructure concept thoroughly. Roads that cross the region are classified into primary, secondary and tertiary roads depending on their size. Primary roads are main traffic routes and also the largest roads. In this case there are two primary roads. One called Tiss Abay Road, which runs as a north south connection along the settlement. The other one called Merab-Msraq Road runs through the entire area from east to west. In addition there are smaller secondary and tertiary roads that run through the area, allowing the shortest possible routes and good availability and accessibility of all compounds.

The whole settlement consists of about 115 compounds, whereby the number of houses slightly differs because of the various building densities. For example the northern area is characterized by high building density, with the largest share of compounds and also the most houses per unit. The southern and western part of the area has a loosened structure with lot more free space inside of the compound and less houses. The total number of inhabitants is fixed at 4000. This also serves as a basis for planning. However, the actual population is difficult to assess, especially in the sense that the settlement evolves and that population numbers are expected to increase.

In addition to the compounds, which serve as areas for construction of residential buildings,

there are a number of important buildings with particular purpose. There are several commercial buildings, as well as micro-scale enterprises placed which usually sell or produce various goods. All of these buildings are located along primary roads and thus offer the best possible accessibility.
Within the settlement there are a big market and a piazza to be found serving as social spaces. Other significant buildings like a school and a hospital are also found within the area.

Fig. 6: Overview Planing Site

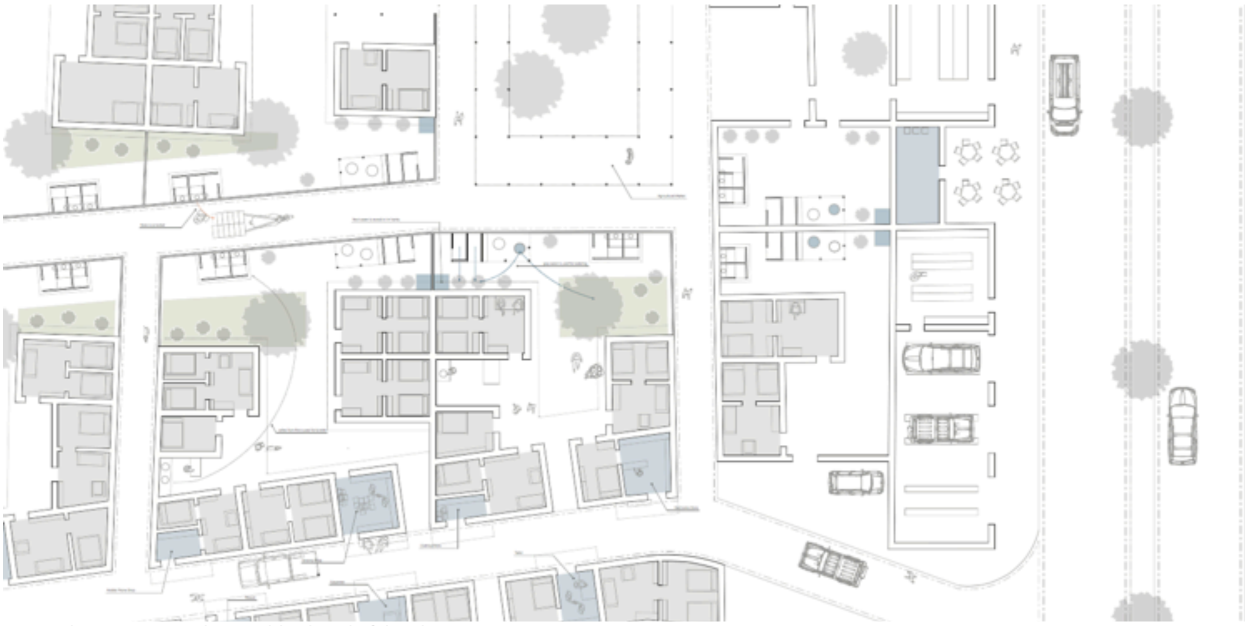


Fig. 7: Closer View into the Neighborhood of the Planning Site

HOUSEHOLD LEVEL

As already mentioned the common form of housing in rural areas is the concentration of houses to a compound. These compounds provide housing for several families and additionally serve as a place for working, community activities of all residents, livestock and growing food. Depending on the size of the compounds the use can vary greatly. Especially in densely populated areas, the usability is limited to the residential and small acreage for vegetables. Compounds that are less built up and thus provide more open space can also be used for livestock and for large-scale cultivation of food. The number of residential units may differ. Typically, it will vary between 4 to 10 units per compound. The average number of residents per compound is assumed to be 35. Likewise the structural design varies according to the building materials and construction.
Despite the different implementation, the aim is to build simple, cost-effective, robust buildings that are constructed entirely with local materials. When planning the compounds, care has been taken to provide well-planned sanitary facilities for all residents. Equally important is the placement of dry toilets, which are easily accessible from the street to enhance the collection of feces and urine. The spaces for storing waste are also designed for removing the containers from the compound easily and quick. The exact implementation of these ideas and thereby arising benefits are discussed in more detail in the corresponding chapters

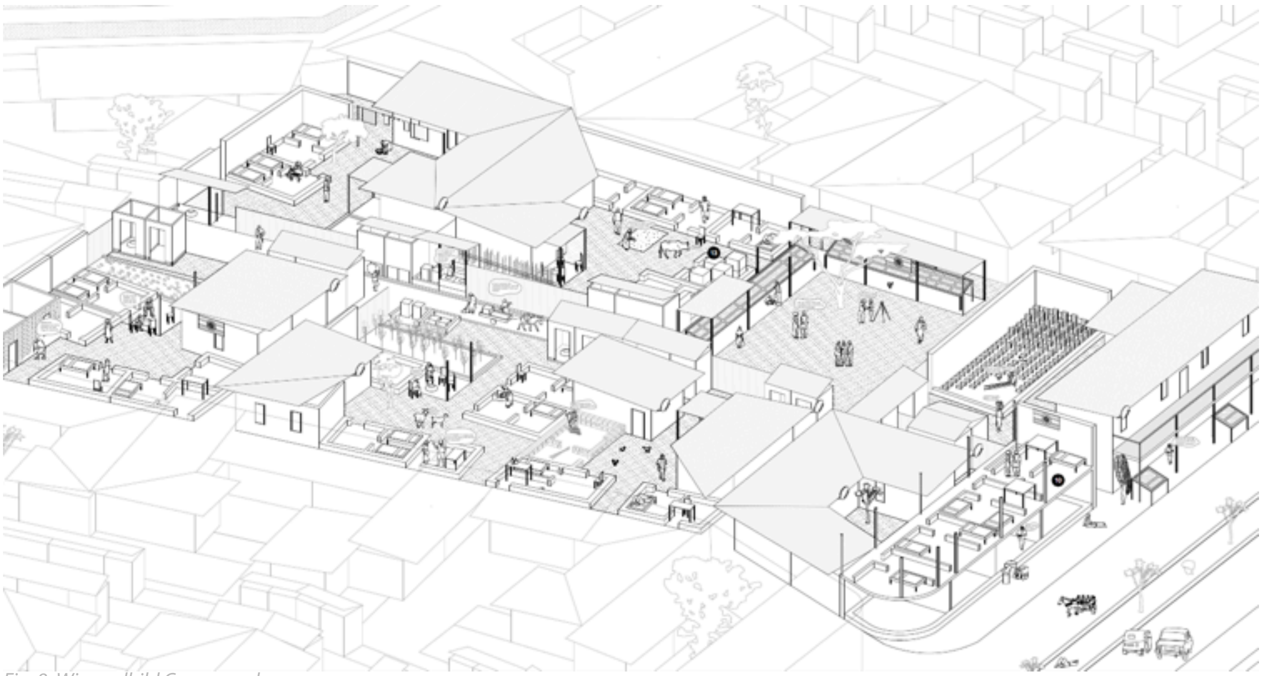


Fig. 8: Wimmelbild Compound

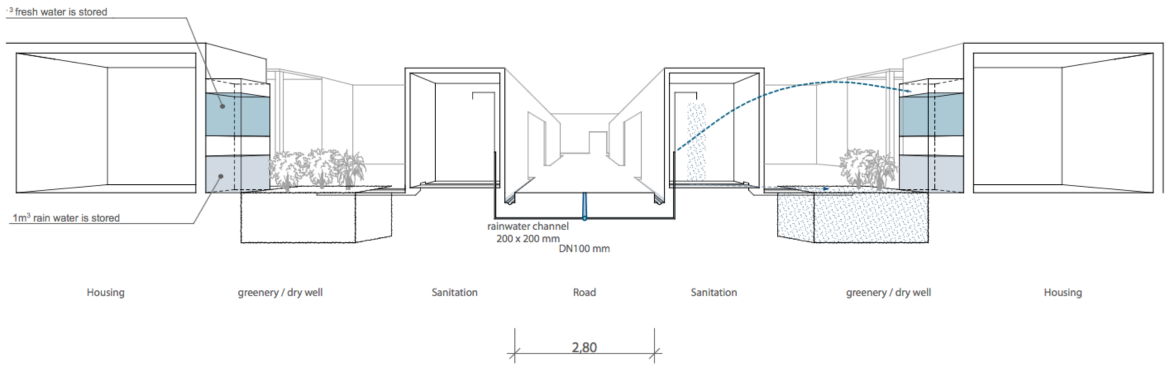
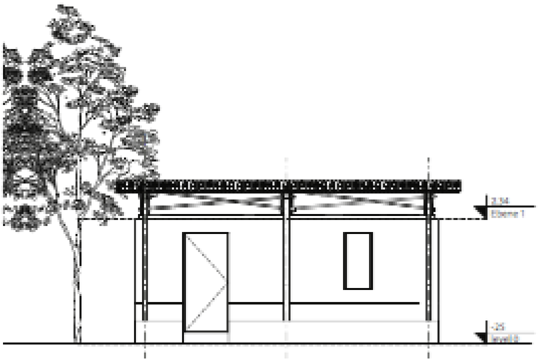


Fig. 9: Integration of Infastructural Parts at Tertiary Roads



south elevation

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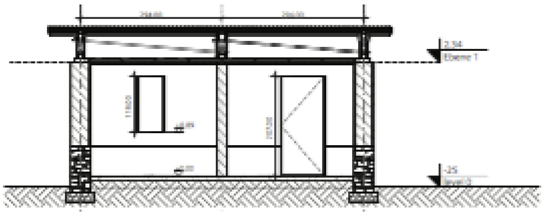

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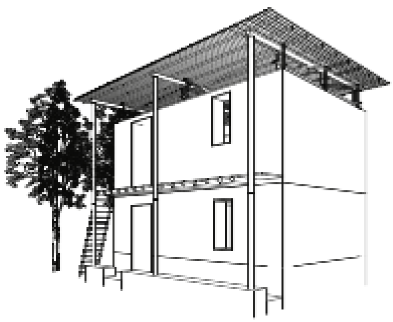

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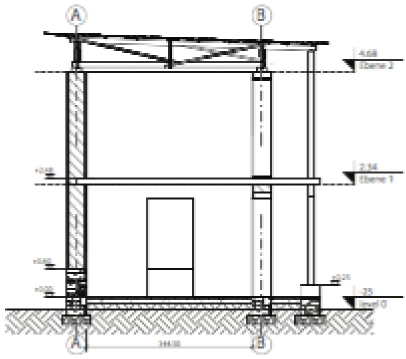

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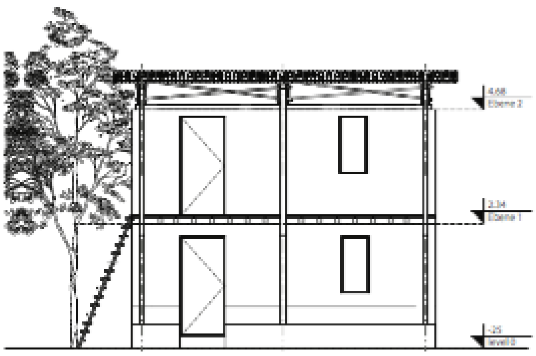
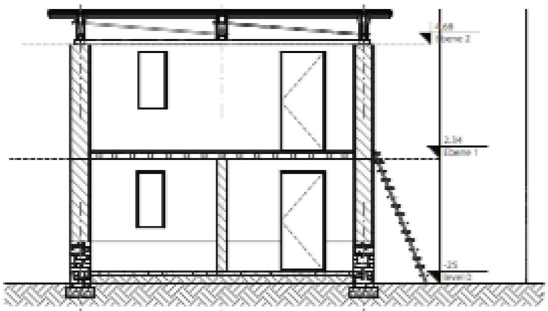


south elevation g+1

M 1 : 50



section 1 g+1

M 1 : 50

Fig. 10: G+0 and G+1 Buildings

INFRASTRUCTURE SYSTEM

4 INFRASTRUCTURE SYSTEM

The oxford dictionary defines infrastructure as: *"The basic physical and organizational structures and facilities needed for the operation of a society or enterprise"*. [11]

This broad definition includes many different parts, each of them being essential for the operation of a society. Technical infrastructure, also called 'hard infrastructure', includes streets, sanitation facilities, rainwater management, water supply, wastewater management, electric power supply, solid waste management and telecommunications. Institutional infrastructure, also called 'soft infrastructure', includes the education system, the healthcare system, the financial system, public administration and law enforcement.

Covering all these topics was way beyond our possibilities. Therefore, we had to make a selection. Our final choice was to focus on **rainwater management, water supply, wastewater management, sanitation and solid waste management**. We considered these topics as matters of basic human needs rather than luxury. Living in a city which lacks adequate solutions to these topics is not simply uncomfortable, but dangerous to health. On top of that it can lead to severe pollutions affecting the generations to come.

The soft infrastructure is just as important as the hard infrastructure and is often necessary to realize e.g. a working water supply. But it is more complicated to establish, as it mostly relies on people, not on techniques. Building parts of the technical infrastructure on the assumption that the soft infrastructure exists or will develop by itself somehow is a major mistake. Technically well designed projects can fail for this reason.

We tried to include this knowledge by the concepts of participatory planning. More information can be found at the end of the chapter. However our focus was on the technical infrastructure, as concentrating on our specialization brought the biggest benefit to the project. Including all factors that would play a role for a realization of our ideas would have gone beyond the scope of the project.

While rainwater management and water supply are well defined topics, the other named topics might need further clarification. Wastewater management is to us a holistic concept including all water flows. The usage of every water flow that enters the settlement has to be considered. This enables us to estimate the volume and origin as well as the type and degree of pollution of the water flows that leave the settlement. Adapted treatment according to the demands of the specific water leads to an increased efficiency. A basic categorization of municipal wastewater differentiates between grey- and blackwater. Blackwater is water coming from toilets, including urine, faecal matter and flushing water. All wastewater not coming from the toilet is called greywater, e.g. from personal hygiene, washing or cooking. We chose to divide the wastewater in lightly polluted greywater from personal hygiene and highly polluted greywater from cooking and laundry. Blackwater was considered as a part of sanitation rather than wastewater management, as the term only makes sense if excrements are actually mixed with water. While this is usual in the western standard approach (flush toilets) it is not at all necessary.

Sanitation can be defined in different ways:
"Sanitation generally refers to the provision of facilities and services for the safe disposal of human urine and faeces […]" [12]
"1. The study and application of procedures and measures designed to protect public health, as in the provision of clean water and the disposal of sewage and waste.
2. The disposal of sewage and waste." [13]

For us, sanitation includes all facilities for defecation, treatment and reuse or disposal of human waste as well as measures for the protection from contaminations and diseases related to pathogenic germs. Possible transmission ways of these germs are shown in the so called "f-diagram" (Figure 11). This diagram also includes the barriers that can stop the transmission: Toilets, clean water supply and hygiene. For the first two barriers we developed detailed technical proposals. Hygiene is less a matter of physical infrastructure but of promotion and education. Programs devoted to this matter already exist, e.g. the Community-Led Total Sanitation approach or the Health Extension Programme of the Ethiopian government. Nevertheless, we assured to include the necessary facilities for hygiene into our planning.

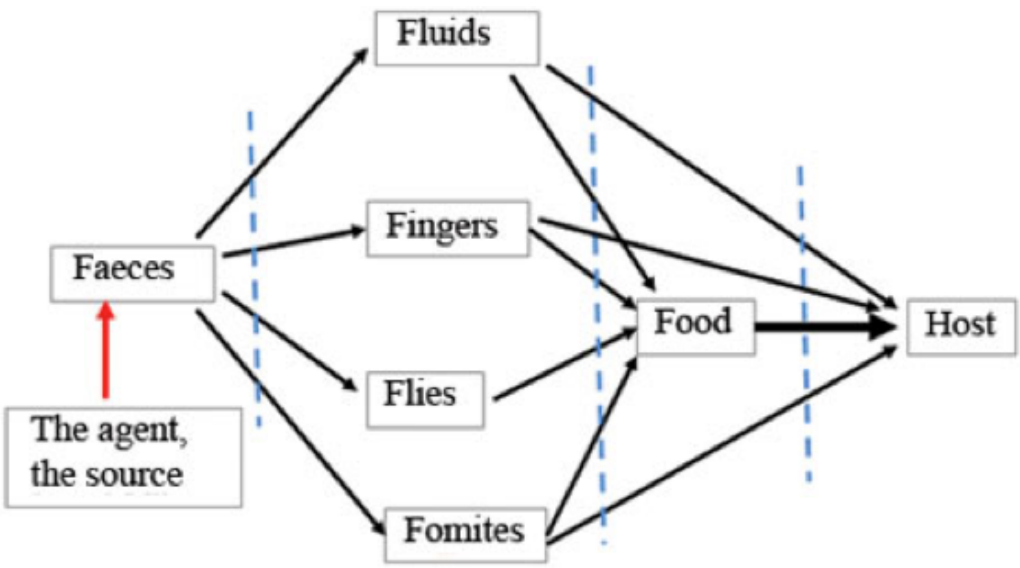


Fig. 11: The f-diagram showing different transmission ways and possible barriers of diseases [14]

Solid waste management is here limited to municipal solid waste. We regarded the leftovers from the use of goods in private households and categorized them by material. Similar to the topics of liquid and human waste, we included consideration on the origin of the waste, the collection, the treatment and the reuse or final disposal.

Each topic was covered in its own chapter. At the beginning of each chapter we described the current situation and problem space on the project site. In the next step we developed a number of measures that are adequate to address the named problems. We then decided which measures are best suited to form a working system. The criteria on which we decided are:

The required **investment cost** for the measure. Since the financial resources on the project site are limited, the measures have to be cheap in investment.

The degree of **maintenance** required to sustain the system. Running costs are a major part of the total costs, measures which are expensive in investment can still be comparatively cheap in total. Furthermore this criterion is about the complexity of the necessary work. We considered measures that need manual labour by unskilled workers as easy to maintain. Measures that need constant power supply, wearing-out technical devices and replacement parts or highly qualified workers were considered as difficult to maintain.

The **effectiveness** of the system. While all proposals are suitable to fulfil the identified requirements, there are differences in how good the expected results are. Obviously the measure with the best results is favourable.

The **adaptability** of the system. This criterion describes how well the proposed measure fits to the local conditions. We especially considered whether people in Ethiopia would naturally accept the measure or perceive it as a foreign body in their daily life.

The **expandability** of the system. As stated before, the population in Ethiopia is growing quickly. A settlement that provides a working infrastructure and comfortable living space is likely to attract many people from the hinterland. It should thus be possible to expand the infrastructure system without completely reworking it.

The selection process included discussions between all project participants. The advantages and disadvantages of every proposal were considered and were mentioned in the according description. For a quick overview of the named measures, we rated all measures on a 3-point scale: good (+), neutral (0), bad (-). The results were grouped in an overview table (Figure 12).

	investment	**maintenance**	**effectiveness**	**adaptability**	**expandability**
Measure 1	+	-	+	-	0
Measure 1	+	-	+	-	0
Measure 1	+	-	+	-	0
...					

Fig. 12: Example of an overview table

Environmental Policy

The environmental policy passed by the Government of the Federal Democratic Republic of Ethiopia can be seen as a macro economic policy and strategy framework to improve and enhance the health and quality of every Ethiopian. The main aim is to promote sustainable social and economic development whereby not only the needs of present generations are pleased but also future generations can live in a healthy and safe environment. To ensure that all objectives of the Environmental policy can be fulfilled, there are key guiding principles:

- Every person has the right to live in a healthy environment
- Sustainability is the base of using and managing renewable resources
- Minimizing the use of non-renewable resources
- Use of efficient and affordable technologies
- Increasing the awareness and understanding of the environment

There are also guidelines concerning the protection of soil and promoting sustainable agriculture. Since the agricultural sector is dominant in ecology and provides by far the largest amount of jobs it is inevitable to develop a policy for sustainable agriculture. Therefore part III of the environmental policy clarifies that existing farming systems should be improved and intensified by "economically viable and environmental beneficial" technologies. Furthermore the use of organic matter as a fertilizer to improve the soil's nutrient content should be strongly promoted.

Ethiopia is increasingly struggling with soil erosion, which inflicts great damage to the country's economy. To prevent the permanent loss of Ethiopia's soil resources it is necessary to find effective ground cover for soil conservation. All in all Ethiopia's governmental regulations emphasize on soil husbandry and sustainable agriculture, which tries to assure the livelihood of the majority of Ethiopia's population as well as the food security.

RAIN
WATER

5 RAINWATER MANAGEMENT

Rainwater management is a challenging topic in Ethiopia. Even though there is a sufficient amount of rainfall, the unequal distribution leads to water shortage as well as flooding.

The annual amount of precipitation in Bahar Dar is 1451.9mm, which is more than twice as much as in Weimar, Germany. Figure 13 shows the annual distribution of this precipitation. It is to see that there is nearly no rainfall from November to April, but very strong rainfalls from June to September. Further references to dry season refer to the months from November to April, while the wet season refers to the months from May to October.

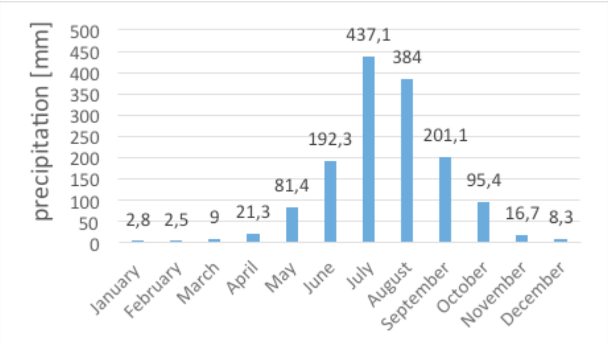


Fig. 13: Annual distribution of precipitation in Bahar Dar (based on Engida, Esteves (2011)

To protect the settlement from possible flooding during the wet season, the rainwater must be infiltrated or discharged. In order to deal with the water shortage during the dry season, the rainwater must be treated and stored.

Since we were able to spend only little time during the dry season on the project site, we could not observe the discharge characteristics. But we could see that the area is slightly sloped eastwards towards the Tiss Abay Road. Since the Blue Nile River is only about 800 meters to the east of this road, it is most likely that the rainwater discharges in this direction. For further considerations we assume that our project site has a constant slope of 4‰.

The total size of the project site is about 9 ha, thus the total amount of precipitation in the area is 130,000m^3/a. With a total population of 4000 inhabitants and a water consumption of 50 l/(p*d) the water demand in the settlement is 73,000 m^3/a. As the precipitation is twice as high as the demand, it would theoretically be possible to cover the full water demand of the settlement by rainwater use.

In praxis this will not be possible for various reasons:

It is not possible to collect all the precipitation
The necessary storage volume would be around 36,000 m^3
Depending on the further use an extensive treatment of the rainwater would be necessary
The long storage time of six months would lead to a sharp decrease of the quality of the stored water

Nevertheless rainwater should be considered a valuable resource that can help to provide a reliable and inexpensive water supply.

Fig. 14: Assumed topographic characteristics of the project site

In order to calculate the effectiveness of flood protection measures, more detailed numbers, than presented above, on precipitation are necessary. Highly intensive rainfalls which lead to overflowing channels and sewers are usually of short duration, e.g. five to ten minutes. Unfortunately, reliable numbers on intensity and duration of rainfall events in Ethiopia are not available. Engida and Esteves (2011) conducted a study in order to create a daily rainfall disaggregation model. Figure 15 shows the mean hourly distribution of rainfall in August. The white bars represent the actual values, while the black ones represent the output of the mathematical model Engida and Esteves developed. One can see that the strongest rainfalls occur in the evening hours from 18:00 to 21:00 (1.2-1.5 mm/h) and that there is nearly no rainfall from 8:00 to 11:00. During the rest of the day there are more or less steady rainfalls with an intensity of about 0.6 mm/h. These values are not sufficient for further calculations, since the hourly scale is still too rough. Furthermore they are mean values instead of maximum values.

Figure 16 shows the maximum daily precipitation per month. The highest value occurs in August with 200.3 mm/d. For comparison: The mean daily rainfall as shown in Figure 15 is only 15.2 mm/d. If we assume that 60% of the rain falls within 4 hours (the evening hours) this leads to an intensity of 84 l/(s*ha). While this value is no representation of the maxima that occurs during heavy storms, it represents the maximum rain intensity over longer time. Thus, the rainwater infrastructure has to be able to at least cover this rainfall in order not to overflow regularly.

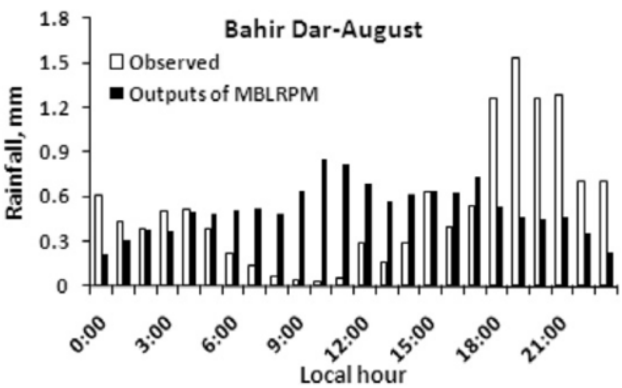


Fig. 15: Mean hourly rainfall intensity in Bahar Dar (based on Engida, Esteves (2011))

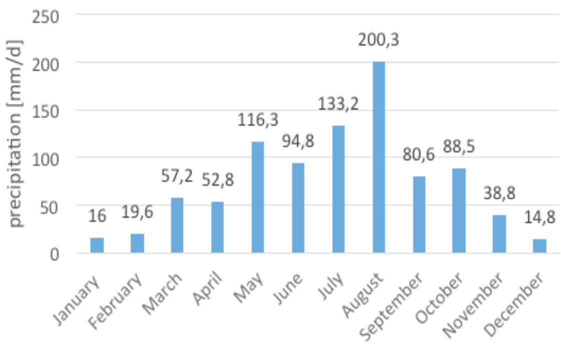


Fig. 16: Maximum daily rainfall intensity in Bahar Dar (based on Engida, Esteves (2011))

TECHNICAL ALTERNATIVES

Technical alternatives for rainwater management include different options for water **discharge**, water **storage** and **infiltration**.

I Sewers
II Channels
III Rainwater Storage
IV Infiltration

I Sewers

Underground sewers for rainwater discharge are the most common approach in Western Countries. Building underground allows to use big pipes without interfering with the above ground land use. By varying the cover height it is, to a certain extent, possible to build the sewer in a different slope than the natural slope of the area. These advantages allow high discharges. Typical pipe materials are (reinforced) concrete, stoneware and glass fibre reinforced plastics. Due to the durability of these materials and the protection an underground sewer has from direct environmental influence, it can endure for 50 to 100 years [15]. Yet, this also means that building a concrete sewer is a long-term investment. If the sewer system is used for a shorter timespan the annual costs are accordingly higher. Furthermore, a professional fabrication and laying of the sewer has to be given.

Fig. 17: Pipe installation in Addis Ababa

Our personal experience in Ethiopia showed that sewers are often damaged before they are completed. Situations as shown in Figure 17 are not unusual. Important parts of the sewer system like manholes are often missing and the quality of the available parts is mostly insufficient. Besides the pipe's quality the laying is a major issue. Qualified workers are rare, and important aspects as the pipe bedding are mostly disregarded. The fact alone that many pipes were visible rather than covered underground speaks of the inadequate installation.

II Channels

Open channels for rainwater discharge are common in rural areas, where space consumption is not an issue. They can either be ditches on fields or next to roads, small covered channels within the pavement or mid-sized open channels within paved surfaces. The discharge of the channels can be estimated with the Manning formula:

$$Q = k_{st} * r_{hv}^{\frac{2}{3}} * S^{\frac{1}{2}} * A$$

$Q - discharge \left[\frac{m^3}{s}\right]$

$k_{st} - Manning\ coefficient\ [m^{\frac{1}{3}} * s^-$

$r_{hy} - hydraulic\ radius\ [m]$

$S - slope\ [-]$

$A - cross\ sectional\ area\ [m^2]$

The shape of open channels usually leads to a worse hydraulic radius compared to circular pipes. In addition, the friction losses, represented by the Manning coefficient, are higher.

Thus, an open channel has a lower possible discharge than a sewer pipe with the same cross sectional area. Because of the relatively high space demand, open channels are limited and cannot be used in densely covered city areas.
The advantages of channels are the simple and cheap construction and the accessibility. Especially the last point should not be underestimated. Due to the inefficient waste management system in Ethiopia, high amounts of waste end up in sewers. Clogged pipes are a common sight. While it is difficult to clean underground pipes, waste can easily be removed from open channels by street sweepers. This advantage in maintenance can make the difference between a working and a failing rainwater management system.

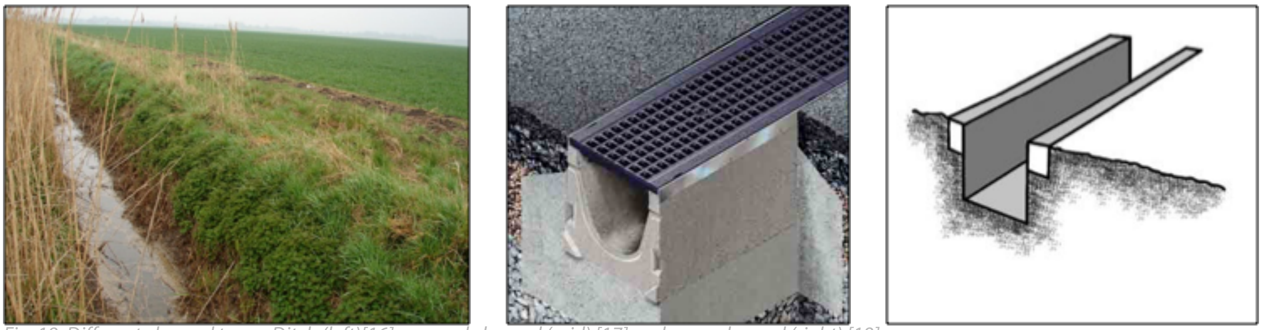


Fig. 18: Different channel types: Ditch (left)[16], covered channel (mid) [17] and open channel (right) [18]

III Rainwater Storage

One differentiates between long-time and short-time storage. Long-time storage is necessary for a further use of the rainwater, short-time storage helps to buffer peak discharges. As shown above, both is necessary under the given conditions.
Storage tanks can be distinguished by their arrangement in the channel/sewer system [DWA 2013]. If tanks are in line, they will fill and empty simultaneously with the sewer. The advantages are the easy construction and operation. By arranging the tank parallel to the sewer, with a flow-dividing structure in between, decoupling is possible. The tank fills and empties after the sewer (Figure 19). While this construction is advantageous in terms of flexibility, it requires either a pump or a great height difference of the sewer before and after the tank. A combination of both construction types is possible.

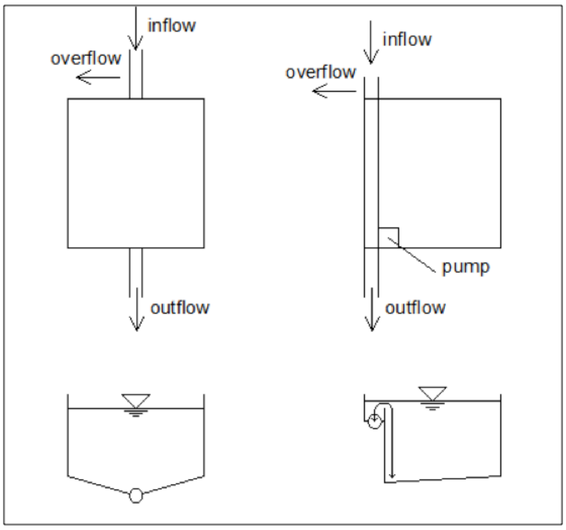


Fig. 19: Rainwater storage tank in line (left) respectively parallel (right) to the sewer

Alternatively to these big storage tanks within the sewer system small storage tanks on a household level are possible too. They can range from small barrels (e.g. 60l PE barrels) to bigger tanks (e.g. 1m^3 IBC-tanks). Since these tanks are not built underground a water catchment at a certain height, e.g. via rain gutters, is necessary to fill them. Experiences have shown that providing high quality storage tanks for every household in projects like these often leads to a high percentage of the tanks being damaged, lost or used for purposes other than intended [Diaz 2015]. However, a decentral rainwater storage is closer to the users and might be better adopted.

IV Infiltration

A further measure in rainwater management is infiltration. The water can either be infiltrated into the ground at the 'source' or at central point. The first option is especially suitable in areas with a low building density. By leading the rainwater from roofs and paved surfaces to infiltration areas in nearby gardens, sewers can become obsolete. As a result of the high space requirement, this is not possible in areas with a high building density. Nevertheless, available areas should be used for infiltration in this case too, as the required size of the rainwater discharge system can be minimized this way. In addition, infiltration leads to groundwater formation. From an ecological point of view this is favourable. It is also preferable over discharging the water into the nearest river, since that increases the risk of flooding downstream.

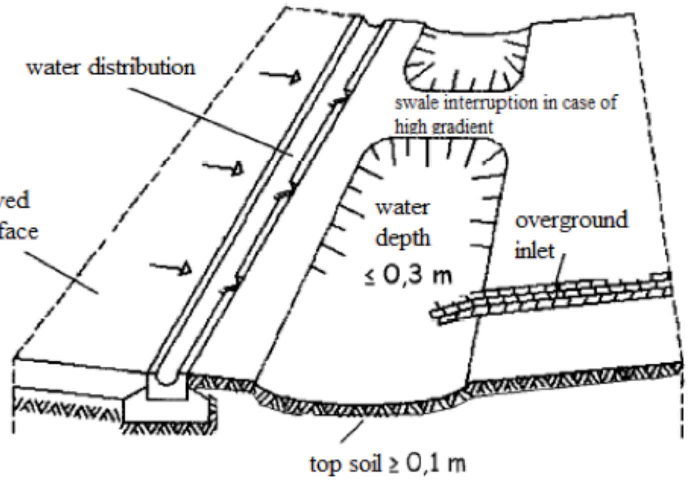
The required area for infiltration depends on its form, the connected sealed surface, design rain fall and soil type. Possible forms are surface infiltration, swale infiltration, infiltration ditches and soakaway pit (Figure 20). In specified order the needed area decreases, but the complexity rises. Surface infiltration, not displayed in the figure, only requires a dedicated area with a suitable soil, e.g. sand or gravel. Planting on the infiltration area is possible and can provide protection from erosion. For infiltration ditches, only plants with shallow roots are suitable, otherwise the pipe might be clogged by roots. Regular mowing of the planting is necessary [19].

All designs except the surface infiltration allow a short-time water storage as additional flood protection. A distance of 1.5m between infiltration surface and ground water level should be guaranteed [DWA 2005]. This becomes difficult if the ground water level is highly fluctuating, as is to be expected under the given conditions with dry and wet season. If the groundwater level is close to the top ground surface there will be limited to no infiltration. In cases of water-saturated soil combined with further rainfalls, surface runoffs will sharply increase and a harmless discharge is hardly possible. It is likely that such events take place within the project area at the end of the wet season. A proper solution to such a situation would not only require detailed information on rainfall events (see above), soil type and terrain, but also sophisticated and expensive technical measures.

As these requirements are not met in this project, we will assume that groundwater level and soil type are in principle suited for infiltration. If the project were to be realized, measurement on the ground would be mandatory.

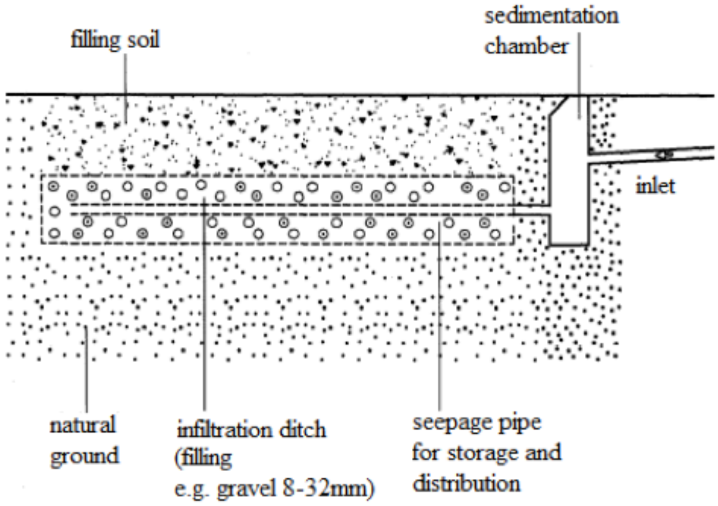
Swale Infiltration:

The swale can store water for short time. Long-time filling and too high depth can lead to clogging of the surface



Infiltration ditch:

Water can be stored in the ditch/pipe for short time. The sedimentation chamber reduces the risk of clogging.



Soak-away pit:

The flanks of the pit partly serve as infiltration surface and thus minimize the base area. An impermeable natural soil layer can be pierced by the pit.

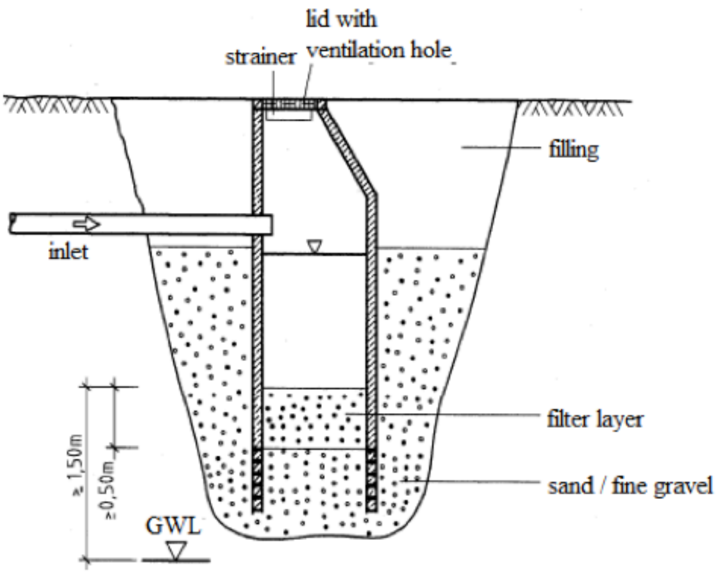


Fig. 20: Infiltration forms [DWA 2005]

CHOSEN TECHNICAL SOLUTION

Table 1 gives an overview over the presented technical measures for rainwater management.

	investment	maintenance	effectiveness	adaptability	expandability
Sewer	-	-	+	-	-
Channel	+	+	-	+	0
Central storage	-	0	+	+	0
Decentral storage	+	+	-	0	-
Swale infiltration	+	+	0	0	-
Infiltration ditch	0	-	+	0	-
Soak-away pit	-	-	+	0	+

Table 1: Overview of technical solutions for rainwater management

Based on this comparison we decided to use open channels for water discharge, central water storage and swale infiltration.

The main priority of the system is to protect the settlement from flood damage by discharging the rainwater on the quickest way to Blue Nile River. Even though sewers would be more effective for this goal, we decided to use open channels, as we do not expect a sewer system to be feasible under the local conditions. For uncomplicated construction, the channels should be rectangular. Possible building materials are concrete or cobblestone and mortar. On every compound there will be a 20x20 cm channel leading the water to the nearest street. Beside secondary streets the channel will have a size of 30x30 cm. On the main streets we wanted the channels to be as big as possible. We settled on a size of 40x40 cm as we considered anything bigger as too much of a barrier in the street room.

Fig. 21: Overview of the main rainwater channels

Figure 21 shows the location of the main water channels in the whole project site. The slope is 4‰ from east to west. East of the Tiss Abay Road the channels are connected to one ditch leading to Blue Nile River..

We will focus on a centralized solution for water storage. Besides the aforementioned disadvantages of decentral water storage, the dwellings will not have rain gutters. We engineers decided against rain gutters as their maximum drain is limited, they tend to overflow in case of heavy rainfalls. This risk is increased if the rain gutter is not kept clean, especially clogging by leaves occurs often. Since the dirt in a rain gutter is not directly visible, the gutter is also less likely to be cleaned regularly. The architects in our team decided against rain gutters on the roofs of their buildings, as they did not fit in the overall concept of the roof structure and caused additional costs. Without rain gutters a decentral water storage is highly complicated. Nonetheless, decentral rainwater storage remains an additional possibility. We leave it to the inhabitants to care for small rainwater tanks on their own. The central storage tanks will be cisterns with a size of 50m³. They will be placed on public spaces and provided with hand pumps. The stored water is accessible for every inhabitant in the area.

Figure 23 shows a top view of the inlet to a cistern. The main channel is on the right side. The main water flow comes from the top and is then redirected to the left through a screen for primary cleaning. The following serpentine channel serves as a sedimentation line. This layout allows a longer line on limited area and is supposed to slow the water flow down. A sill with a height of a few centimetres prevents light rainfalls from entering the cistern, which mostly transport mud from streets and channels. This design originates from India, where the so called tankas are traditionally used for rainwater harvesting [Goyal, Isaac 2009]. Figure 24 shows a perspective view of the inlet. In case of heavy rainfalls or if the cistern is full, the water will overflow over the 20cm high sill in the main channel and discharge to the river. Figure 22 shows the cistern with the inlet, the hand pump for water extraction and a manhole for maintenance.

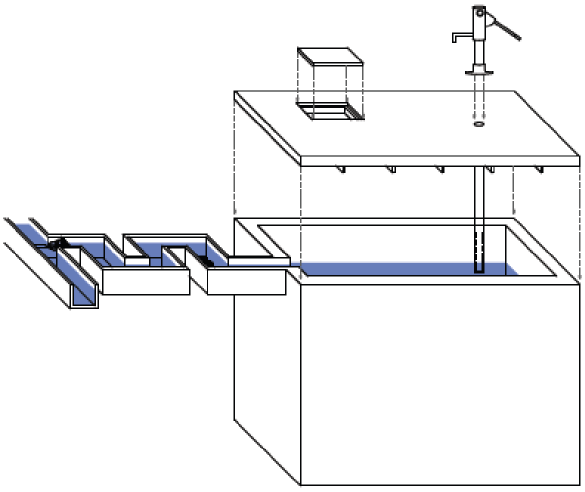


Fig. 22: Top view of a cistern inlet

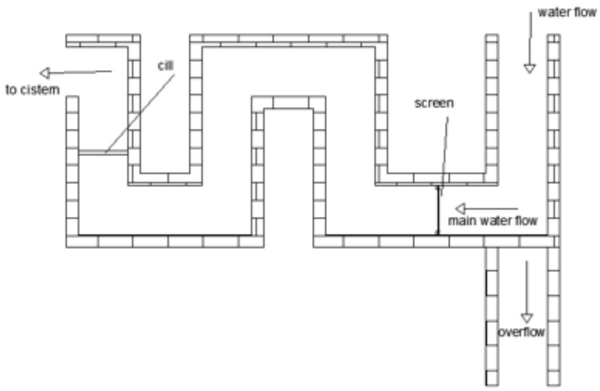


Fig. 23: Perspective view of a cistern inlet

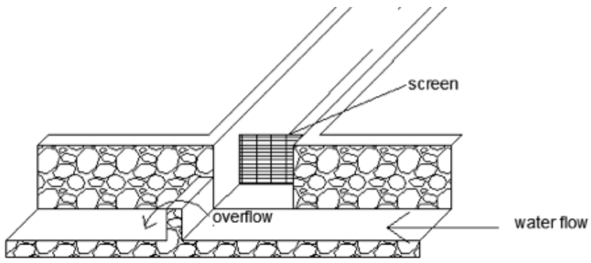


Fig. 24: Rainwater Cistern

Due to its easy construction and maintenance we decided on swale infiltration as an additional measure in flood protection. The limited disposable space does not allow to infiltrate all the rainwater, a discharge to the Blue Nile River is still necessary. The depth of the swale will be 40cm. This exceeds the suggestion by DWA 2005 by 10cm, but equals the depth of the main channels which is – due to our design – necessary for the water to flow in the wanted direction. The size was chosen as big as possible.

Figure 25 shows the inlet to a swale. In case of low rainfalls all the water is discharged. Only if the channel is more than half-filled the exceeding water gets to the swale. While this design is disadvantageous from an ecological point of view as water should rather be infiltrated than discharged, it helps to prevent flooding. If the water were lead to the swale from the beginning, it might already be filled when the peak runoff occurs.

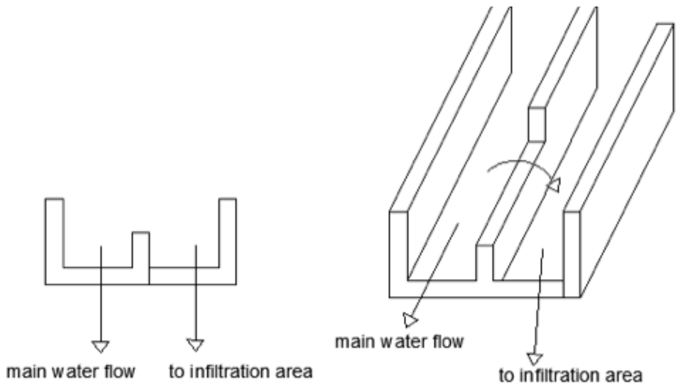


Fig. 25: Inlet to an infiltration swale

Figure 26 shows a detailed plan of the rainwater management system of the eastern part of the settlement, including channels, two cisterns with 50 m^3 volume each and one infiltration swale with a size of 15x10 m. The orange lines mark the catchment areas of the rainwater channels. Based on this allocation a calculation has been done, proving that rainfalls up to 120 l/(s*ha) can be discharged without any water overflowing. A rainfall event with a precipitation of 200 l/(s*ha) would fill the storage volume within 20 minutes. Only if it rained with this intense for a longer time, the channels would overflow. In case of heavy rains with a precipitation of 300 l/(s*ha) the storage volume is filled within 10 minutes, which is still longer than such heavy rains would last in Germany. However, at the eastern end of the map the Main Channels 1 and 2 would overflow. This would be acceptable, as the piazza can be found in this part, which is unlikely to be used during heavy rainfalls. East of the piazza further cisterns are planned.

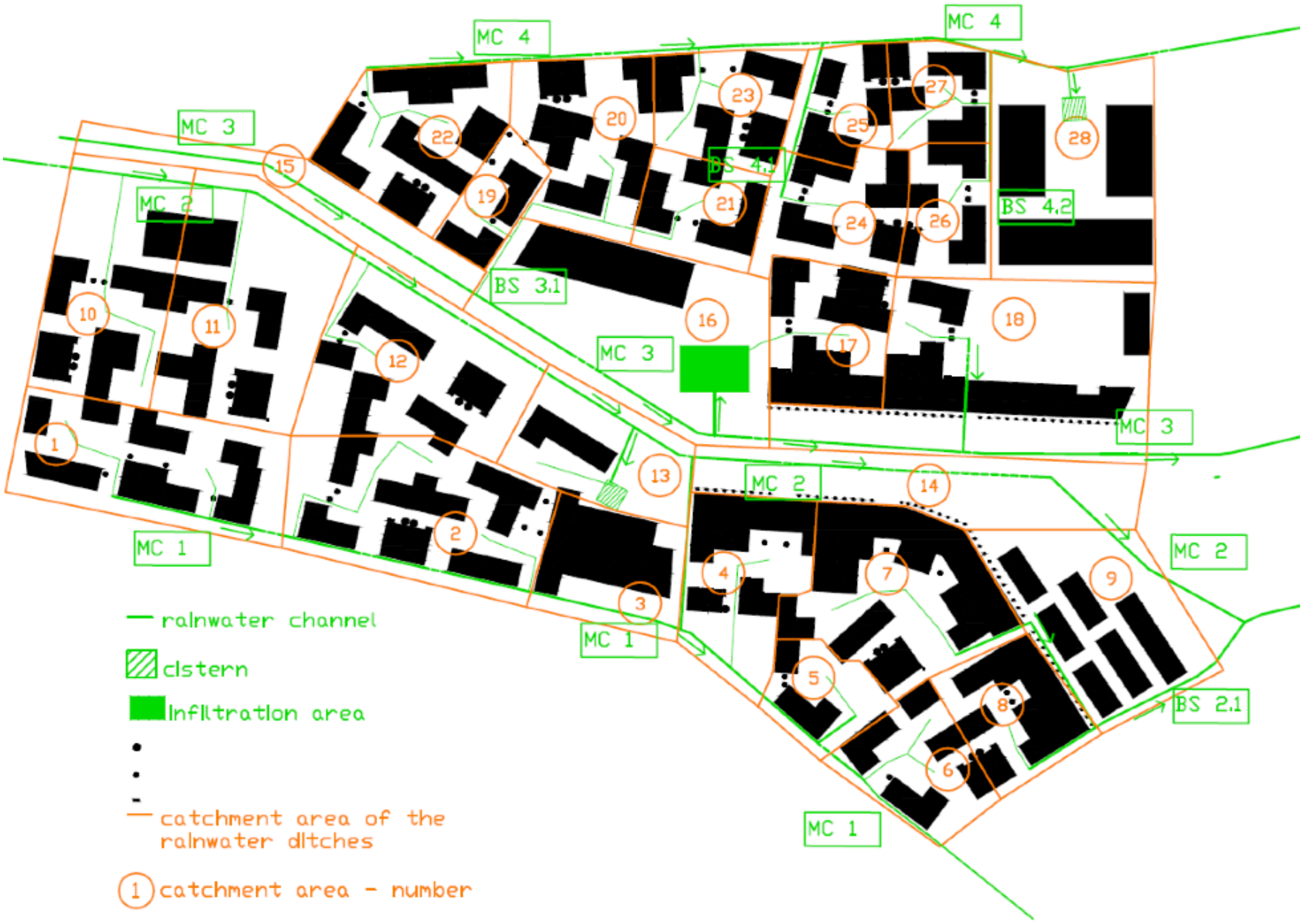


Fig. 26: Detail plan of the rainwater system of the eastern part of the settlement

Conclusion

The presented rainwater management system provides decent flood protection with the possibilities of rainwater reuse and groundwater formation by infiltration. The measures to achieve these goals are cheap and easy in construction, no complex maintenance or replacement parts (such as pumps) are required. The people can participate in planning and realization, e.g. by deciding on the location of cisterns and swales, making rules for the distribution of the stored water and by building the channels themselves. It is also possible to create a job for a sweeper who would then be in charge of keeping the channels clean.
The system is easily extendable to the north and south by adding more main channels. If it was to be extended to the west, buffering the peak runoffs by storage or infiltration would be crucial. Supposed the settlement developed to an inner-city area with a high degree of sealing, the channels could be replaced with sewers.
Figure 27 shows the rainwater cycle of the settlement, provided that the cisterns are filled twice per year and the infiltration areas are filled 15 times per year.

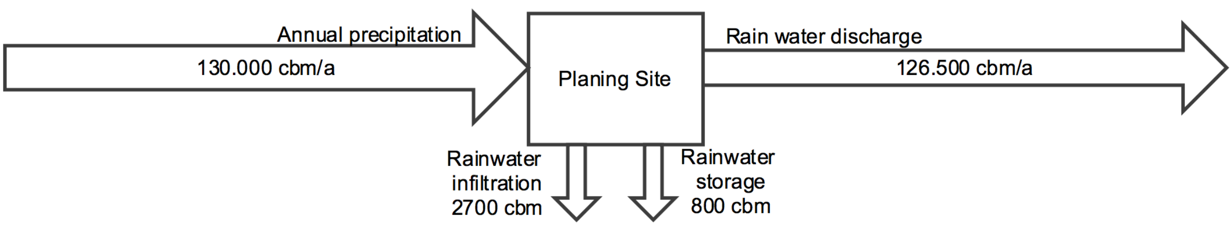


Fig. 27: Rainwater cycle

SANITATION

6 SANITATION

15% of all deaths in Ethiopia are related to water service and sanitation [Drewko 2013]. This number alone shows the urgent need for improvement in access to sanitation in Ethiopia.
According to Morella and Banerjee (2011) about two thirds of the urban population have no access to improved sanitation, two thirds of the rural population do not have any access to sanitation facilities at all. However, they also state that Ethiopia is successfully improving sanitation as the number of people practicing open defecation is sharply reducing. Figure 28 shows that this is achieved by providing access to traditional latrines. The authors call this: "Ethiopia – Getting onto the bottom rung".

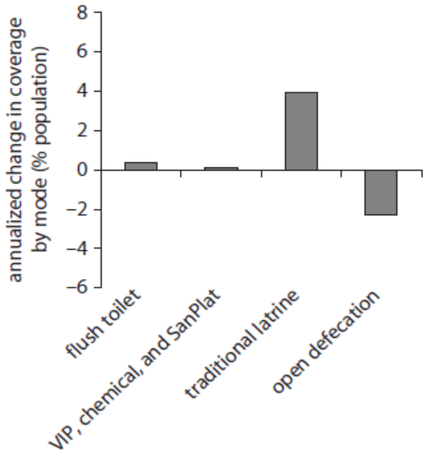
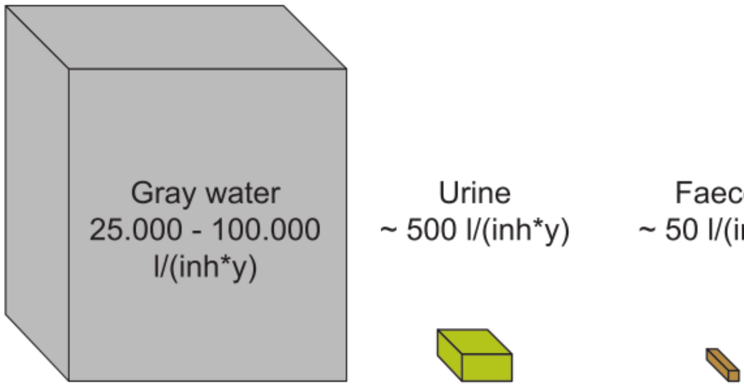


Fig. 28 Change in access patterns to sanitation [Morella, Banerjee 2011]

The trend can be confirmed by the numbers presented by the Joint Monitoring Programme for Water Supply and Sanitation (JMP) (2015). They show that one third of the rural population practices open defecation, one third uses traditional latrines and one third has access to improved sanitation. While the number of people with no access to sanitation facilities is still high, it halved within the last ten years.
Traditional latrines prevent a direct contamination of crops with faecal matter and provide some comfortability for the users (especially women) in terms of sight protection and a settled place for defecation. Furthermore, the faecal matter is not spread over whole areas and in direct contact with people and animals as it is when there is no access to sanitation facilities. Nevertheless, traditional latrines can still contribute to a spread of diseases, as there is mostly no reliable sealing and germs can get in touch with the ground water. Especially if wells are used close by, this pollution is highly dangerous health risk. Additionally, traditional latrines – if badly executed – are uncomfortable due to a possibly instable floor and bad odour. Reuse of urine and faeces is not possible.
This reuse, which does not take place in western countries either, is a main priority in new alternative sanitation systems. Not only because of our before mentioned environmental paradigms of recycling instead of dumping we consider this important. Urine contains high amounts of nitrogen and phosphorus, as well as some potassium. Faeces contain lower amounts of these nutrients but high amounts of organic carbon (Figure 29). Thus, urine and faeces are well suited as natural fertilizer, if a hygienization – killing off microorganisms to prevent a health risk – can be ensured. Especially in case of phosphorus, which is a limited resource, recycling is absolutely necessary. Otherwise the natural resources will be highly depleted by 2100, leading to increased prices of fertilizer and having a negative effect on the sustainability of agriculture [Van Vuuren et al. 2010]. Emerging countries as Ethiopia can be the first to implement a resource-oriented sanitation system. The non-existing infrastructure can be received as a chance to prevent the mistakes which have been done in the choice of the sanitation system in western countries. Since new sanitation facilities have to be built in Ethiopia anyways, we can create a system based on recent knowledge and innovations. Unlike Germany or other countries Ethiopia is not bound to an already built technical infrastructure which has to be paid over the next decades.



	Volume flow	Gray water 25.000 - 100.000 l/(inh*y)	Urine ~ 500 l/(inh*y)	Faeces ~ 50 l/(inh*y)
N	~ 4 - 5 kg/(inh*y)	~ 3 %	~ 87 %	~ 10 %
P	~ 0,75 kg/(inh*y)	~ 10 %	~ 50 %	~ 40 %
K	~ 1,8 kg/(inh*y)	~ 34 %	~ 54 %	~ 12 %
COD	~ 30 kg/(inh*y)	~ 41 %	~ 12 %	~ 47 %

Fig. 29: Amount of nutrients in faeces and waste water [based Otterpohl 2001, illustrated by iReBa 2015]

On the project site we could observe that traditional latrines were commonly used. There was one latrine per compound, usually placed at the edge of the compound. Whether open defecation has been practiced as well cannot be said. The latrines had no pits underneath, but a slightly elevated floor of simple wood planks with a hole for defecation. They were quite small, the width and length was approximately half a meter. On the project site the latrines had a height that allowed standing upright. At other places in the area latrines with a very low height (approximately 1.5m and less) could be seen too. A bad smell and flies were common at the latrines. Overall they can be described as uncomfortable. Water and soap for handwashing were not available around the latrines. The people practiced dry anal hygiene, wet cleaning was not common. However, they lacked toilet paper. Instead, sheets from old school exercise books were used for this purpose. Animal dung was dried and then used to make fire. The ashes were used as fertilizer in the gardens. Human faeces were not used in any way, the locals seem to be rather reluctant to deal with human waste.

Fig. 30: Traditional Pit Latrine

TECHNICAL ALTERNATIVES

Technical alternatives for sanitation include different options for toilets and treatment of faeces. In a variety of projects practical solutions for these matters have been tested, it is not necessary to start from scratch and develop completely new sanitation systems. Instead, different options have to be discussed and modified to fit the local conditions.

Flush toilets

Flush toilets are the western standard approach for sanitation. The toilet we are used to, was developed over centuries and thus is the first thing to come to our mind if we think of sanitation systems. As it is highly convenient for the user and people in emerging countries usually want to achieve the living conditions they know from industrialised countries, these toilets are often built there too.
For flush toilets either sitting or squatting toilets can be used. The urine/faeces as well as cleansing material is then flushed away with 3 to 20 litres of water. While drinking water is often used for this purpose, recycled water with lower quality is sufficient as well. Figure 31 shows the structure of a flush toilet. The toilet bowl or squatting plate can be made of porcelain, plastic or metal and is mass produced. They were also available on Ethiopian markets.
The flushed-away black water is then transported in sewers to a central treatment plant. High investment and maintenance costs are caused by building and running the sewers and the treatment plant. Inadequate construction work or operating can lead to major environmental damages and contaminations that might cause epidemics, as the black water contains pathogenic germs. A reliable water supply is required for the system to work.

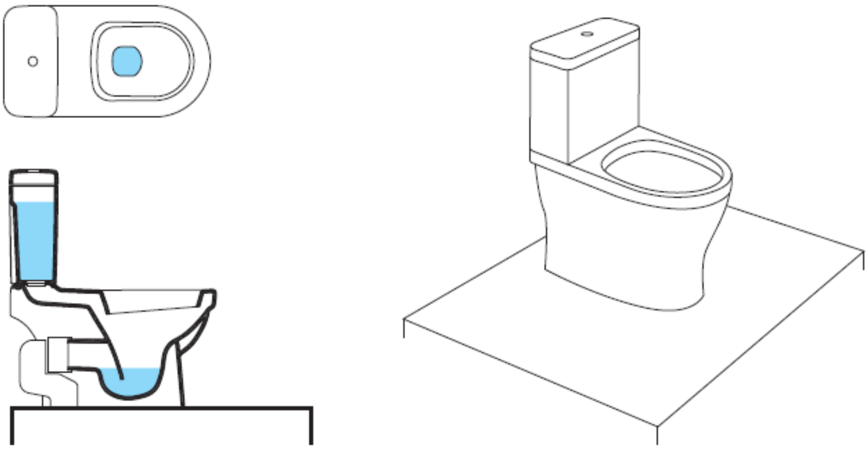


Fig. 31: Flush toilet [Tilley et al. 2014]

None of these requirements can be met under the given conditions on the project site: Concrete pipes and parts are often not available or of a poor quality, there are no skilled workers who know how to run a sanitation plant and the water supply is not reliable. Out of the seven days we spent in Bahar Dar, the water supply did not work on four days. Flush toilets would definitely be the wrong choice in Ethiopia. While we came to this conclusion very early in the project it was important to raise awareness amongst the other project participants who often did not know about alternatives to conventional flush toilets.

Ventilated Improved Pit Latrine (VIP)

The VIP latrine is a simple improvement of traditional latrines that provides better hygienic conditions and higher comfort for the user. The interior and superstructure can differ depending on the preferences and means of the user. The crucial point is a ventilation pipe, which is connected to the pit. The pipe heats up in the sunlight and thus creates an airflow from the pit through the pipe (Figure 32). Since flies in the pit can be attracted by the light at the end of the pipe, a fly screen at the top can be very useful. The elimination of odour and flies at the latrine is a high improvement at low cost and can lead to much better acceptance.

However, the before mentioned disadvantages of the traditional latrines regarding ground water pollution still exist. VIP latrines are a cheap but limited option.

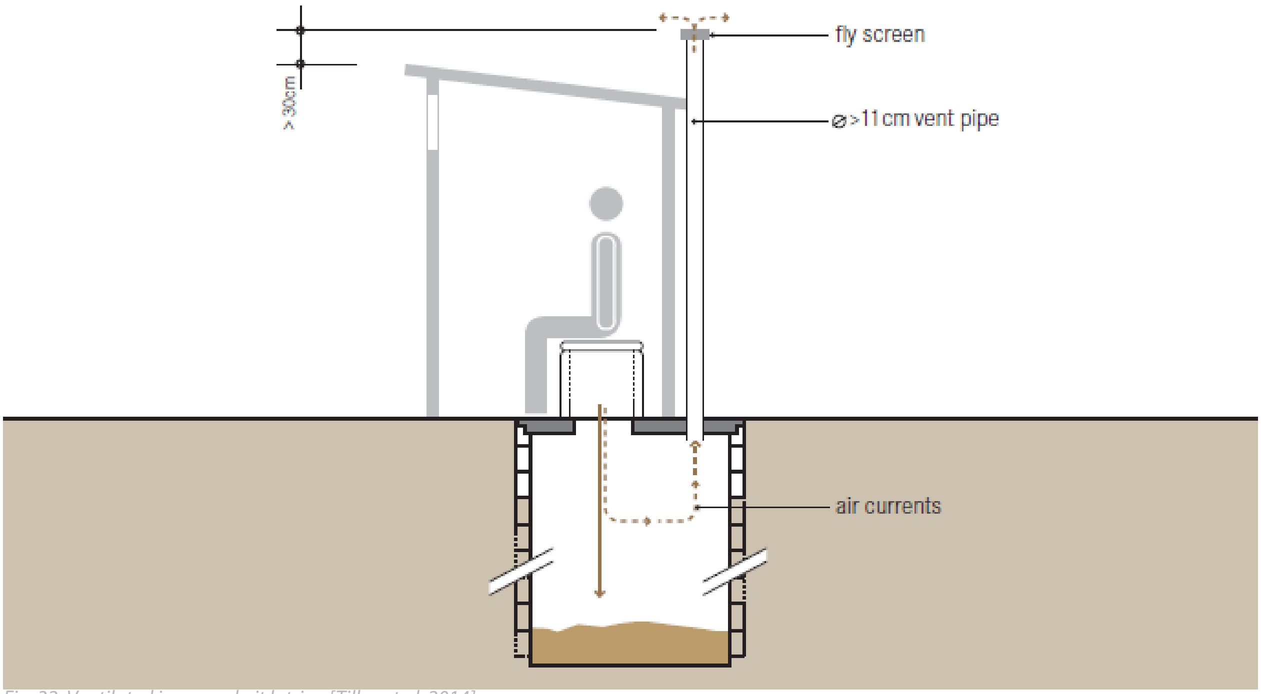


Fig. 32: Ventilated improved pit latrine [Tilley et al. 2014]

Composting Toilets and Dehydrations vaults

Further improvements of the latrine like composting toilets or dehydration toilets present different possibilities to avoid contaminations and allow further use of the excreta. They both require a water proof-pit or vault under the toilet.
In case of the compost toilet the faeces are stored for several months or even years. A ventilation provides oxygen in the pit/vault, additional water to reach a moisture content of about 50% and carbon (toilet paper, saw dust, etc.) to reach a C:N ratio of about 25:1 has to be added. The leachate at bottom has to be collected and treated. If these conditions can be provided, a decomposing will take place. The produced compost can safely be applied as natural fertilizer.
Dehydration vaults separate faecal matter and urine. The urine can be stored, treated and used or lead in a constructed wetland. The faecal matter is dried in the vault by solar heating, which kills off the germs.

Urine Diverting Dry Toilets (UDDT)

Like the before mentioned options the UDDT does not need any flushing water but a vault under the toilet. The key element of an UDDT is a toilet bowl or plate with separate holes for urine and faeces. The design is well tested and the urine diversion works as long as the toilet is used in a common way and men sit down to urinate. Figure 6 shows an UDDT slab and bowl. A major disadvantage is that these parts are not as available as parts of conventional toilets. One often has to rely on custom products. In emerging countries like Ethiopia the parts often have to be imported. Drewko (2013) calculated that it can be feasible to produce plastic toilet slabs in Ethiopia. If such a business company establishes in Ethiopia in the future, UDDTs can be built at very low costs.

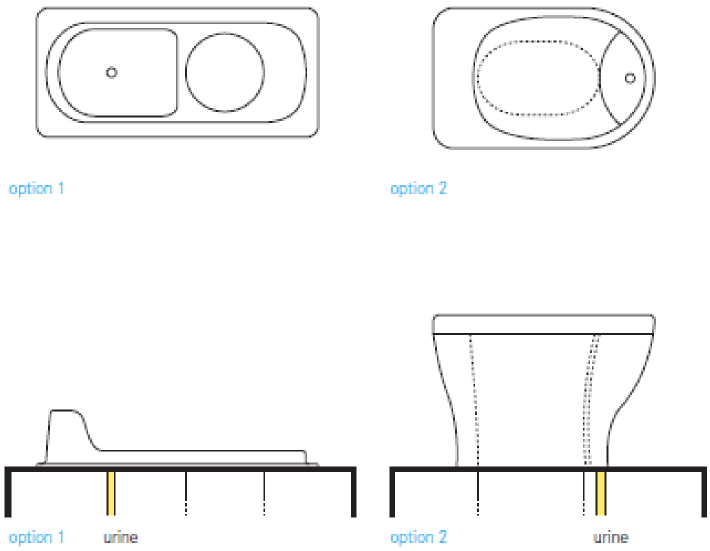


Fig. 33 Urine diverting dry toilet [Tilley et al. 2014]

The urine diversion allows much easier reuse of the excreta. Urine and faecal matter can be collected and treated in two separate containers. If the vault is ventilated as the VIP latrine, no problems with odour or flies occur. Reuse possibilities for the excreta are composting, anaerobic digestion and direct application as fertilizer.
In former projects in Ethiopia differing experiences with UDDTs have been made.
Within the project ROSA an UDDT was built for a household near Arba Minch in southern Ethiopia [Kassa 2010]. The owner asked for a solution to his collapsing pit latrine and worked together with the project team to build the UDDT at a total cost of 325€. According to Kassa, the family was satisfied with the outcome and does not only use the toilet but also reuses the excreta as intended.
At the Adama University in central Ethiopia 24 UDDTs and 6 urinals for 400 users were built [Yeboah 2012]. In this case the students had asked for a new sanitary complex close to the lecture halls. The total investment costs was approximately 45,000€. After completion the toilets are only used by 80 staff members or less and are not accessible to students. The toilets are not cleaned as regularly as intended and the collected excreta are not used.

These two examples show that UDDTs can be a great solution in Ethiopia, but an intensive cooperation with the users and other stakeholders is crucial.

CHOSEN TECHNICAL SOLUTION

Because of its simple construction and the best reuse possibilities of all presented solutions we decided on UDDTs. Two possible layouts are shown in Figure 34 and 35. Additionally to the toilet, facilities for handwashing were included. Each toilet is to be used by ten to fifteen people. We considered this as a compromise between comfort and investment cost. From our experience we can also say that this relation of persons per toilet coincides with what local people are used to. The materials needed for the toilet – stone, eucalyptus and corrugated iron – are locally available. Encouraging the users to build the toilets themselves does not only reduce costs but can also lead to a better acceptance of the toilets, as the people might rather see it as their own property and responsibility. Morella and Banerjee (2011) state that the main driving force for latrine construction in Ethiopia are women, which should be considered for the participatory planning. The book "Sanitation Without Water" by Winblad and Kilama (1985) gives detailed information on how low-tech toilets can be built by using simple methods.

	investment	maintenance	effectiveness	adaptability	expandability
Flush toilet	-	-	0	-	-
VIP latrine	+	0	-	+	+
Composting toilet	0	+	0	0	+
Dehydration vault	+	+	0	+	+
UDDT	+	+	+	0	+

Table 2: Overview of technical solutions for sanitation

Another measure to accustom the users to the UDDTs could be a workshop and setting up a sample toilet. Further, by introducing the new toilet to local schools first, children can adapt to use them. Children form new habits more easily and can act as agents of change within their families. This circumstance is already used for hygiene promotion [20]. The advertisement for UDDTs could and should be combined with a hand-washing campaign to achieve a comprehensive improvement in hygienic conditions.

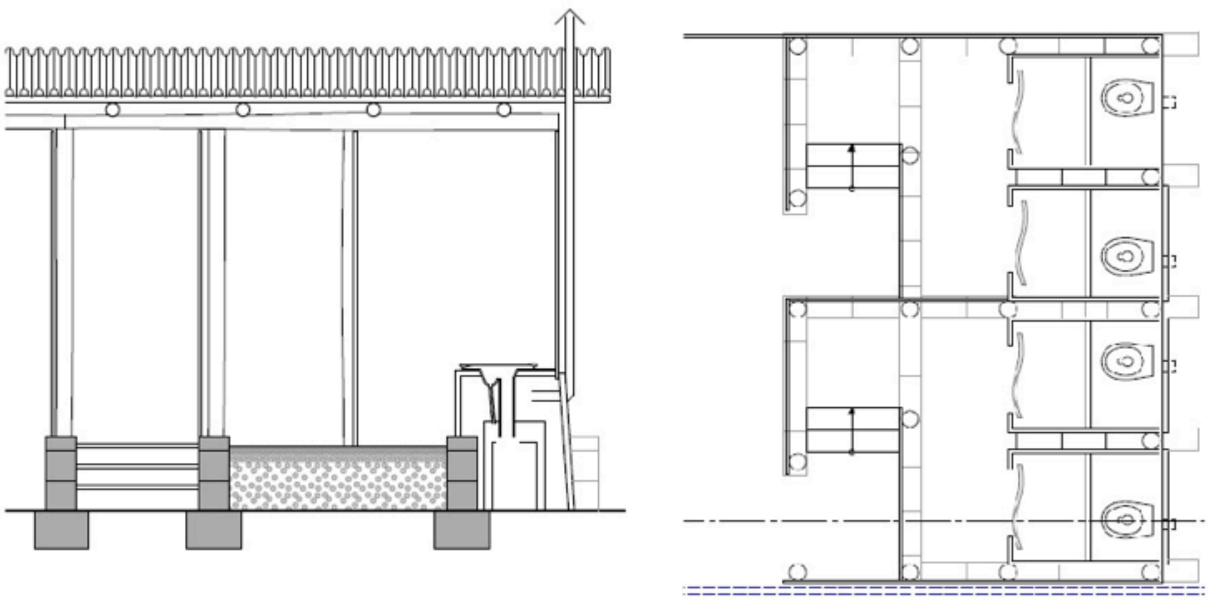


Fig. 34: Vertical and horizontal section of sanitary facilities.
Facilities for handwashing are further to the left, outside the depiction

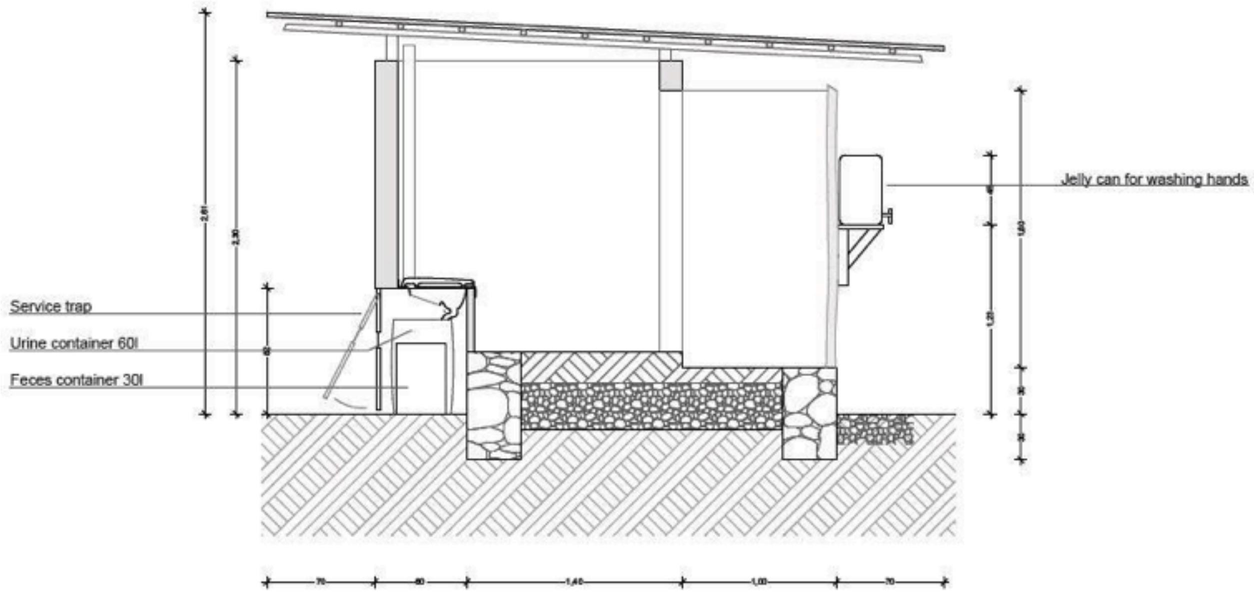


Fig. 35: Possible layout of a urine diverting dry toilet

The estimated amount of urine is 1 litre per person per day, the amount of faecal matter is 0.1 litres per person per day. We suggest to add the same amount of ashes to the faecal matter after each toilet use to reduce odour. Additionally, the ash dries the faecal matter. By reducing the moisture, worse milieu conditions for microorganisms and flies are accomplished. Contaminations could be reduced. The lower water content can also be advantageous for the following treatment.
The urine is collected in 60 litres PE barrels, the faecal matter in 30 litres PE barrels. The standard height of the bigger barrel is about 60cm. The vault has to be high enough for this barrel to fit in, in the specific case it is about 80cm high.

The trap at the backside allows quick and easy exchange of the barrels. Every toilet was placed with the back adjoining the street. The urine barrels are exchanged every other day, the faecal matter barrels once per week. For the collection a donkey cart can be used. Such carts can load up to ten barrels and are a common sight in Ethiopia. When fully loaded the cart returns to the composting plant, which is described in chapter 9. There the full barrels will be replaced with empty ones and the cart will return to the settlement to collect more barrels. A detailed plan of one collection route is shown in chapter 9. Table 3 shows the weekly workload to collect the barrels from the whole settlement. We assumed that 35 people live in one compound, leading to 115 compounds in total. In average there are three toilets per compound. In total, 175 working hours are needed. The weekly working time shall be 40 hours. Thus, five teams are needed for the collection. Every team consists of two workers and one cart, so we need ten workers.

Type of waste	**Weight**	**Volume**	**Load capacity**	**Charge amount**	**Comp./trip**	**Trip number**	**Working hours**
	*kg/comp*w*	*barrels/comp*w*	*barrels*	*kg*	*-*	*-*	*h*
Urine	245	10,5	10	300	0.95	121	131
Faecal Matter +Ashes	31,85	4	10	300	2.5	35	44

Table 3: Weekly workload for the collection of urine and faecal matter

The collected faecal matter will be composed with the organic waste. According to WHO guideline (2006) the temperature has to exceed 50°C for at least one week to achieve a hygienization. The temperature may be lower, if the time is longer. Generally, a temperature of 50°C can be ensured during a composting process. In the specific case we planned a duration of the composting of six months. Thus, there should be no problems with hygienization.

For urine the WHO (2006) recommends a storage for one month at a temperature of 20°C. After this time, the urine can be applied as fertilizer on crops that are to be processed and fodder crops. There should at least be one month between the application of urine and the harvesting of the crops. The urine has to be stored for at least six month if it is to be applied on crops that shall be consumed in a non-processed state. We decided on a storage time of one month, since fulfilling the higher requirements would result in a six times higher storage volume and the storage tanks are highly expensive. This solution requires a storage volume of 150m^3. Seasonal fluctuations in demand for fertilizer might result in an even higher volume.

The annual amount of nutrients in the urine of one person depends on personal factors and nourishment and differs from country. Table 4 gives an overview over estimated nutrient amounts per person and year.

Country		Nitrogen kg/cap, yr	Phosphorus kg/cap, yr	Potassium kg/cap, yr
China, total		4.0	0.6	1.8
	Urine	3.5	0.4	1.3
	Faeces	0.5	0.2	0.5
Haiti, total		2.1	0.3	1.2
	Urine	1.9	0.2	0.9
	Faeces	0.3	0.1	0.3
India, total		2.7	0.4	1.5
	Urine	2.3	0.3	1.1
	Faeces	0.3	0.1	0.4
South Africa, total		3.4	0.5	1.6
	Urine	3.0	0.3	1.2
	Faeces	0.4	0.2	0.4
Uganda, total		2.5	0.4	1.4
	Urine	2.2	0.3	1.0
	Faeces	0.3	0.1	0.4

Table 4: Estimated excretion of nutrients per person and year (Jönsson et al. 2004)

For further calculations we estimate values of 3kg N/(p*a) and 0.3kg P/(p*a).For the entire settlement of 4000 people this leads to 12,000 kg N/a and 1200 kg P/a. The area of cropland that can be fertilized with these amounts of nutrients depends on soil conditions, the kind of the planted crop, the harvested quantity and other factors [ltz 007]. A rough estimation can be done on basis of the values given by Gebre (2003). A fertilizer rate of 60 kg N/ha results in an additional crop yield of at least 600 kg/ha compared to the yields that are gained if no fertilizer is applied. According to Rashid et al. (2013) the application rates of fertilizer in Ethiopia are far below recommended levels. Furthermore, fertilizer has to be imported and often does not get to the farmers. Therefore, it is likely that the whole collected urine could be used on fields, on which no fertilizer is used yet. The resulting additional crop yield can be estimated on 120.000 kg/a (Figure 36).

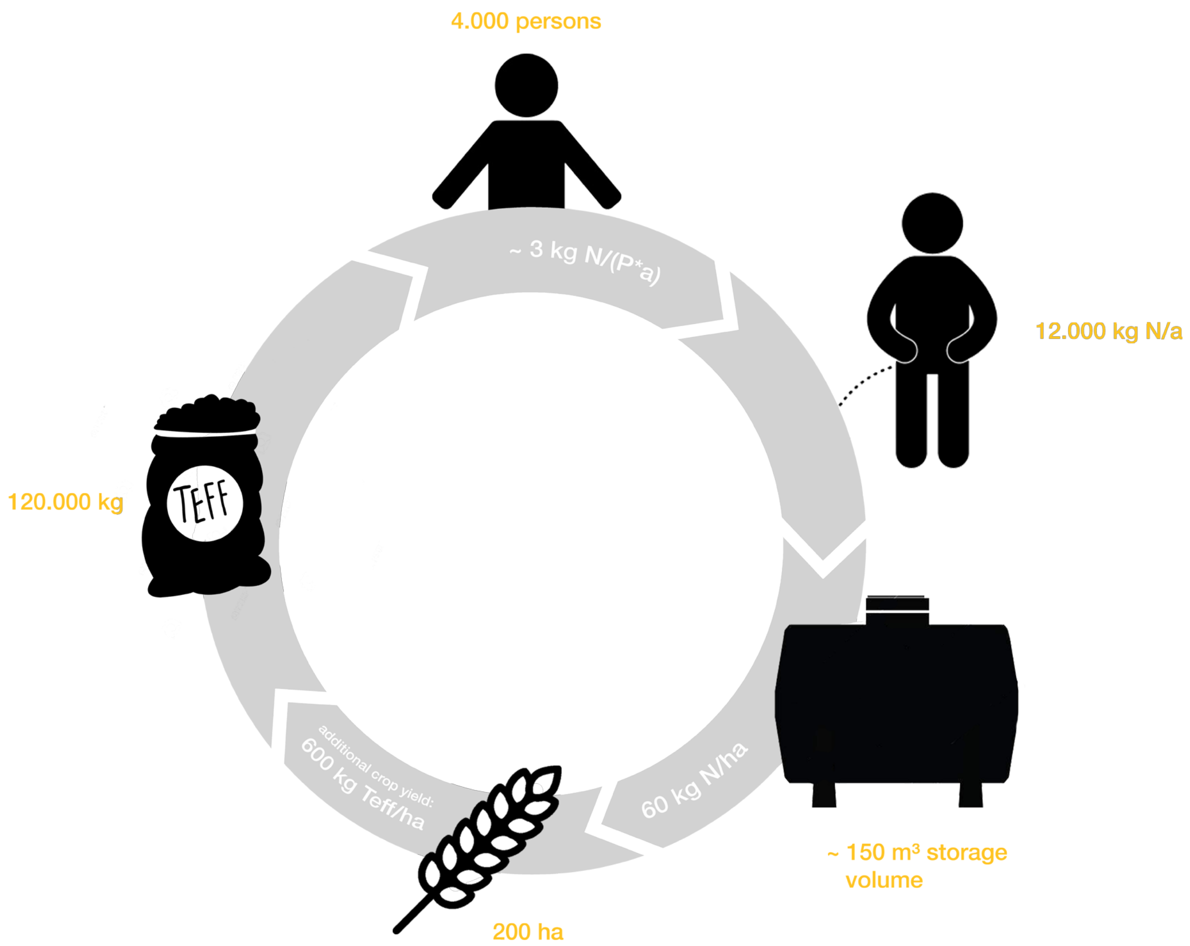


Fig. 36: Possible additional crop yields by applying urine as fertilizer

The monetary value of the nutrients in urine is estimated in comparison with local fertilizer costs. Rashid et al. (2013) state that only two fertilizer types are available in Ethiopia:

Urea contains 46% nitrogen and costs 648 US$ per ton in Amhara region, leading to a cost of 1.41 US$ per kg nutrient
DAP (Diammonium phosphate) contains 18% nitrogen and 46% phosphorus and costs 814 US$ per ton in Amhara region, leading to a cost of 1.27 US$ per kg nutrient

Multiplying the assumed amount of 12,000kg N/a and 1200kg P/a with the calculated value of 1.27 US$/kg results in a total generated value of 16.764 US$/a. While this would probably not be enough to refund the investment cost, at least the maintenance costs of the proposed infrastructure system could be covered this way.
According to the calculation above, urine has a value of 0.011 US$/l. This coincides with the results of Drewko (2013) who calculated a value of 0.008€/l for urine in Ghana.

CONCLUSION

The provided sanitation concept includes UDDTs, a central composting plant and urine storage and reuse. It is not only a low cost improvement of the hygienic conditions on the project site but also generates a financial and ecological benefit, as expensive chemical fertilizer can substituted. Except the required containers all parts of the system can easily be acquired at local markets. The construction and maintenance of the system can be carried out by local residents. The system can grow with the settlement by simply adding further UDDTs and containers.

DRINKING WATER

7 DRINKING WATER

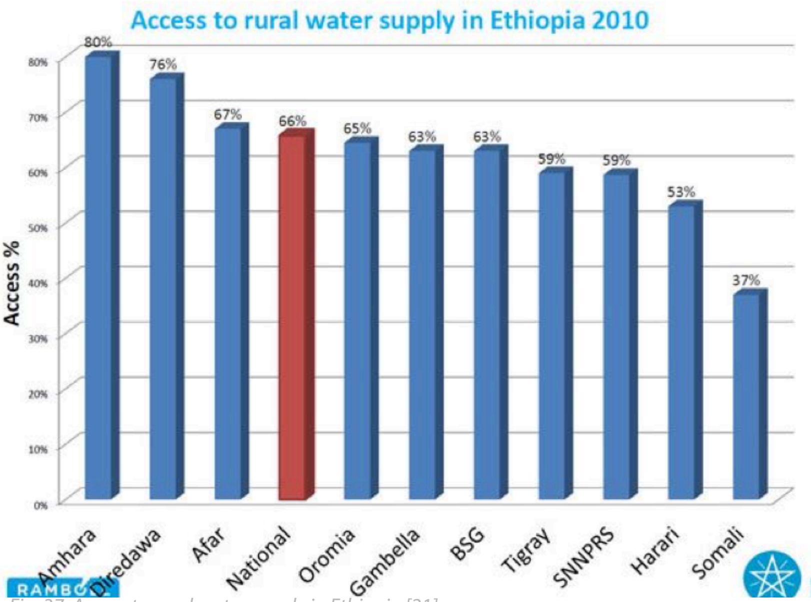


Fig. 37: Access to rural water supply in Ethiopia [21]

Ethiopia is also called "The water tower of Africa". The main reason for that is the Lake Tana, located in the Amhara Plateau. It is the source of the Blue Nil River at the city of Bahar Dar, which flows continuing through the country of Sudan and Egypt until it reaches the Mediterranean Sea. Despite the big water resources, Ethiopia is actually using only three percent of them. Because of the insufficient infrastructure, not everyone in Ethiopia has adequate access to water supply and clean drinking water(Fig. 37). Ethiopia has one of the lowest access rates worldwide. However, the country is more successful in providing access to drinking water, than it is in providing access to sanitation. But both remain at a low level.

Nevertheless, we have to deal critically with such statistics. According to some additional researches of the German aid organization "Deutsche Welthungerhilfe e.V.", approximately only one third of the Ethiopians have real access to clean drinking water. In rural areas it is even a quarter [22]. In fact, the average water consumption in Africa is actually around 20 l/p*d. The United Nations Organization (UNO) says that a human being needs at least 50 litres of water per day in order to prepare meals and to have enough for personal hygiene. 50 litres of water per day are also necessary in order to avoid diseases and to retain efficiency [23].

According to the national water footprint accounts by Hoesktra and Mekonnen (2011), the blue water footprint of Ethiopia is around 24 litres per capita. That shows that water is really scarce in the country. Every fifth household retrieves its water from open sources or rivers [24]. But the rivers are mostly contaminated with microbes and bacteria because of the uncontrolled input of waste and sewerage. The risk of infection with heavy diseases is enormous, especially to children, women and old people.
During our site visit in Ethiopia, we gained information from the local inhabitants that there is a pipe located close-by, coming from Bahar Dar with an extraction point where the people get their water from. So, for our further implementation we assume that the pipe or rather the network of pipes from the city can be expanded and enlarged to the project site. From the beginning, we have excluded the opportunity of public water pumping with wells within the area. Due to the fact that there is a waste disposal site nearby, the risk of contaminations in the groundwater is too high. This alternative comes also into conflict with the local soil erosions and the fluctuating groundwater level. Wells are also a less adaptable and effective solution when the population is increasing.

TECHNICAL ALTERNATIVES

I Water distribution network and extraction points in compounds

The main aim is to ensure and cover the UN-recommended daily demand of freshwater of 50 l/p*d. Therefor a simple piping network can be installed and connected to the existing main pipe coming from Bahar Dar City. The distribution to several compounds can be realized by distribution via transmission and supplying pipes.
For correct accounting, every compound can be provided with a water counter. Within the compounds, water can either be taken from an extraction point with only one tap or a distribution facility with several taps. Furthermore, sinks and showers at the sanitary facilities can be connected and supplied with tap water.

A huge advantage is that tap water is directly provided in every compound and there is no need to cover long distances to collect water anymore. So, time can better be used for e.g. work, education or leisure activities. The consumption is controlled and regulated by water meters. Furthermore, cleanness and correct operation of the instruments within the compounds can be guaranteed by maintenance staff.
Then again, planning and building a functional water piping network is associated with high investment costs and advanced knowledge. The calculation of pipe dimensions directly depends on the population density and has to be executed sufficiently. Another problem could be the exact accounting of fees between the inhabitants of the compound. In chapter 11 possible solution for fair cost distribution is presented.

II Water distribution network and public tapping points

Similar to the first alternative, water supply and distribution is realized by a water network connected to the supplying line from Bahar Dar. But instead providing water to every compound, it is only available at public tapping points which are evenly spread all over the settlement area. One positive aspect of this solution is that only a small water network needs to be planned and built. This option saves costs of investment and material. The accessible tapping points can be considered as additional social meeting points within the urban area. Due to the fact that water is mainly collected and transported on foot in a small amount, the total local consumption is comparatively low.

Some disadvantages can be seen in the limited possibilities of controlling and accounting the water withdrawal. An excessive and unwatched water intake can directly cause water shortages in the whole region. Corruption is also a big problem. Without enough controls on the part of the water supplier, operation safety and hygiene cannot be ensured. Furthermore, many people still have to cover long distances for getting water. This is time-consuming and physically demanding, because water is commonly transported in plastic canisters with a volume up to 25 litres.

CHOSEN TECHNICAL SOLUTION

Based on the comparison and to ensure the security of water supply, we decided for the first alternative, a water distribution network and tapping points within the compounds.

The upcoming pipe from Bahar Dar serves as a basis for implementing a simple piping network within the project site (Figure 38). Supplying every compound is achieved by different types of pipes:

- main pipe (primary) DN150
- supply pipes (secondary) DN80-100
- connecting pipes to compounds (tertiary) DN40

In our opinion, the most suitable pipe material is high-density polyethylene (PE-HD). It is a light and robust material and more favourable than galvanized steel or ductile cast iron. All pipes can be manufactured in the nearby Amhara Pipe Factory of Bahar Dar. The installation with fittings is easy to handle. For protection against damaging, sunlight or also illegal pipe tapping, an installation 0,5m below ground level is recommended. A well installed water pipe network can also be better expanded than a small one.

Fig. 38:Overview of the water piping network

Within the compounds, shut-off valves are installed in front of the water meter to connect or disconnect consumers from water supply (Fig. 39). These valves are only accessible to the local water supplier. The extractions points are aboveground and made of galvanized steel with a dimension of DN25 (1 Inch). To collect water, jelly cans or buckets can be directly placed on the stone or concrete cube under the water plug.

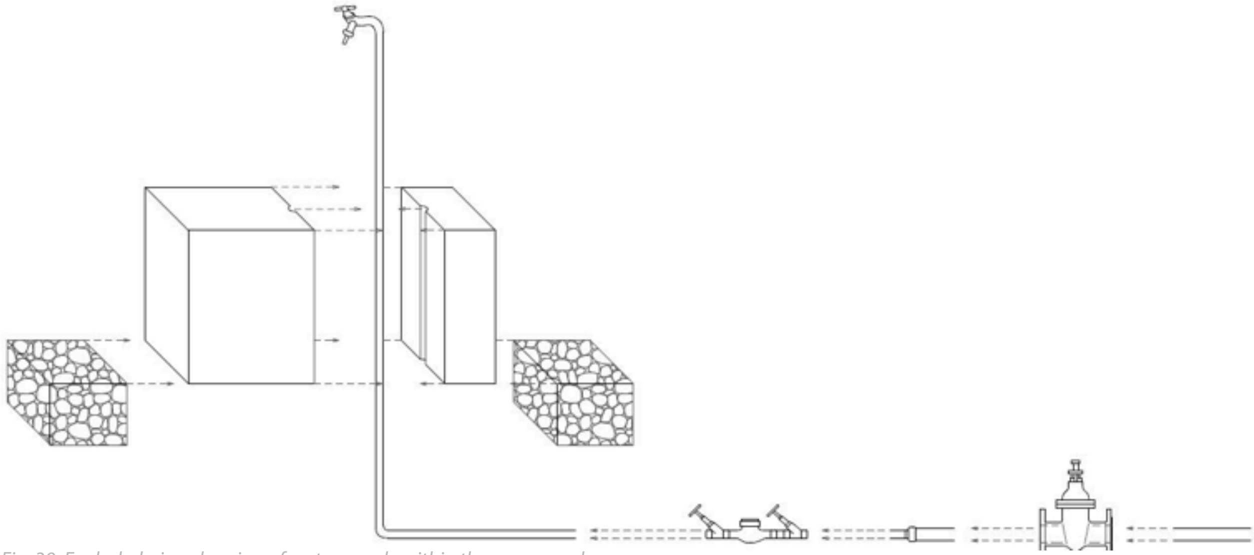


Fig. 39: Exploded-view drawing of water supply within the compound

To ensure the security of supply, people can use tanks. The tanks would have to be kept filled and used in case of water shortage or pipe burst. One option for every compound is the so called IBC-tank with a volume of one cubic meter. If we assume that water shortage occurs and the daily water demand is thus decreased to 20 l/p*d, water supply can be ensured up to one and a half day maximum per compound. During this time, required repairs on pipes or taps can be done.

Other than in Germany, drinking water quality cannot be ensured or provided because of lacking technology. Therefore, it is strongly recommended to prepare tap water before consumption. There are simple methods already existing in Ethiopia. The easiest way of treatment is boiling. Another possibility to avoid microbiological contamination is using the Solar Water Disinfection treatment method (SODIS). This method on household level is very easy to apply and was already proposed by the NESTown Group during the rural town project "BuraNEST" in Ethiopia. For water treatment, a transparent, clean PET bottle has to be filled with water and then placed in direct sunlight for at least 6 hours (Figure 40). After that time, water is microbiologically disinfected and can be consumed [EAWAG, 2002]. A third possibility for water treatment on-site is the usage of small chlorine dosing units at the tapping points. According to researches of the Stanford Woods Institute in March 2015, such devices were tested during the Stanford Lotus Water Project in Dhaka, Bangladesh. As long as the water is free from particles the method can be successfully adapted [Stanford, 2015].

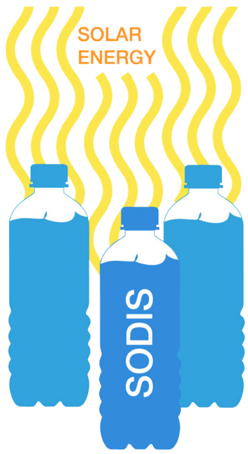


Fig. 40: SODIS Method

CONCLUSION

Based on the available piping system from the nearby city of Bahar Dar, a simple water pipe network for water supply was implemented within the project site. Every compound is served with tap water. Water shortages or pipe burst can be bypassed with several options for temporary water storage. There are lots of safe and effective possibilities of water preparation before consumption. Setting-in the construction process is primarily associated with considerable technical effort and costs, but the system is getting more and easily expandable in the future when population is growing.

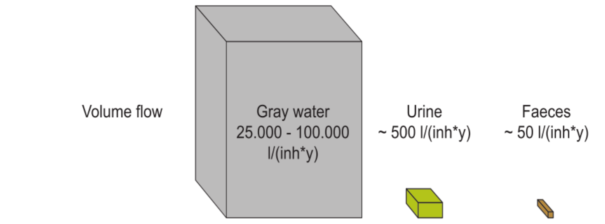
GREYWATER

8 GREYWATER TREATMENT

Most households in Ethiopia are not connected to a sewer system. They collect their greywater in jerry cans or buckets to dispose of it either on their own compound or outside. In urban areas, the greywater is often disposed through informal hand-dug sewerage connections or by emptying jerry cans on the streets, or into the municipal open storm water drains or streams and rivers flowing through the city. This water might then be used for productive purposes downstream (off-site). A common practice in and around Addis Ababa is reusing wastewater for irrigation. The wastewater (greywater, black water and surface runoff) drains into rivers, where it is used for vegetable crops downstream, including those consumed raw [EPA, 2004].

Our personal experience in the rural area of Bahar Dar has shown that polluted water, including greywater, was also often disposed of into natural channels next to dirt roads and then "re-used" by children or women for washing or personal care downstream. Only in rare cases, greywater was directly used within the compounds for irrigation and gardening.

Alternatively, greywater can better be used for more productive purposes on site, at household or compound level. This would be only one dimension of the closed-loop-concept of ecological sanitation. Due to the fact that greywater is wastewater without faeces, it only requires simple treatment. As shown in Figure 41, greywater accounts for the biggest part of the wastewater volume stream. It is lightly polluted with organics and contains only few nutrients. Greywater poses a low hygienic risk.



N	~ 4 - 5 kg/(inh*y)	~ 3 %	~ 87 %	~ 10 %
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COD	~ 30 kg/(inh*y)	~ 41 %	~ 12 %	~ 47 %

Fig. 41: Amount of nutrients in faeces and waste water [based Otterpohl 2001, illustrated by iReBa 2015

For that reason, greywater has a high potential for reusing. It can be used especially for watering and gardening, because the small amounts of nitrogen and phosphorus can additionally serve as fertilizer.

TECHNICAL ALTERNATIVES

Based on the separation of material flows, the technical alternatives for greywater management include different options for gathering, discharge, filtration and infiltration.

I Open Channels + Constructed Wetlands
II Greywater Towers
III Infiltration via Soak-away Pit

I Open Channels + Constructed Wetlands

The first idea was to collect and discharge the whole greywater of every compound in open channels for further treatment in constructed wetlands nearby the project site. Open channels are a common view in Ethiopian cities and rural settlements. Such channels are simple constructions made of concrete, natural stones or cobblestones (Figure 42) and can be built in all places where space consumption is no issue. Nevertheless, the insufficient waste management in Ethiopia leads to a high amount of solid waste being dumped in the channels. Without adequate maintenance the discharge is disturbed more and more, until the channels are entirely clogged. If the effluent stagnates, suspended matters deposit and could rot, thereby causing bad smell. An additional problem can occur during the rainy season, when huge amounts of rainwater infiltrate the channels and get mixed with greywater and solid waste. The channels and constructed wetlands could overflow, causing an uncontrolled flooding of the area and soil erosions. A sufficient discharge and treatment could not be guaranteed anymore.

Solid waste and untreated wastewater would be spread all over the area, infiltrating not only the compounds, but also soil and surface water. During the dry season less amounts of water and the heat of the sun can lead to a high rate of evaporation. Water evaporates on its way to the constructed wetlands which then could dry out and become useless.

Constructed wetlands are some of the most biologically diverse and productive natural ecosystems in the world (Figure 43). While not all constructed wetlands replicate natural environments, it makes sense to construct wetlands that improve water quality and support wildlife habitat. Wetlands are often less expensive to build than traditional wastewater treatment options. They have low operating and maintenance expenses and can handle fluctuating water levels. Additionally, they are aesthetically pleasing and can reduce or eliminate odours associated with wastewater. Wetlands are in many ways beneficial to both humans and wildlife. One of their most important functions is water filtration. As water flows through a wetland, it slows down and many of the suspended solids become trapped by vegetation. Other pollutants are transformed to less soluble forms taken up by plants or become inactive. Wetland plants also foster the necessary conditions for microorganisms to live there. Through a series of complex processes, these microorganisms also transform and remove pollutants from the water [EPA, 2004].

Wetlands can be built in two different ways – horizontally or vertically traversed. According to DWA-A 262, a specific surface area between 3 and 5 square metres per person [m^2/p] has to be assumed for dimensioning such constructed wetlands. A rough calculation with around 4000 persons living in the rural area leads to a required size of at least 12,000 till 20,000 m^2, not including factors of safety or other boundary conditions. This is quite a lot of space within the fast growing rural area around Bahar Dar where every place is needed for living or agriculture. It does not matter, if there are several small or one big wetland. The bigger the size of the wetlands, the more material would be necessary, including pipes or impermeable liner. Furthermore, constructed wetlands require a pre-treatment processes to prevent clogging. To eliminate coarse substances, it would be necessary to install a screen or something similar. To eliminate suspended matter, a settling tank would be required.

Fig. 42: Open Channels between Pathway and Street

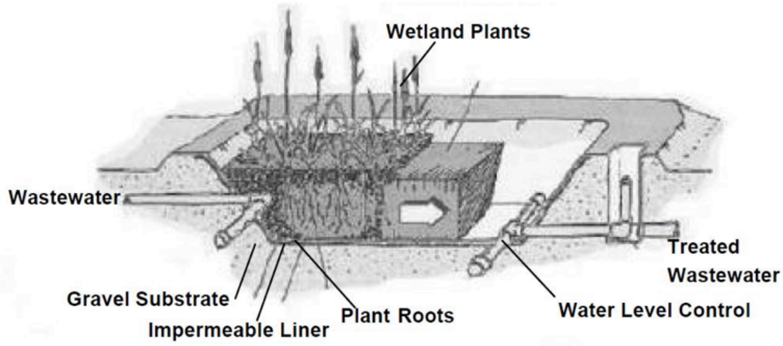

Fig. 43:Parts of a constructed treatment wetland [EPA 2004]

II Greywater Towers

The so called "greywater towers" are a suitable possibility for the decentralized treatment and save re-use of the accruing greywater from the households in peri-urban and rural areas.

A greywater tower is a circular bag with a mixture of soil, ash and compost (ratio 3:2:1) in it and a gravel column at the centre. The required stability and form is given by poles made of eucalyptus or bamboo and shade cloth, which is wrapped around the poles. A bottomless bucket with gravel is placed on the top. Furthermore, vegetables or leafy plants can be planted in holes cut in the sides of the bag. As shown in Figure 4, the daily available greywater can easily be poured into the greywater tower [Shewa & Geleta, 2010].

Fig.44 :Pouring greywater into the tower [SuSanA 2010]

The advantages of this construction are the simple manufacture and the powerless and safe operation. No skilled labours are necessary and all materials can be acquired in the nearby region. Possible repairs or expansions can be simply done by the inhabitants.

A study conducted by the EU-funded project "Resource-Oriented Sanitation concepts for peri-urban areas in Africa" (ROSA) about greywater reuse in Arba Minch (Ethiopia) has already shown that these greywater towers are cost-efficient and easy to handle. In this case study, 9 greywater towers covering 47 inhabitants were built and tested at household level. The daily average amount of greywater was around 45.7 litres per family. The total investment costs aggregated up to only 180 EUR. The concept was well proven and successfully adopted in Arba Minch [Shewa & Geleta, 2010].

III Central Infiltration via Soak-Away Pit within the compound

A further measure in greywater management is the simple infiltration of greywater via a central soak-away pit in every compound. For this solution, a strict separation between rainwater and greywater has to be carried out and an additional closed piping system for collecting greywater of every house or sanitary facility has to be built. The pits are fed underground. Similar to constructed wetlands, infiltration of greywater in that way requires sufficient pre-treatment to prevent clogging and resulting overloading of the pit. Typical devices are sludge sumps or settling tanks. Within the pit, water infiltrates through the bottom and side walls and the adequate volume allows a temporary storage of the accruing greywater (Figure 45) [DWA, 2013].

This solution can be seen as one of the easiest, but not as the cheapest. Despite that, only little space is required and the overlying area can be used for several purposes, no purification takes places and maintenance is limited. Remedying clogging because of particulate matter is associated with high costs. Due to the fact that the groundwater level is highly fluctuating in Ethiopia because of the alternation of dry and rainy season, groundwater can closely reach the top ground surface and limit a continuous infiltration.

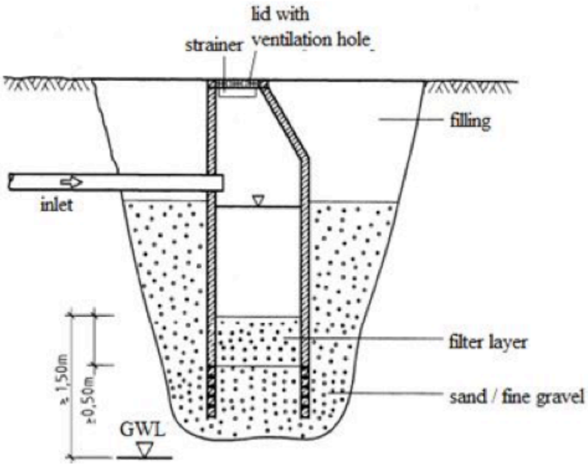

Fig.45 :Composition of a soak-away pit [DWA 2013]

CHOSEN TECHNICAL SOLUTION

Table 5 gives an overview and the assessment of all explained measures for greywater management.

Based on this comparison, we decided to use greywater towers and small infiltration areas under or next to the showers within the compounds.

	investment	maintenance	effectiveness	adaptability	expandability
Open channels	0	+	-	0	+
Constr. Wetlands	0	+	+	+	-
Greywater tower	+	+	+	0	+
Soak-away pit	-	-	+	0	+

Tabel 5: Overview of technical solutions for greywater treatment

Main priority is to gather, treat and possibly re-use the accruing greywater on-site. Therefore, we decided for decentralized solutions. Greywater towers are simple constructions and they can easily be built by the inhabitants. The required materials can either be found on the compounds itself or in the nearby area or they can be bought at traders or shops (e.g. shade clothes). The investments costs and complexity will be comparatively low. Finished, every tower has a diameter between 0.8m and 1.0m depending on the detailed execution. Nevertheless, the size can be changed or adapted by the citizens. The great benefits are the simple treatment technology via filtration and the easy and powerless operation. There will be no risk for health and hygiene, because using a greywater tower is harmless. The planted vegetables or leafy plants can be grown by ingesting the nutrients of the

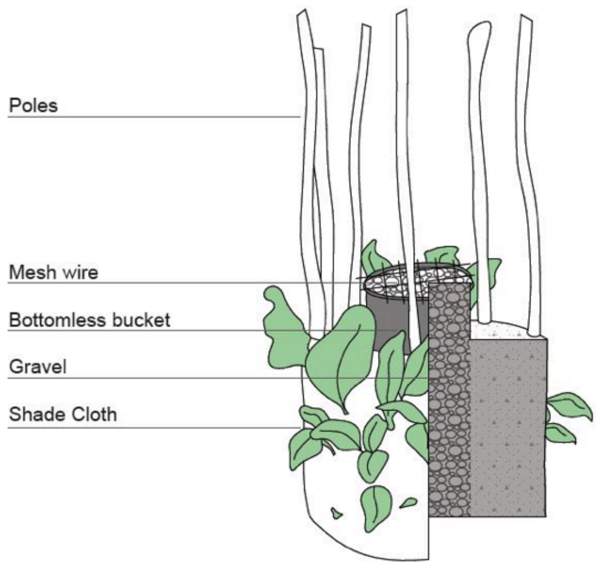

Fig. 46 :Overview of technical solutions for greywater treatment

greywater. Due to the fact that greywater includes a certain amount of bigger particles and suspended solids, the use of mesh wire on the top of the bucket is recommended to prevent the tower from clogging as long as possible (Figure 46). Against tearing and for strengthening the shade cloth cover, an additional layer of shade cloth or also mesh wire can be applied.

Another solution for decentralized greywater infiltration in small scale is shown in Figure 47. As part of a sustainable sanitation system in an emerging country like Ethiopia, the implementation of simple bucket showers in compounds was carried out by some of the Architects and Environmental Engineers. The bucket showers are part of the sanitary facilities and require only little space and a small amount of fresh water in the bucket. Showers are often realized as small cabins surrounded by metal sheets or fabric curtains. The platform is made of wood planks or grids. This way greywater from showering can easily infiltrate into the underground. Therefore, loose material like gravel or rough natural stones are preferable. Garden beds placed next to the showers can be suggestive for a further reuse of the infiltrated greywater and fruits or vegetables can be grown. However, plants with long roots have to be avoided to prevent damages on the shower construction and infiltration area.
Figure 48 shows another possibility for greywater infiltration next to a shower facility. The accruing water from the cabins is discharging via the natural slope into floor drains and then infiltrating into ground via subterranean drainage lines. As shown in the sketch, a combination with greywater towers can be built. Gardening next to the infiltration area is also possible.

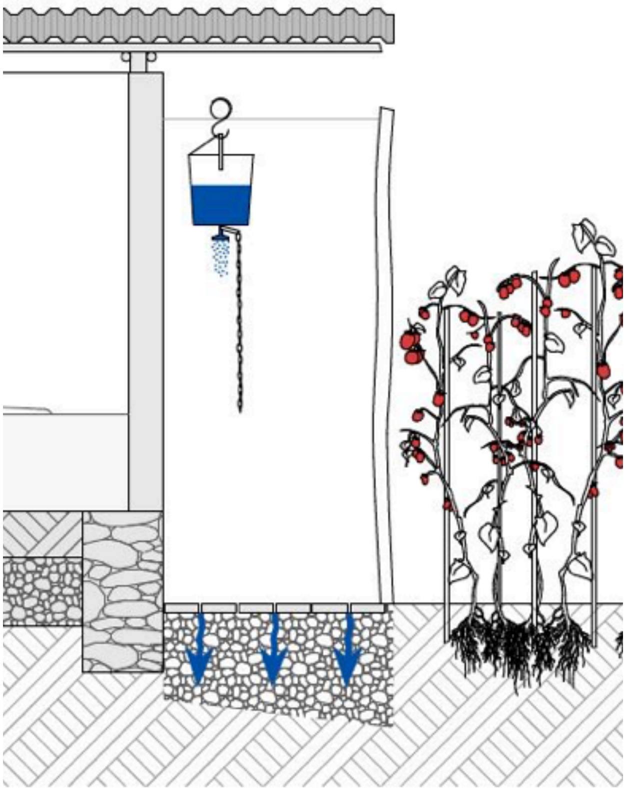

Fig47. :Bucket shower and infiltration

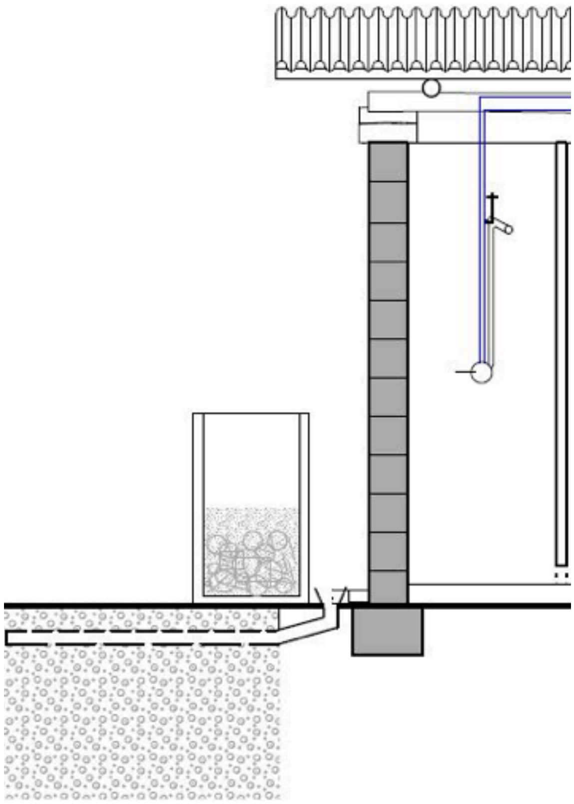

Fig.48 : Infiltration next to the showers

The daily consumption of water per person, and the resulting greywater are visualized in the figure below. It should be noted that the amount of water is 50 l, which is recommended by the UNO for a healthy and hygienic life. However, there is the possibility that the actual water consumption is lower, since people living in rural areas consume less water. Although all parts of the system are designed for 50l, we assume that on average 25l are consumed and consequently the amount of greywater is lower.

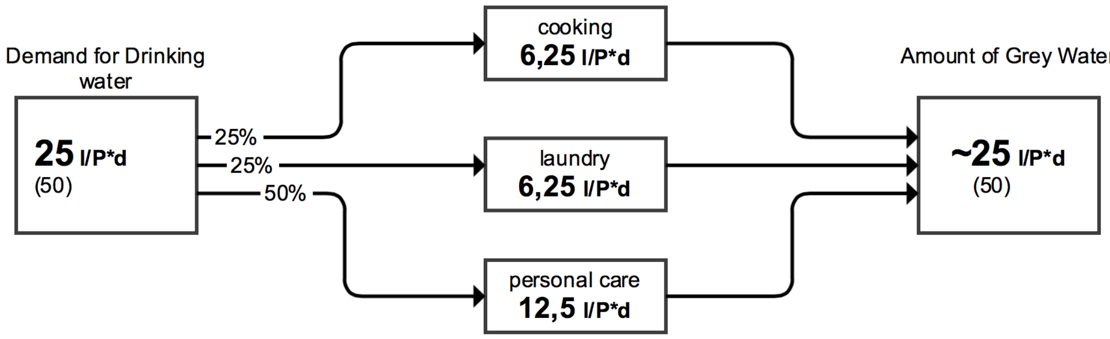

Fig.49: Greywater Flow

CONCLUSION

The listed measures for greywater management are adaptable and decentralized solutions on a household and compound level. Technical implementation is associated with low costs and material input. The hygienic conditions are improved in an ecological way and reusing greywater including food growing is set up in a new way. The construction and maintenance can easily be carried out by the local inhabitants. If the settlements grows, areas and facilities can be expanded or new treatment techniques can be discussed.

SOLID WASTE MANAGEMENT

9 SOLID WASTE MANAGEMENT

In this work the establishment of an integrated, sustainable and holistic concept for waste management and adaption to the local conditions, economy, society and environment is a top priority. It's not just about the fast removal of solid waste and pollution abatement within the settlement, but also the profitable processing of waste and subsequent utilization for reducing the use of primary raw materials. For this reason, an economical and sustainable system for the collection, transportation, processing, safe deposition and marketing of recycled products is created. The thought that solid waste is harmful and must be disposed of as fast as possible has to be changed. The idea of solid waste as valuable materials, which can obtain new utilizations by simple further processing, should be strengthened. The aim is a resource-oriented approach for operating solid waste. The basis for this approach is the division of the total waste into individual material flows. Only this way it is possible to develop sensible strategies for treatment or disposal of waste.

Further fundamental considerations for introducing a sustainable waste management concept are the analyses of the generated waste, including its composition, quantification and characterization. Equally important is an accurate analysis of the current situation of waste management system in Bahir Dar and a discussion about the legal framework and evaluating of the extent to which it is put into practice.

In a country like Ethiopia, the appropriate management of waste is relatively new and the people's knowledge regarding this is low. Therefore the behavior of the people and their habits related to waste needs to be analyzed. By public relations all people have to be convinced and should know about their benefits if all comply with the rules of an integrated solid waste management plan.

According to Klundert and Anschiitz (2001) there are sustainability goals in term of the environment, society and economy, politics, financing and institutions.

Environmental sustainability goals

Waste generation should be minimized by proper organization of production processes and increasing as well as the raw material input.

Orientation towards the 3 R's "Reduce, Re-use, Recycle" and creating "closing the loop" scenarios.

Waste, that has no potential for recycling should be disposed safely and controlled.

Social and economic goals

Jobs that are created by ISWM must offer safe and healthy working conditions for all employees.

Political and social goals

All activities concerning solid waste management shout be recognized officially and accepted by the society. Additionally effective SWM activities should ensure a clean and healthy urban environment.

Financial and social goals

Since SWM is usually financed by the society, it should be affordable for all users. In the same way it should be viable for local authorities like private enterprises.

Institutional goal

Coordination with the sector of solid waste management should be more efficient and intersectoral.

CURRENT SITUATION IN BAHAR DAR

The currently practiced method for waste collection is door-to-door collection. Residential as well as commercial waste has to be stored in plastic bags by the waste generators and is conducted by a private waste management company called Dream Light plc. [UNEP, 2010] Since the regional state health bureau legislated that private companies are part of Bahir Dar's waste management plan, only street sweeping activities are carried out by the municipality [Buwuket, 2013].
The collection takes place in regular intervals, where the bags are charged and transported by carts. For interim storage in larger containers there are transfer stations at several places of the city from which the waste subsequently is transported to the dumping side outside of the city. [UNEP, 2010]

This system only covers 31% of the municipality, so that 69% of the population of Bahir Dar has no chance to receive regulated municipal waste collection. That's why the majority of Bahir Dar's inhabitants burns their waste or illegally deposits it. [EIABC] This leads to degradation of the cityscape, an increase of air pollution but also to attacks by pests. Furthermore there is illegal dumping in open channels and manholes of the city's sewage system, which can cause major problems like clogging and insufficient drainage.

At this time the Dream Light plc. owns 7 vehicles for the transport of waste from the transfer station to the dumping side. However, it is disadvantageous that they are not designed for waste-transport and lightweight packaging often falls down due to a lack of coverage. Currently there is no waste segregation neither at the source of waste generation, nor at the transfer station or dumping side. [UNEP, 2010]

The system is financed by the payment of service fees of the waste producers. Households are paying a service fee of 0,80 US Dollars and commercial units 1-75 US Dollars depending on their size [Cheever, 2013]. However, current estimates show that this system is not sustainable.

Apart from a few incinerators by hospitals and governmental institutions there is no treatment of MSW. Recycling exclusively takes place through the informal sector, since there are no regulations for recycling included in the waste management plan. There are scavengers who look for recyclables at the dumping side and try to resell them. Especially at markets large quantities of plastic vessels are sold because they are highly suitable for the storage of liquids. This kind of recycling is primarily done for earning a living by the poor population and not because of environmental issues.

The current system exists since 2009. Compared to the previous system it is advantageous because the waste does not have to be brought to large containers at several places of the city by waste generators. Accordingly the detection rate is higher and illegal dumping has been reduced. [UNEP, 2010] The Dream Light plc. also plans to introduce sustainable treatments and increasing the recycling rate. Part of that should be treatment of bio waste to compost, the production of smokeless briquettes and biofuel. That's why the Dream Light plc. already received the World Business and Development Award from the United Nations in 2012. [25]

Dumping site

In this work it is also necessary to analyze the existing garbage dump in order to understand how it is used currently and how it could be implemented into our infrastructure concept.

„While there may be income opportunities from converting waste to other uses, it should be understood and accepted that the first priority of waste management should be to dispose the waste safely that the threat to human health is reduced" [Kumar, 2012]

For this reason, the safe deposit is as important as the sustainable treatment of waste and should not be excluded prematurely.

Landfills are always defined in relation to their isolation and differentiation from natural materials such as soil, groundwater, air and people. By sealing layers beneath the landfill and covering with earth or other substances above the waste, the contact with the environment is minimized. [Diaz et al., 2005]
In this case, the deposition can not be considered a landfill under any circumstances. It is only the unplanned dumping of waste on unprotected ground and without cover, and therefore a dump. Arising problems due to an uncontrolled dumping are serious. Since there is no sealing between the soil and the waste it must be assumed that leachate enters the soil. This problem is exacerbated by water, which accumulates into the waste body during rainfall and thus increases the amount of leachate. Leachate can be regarded as highly contaminated waste water containing heavy metals in addition to organic ingredients.
The lack of compaction of waste by mechanical compactors is equally disadvantageous and causes an unnecessarily high volume of waste as well as a high demand for space. The lack of coverage also causes a variety of serious problems. First, there is a risk that scavengers could come in contact with hazardous substances and injure themselves or others. Secondly, as already mentioned the problem persists that water is free to enter the waste body. Likewise animals can burrow through the waste and thus spread diseases.
Because all waste is deposited completely unsorted, it should be assumed that the content of organic matter is relatively high. Thereby the formation of methane gas by biodegradation of organic matter in oxygen-free parts of the waste body can be a result. Consequently the absence of coverage significantly increases the escape of climate-damaging and toxic methane from the waste body.

In summary, one can say that the dump, due to lack of seals and cover and by the absence of management systems for leachate and methane gas, cannot be part of a sustainable waste management system. Nevertheless, we have decided to integrate it. Although it is not possible to improve the overall situation greatly, we found several approaches. The deposition of degradable organic matter should be reduced or prevented because all collected waste is separated, whereby organic waste is composted exclusively. Likewise, the amount of deposited waste is minimized, since only inorganic materials are deposited that cannot be recycled.

Compared to the total amount of waste deposited daily, however, the waste from the planning settlement occupies only a small role, whereby no serious improvements are possible. However, the planning of an independent landfill for safe depositing of waste from the settlement is beyond the scope of this project. In addition to the large number of drawbacks in the use of the dump there is also the advantageous geographical location. Since it is placed right next to the settlement, thus no long journeys are necessary.

Fig. 50: Bahar Dar's Dumping Site

Fig. 51: Closer Look at the Waste Composition of Deposited Waste

Governmental and regional regulations

The Ethiopian Environmental Law directly addresses waste management issues in the Solid Waste Management Proclamation. It legislates the storage at household level, collection and transport as well as treatment and collection of municipal solid waste. Source separation should be achieved by storing waste separately at household level. Urban Administration should regulate that adequate systems for the collection and transportation in the city are available. It should also be ensured that public and other places where waste is generated increasingly, are equipped with suitable containers. Regarding recycling systems glass manufactures should implement actions, which allow the collection and recycling of glass. There is no environmental law in the Amhara region or Bahir Dar established but it was tried to implement national environmental regulations concerning waste management. Since regional differences in Ethiopia are very large, this presents serious problems in terms of implementation and monitoring. Although the Regional State Health Bureau has tried to establish a solid waste management plan the implementation and enforcement of laws and regulations is hardly realized [Bewuket, 2013].

WASTE CHARACTERIZATION

Waste characterization is a major part in planning of solid waste management systems. It is defined as "a determination of quantities, composition, and other properties of municipal solid waste through scientifically conducted field studies." [Diaz, 2015]

Within this project the characterization of waste is of particular importance in the planning and dimensioning of storage, disposal and the further treatment steps. For this reason, great emphasis was placed on truthful data to use in terms of waste volumes and their composition.

The available data was determined by sorting analyzes in Bahir Dar and Addis Ababa [UNEP, 2010'; Escalante et al., 2013]. In both analyses, samples were taken at the source of the waste and afterwards sorted, dried and weighed. Since the analysis of the city Bahir Dar applies to the urban space without differentiation of population groups, the results cannot be transferred to the planned area. Due to the small number of samples and the calculation exclusively with average values for the number of families per housing unit and persons per family, it is to assume that the results of the sorting analysis are not accurate and are difficult to adjust to rural areas. By contrast, the analysis of the processing performed in Addis Ababa is more appropriate, since it considered various income groups. In addition, interviews with each test subject were performed considering the number of family members. Since the waste composition varies very strong seasonally, the results should be differentiated between rainy and dry season or averages must be calculated [Diaz, 2015].

As this was applied in the sorting analyses in Addis Ababa, the results are considered to be appropriate. The results of the analysis are given in the following table.

Waste type	Org.solid waste	Plastics/Metal	Paper	Other waste
Per person kg/P*d	0,09	0,01	0,01	0,04
Per compound kg/comp*d	3,05	0,45	0,35	1,37
Per person kg/P*a	31,8	4,7	3,6	14,3

Table 6: Waste Composition

The division of solid waste into different categories is fundamental, since it is necessary to know which quantities should be deposited, recycled or treated. For this reason, a division into organic, inorganic, plastic/metal and paper is quite useful (Figure 52).

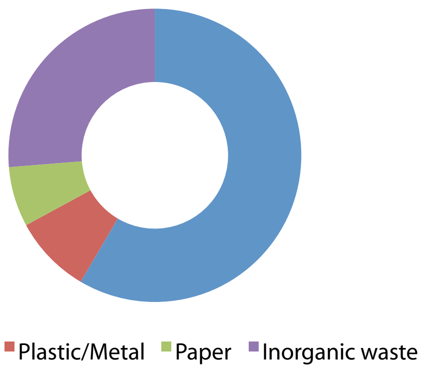

Fig. 52: Waste Composition

Organic waste takes by far the largest share of the generated waste. This is due to the eating habits and lifestyle in rural areas, since large amounts of organic matter occur in the cultivation of food and livestock farming. In this lies the potential for the biological treatment because digestion and composting is also visible. For this reason, the treatment of organic waste is a main focus of our planning process. Additionally it should be noted that the total amount of organics increases because feces are collected separately and processed together with solid organic waste.

The second largest material flow is **inorganic waste** that can be allocated to any utilization or recycling and is thus deposited.

Recyclable metals, and **plastics** only have a small portion. Compared to higher income groups it is much lower, since the consumption of plastic-wrapped goods is lower for financial reasons. Due to the small amounts of recyclables, recycling seems to make little sense compared to the effort for the separation and the separate transport. Nevertheless, this project tries to exploit the potential of valuable materials and provides recycling systems for them. Also the amount of paper and glass is very low, whereby the same procedure as in plastic and metals is selected.

Community bins

Each family is responsible for carrying their waste to the nearest collection point. Since the amounts of waste are very small, the weight to be transported would be low. By a multitude of collection points the distances were short and reasonable for everyone. Waste separation by various containers is also conceivable. Unfortunately it is expected that the collection rate will be degraded because some people could prefer unplanned deposition due to lower expenses. It would also be difficult to empty large containers and transport large amounts of waste, since the required technology in particular trucks is unavailable.

Door to Door Collection

For the door to door collection, it is necessary to store the waste in the compound. At regular intervals each compounds waste is charged and transported by collection services. Residents are responsible for storage in the compound as well as for waste separation. Besides the higher detection rate, because of more comfort, there is the advantage to perform common garbage disposal including the transport of urine and feces.

For these reasons, the decision was made for a door to door collection.

STORAGE AT HOUSEHOLDLEVEL

All generated waste at household level should be stored in sufficiently large trashcans, which are guided by the number of people living in the compound and the removal interval. Additionally there are further criteria to design the storing at household level.

- *Coverage for protection against rain and heat*
- *Coverage and fencing to protect against stray animals*
- *Placement with minimum odors nuisance*
- *Regular cleaning of the trashcan*
- *Easy accessibility for garbagemen*
- *Sufficient size*
- *Handles on containers for transporting and dumping*
- *Max. 25 kg*

As a basis for the calculation 35 people per compound were defined. The collection intervals were chosen according to the amount of waste, since we decided that only 25 kg can be easily carried by garbagemen. In addition, the interval may be short in order to avoid excessive formation of odor especially in hot periods.

As mentioned before, our main focus lies on the treatment of organic waste. Hence organics should be separated from other waste and stored in a belonging trashcan. For storing the amount of inorganic waste there shall be another trashcan. This type of storage is dispensed with further material separation, which means all inorganic waste like plastic, metal, paper, ash, glass and textiles regardless, whether they are recyclable or not, are stored in a single trashcan. The reason we decided against further separation at household level is because the change of their behavior in terms of waste would be to rough. An immediate introduction of waste separation by separate storing of glass, paper, plastic, organics and residual waste would need five trashcans, which is too complex in terms of storing and transport at the present time. Furthermore it is expected that the likelihood of false separation would be very high.
Nevertheless, it should not be excluded, that a later introduction of a more complex separation at household level could be realized after people are more involved and trained in waste management.

COLLECTION AND TRANSPORT

Since the collection and transport of municipal solid waste are considerable parts of a waste management system and also require the highest demand on municipal budgets, we designed a very simple and comprehensive concept. The previously explained storage serves as a basis, whereby it is necessary that the same collection service is provided for each compound. In addition, workers and carts are needed for the following transport. Looking at the route guidance for the garbage collection, it can be seen that the tertiary and secondary roads allow easy access to the compounds. Using the example of the western area, the route guidance is shown. It should be noted that a single route crosses the entire area. This saves time for the refuse collection, since it is the shortest possible route (Figure 53).

A typical problem in developing countries is the integration of modern technology in the fields of collection and transportation of solid waste. Western technology like garbage trucks with tipping gear and compaction are to avoid, for reasons of maintenance and the availability of spare parts. [Diaz, 2015].
The use of simple local and adapted devices should be applied. For this reason, we have focused on the following features.

!

- *Small load volume, for easy discharge and low weight*
- *Low maintenance, availability of spare parts*
- *Adapted to local conditions particularly poor roads (big wheels)*
- *Coverage with tarp in order to avoid falling down of waste*
- *Motorized carts or animal carts*
- *Waiver of the transshipment in large containers or transfer station since the distance to the composting plant and dump is short.*
- *Max. Weight 300 kg since it can be easily pulled by donkeys*
- *Load capacity of carts 2.25 m^3*
- *No variation of frequency*

Fig. 53: Collection Route of the western area

During the collection one or two workers are following a predetermined route on which every compound receives the same collection service. Workers have either access to the compound or the waste is reachable from the outside, whereby the charge time is minimized. Afterwards the waste is carried to the truck and emptied. This procedure has to be repeated until the cart is completely filled. After that, the waste is covered with a tarp and either transported to the composting plant or dumping side. The time needed for the waste collection of one compound is estimated to be max. 4 minutes. Furthermore there is one hour added for the transport from the settlement to the place of discharge if the cart is completely full. For orienting purposes Diaz (2015) evaluated the productivity of workers and vehicles. According to that one worker can process up to 440 kg per day. However, to perform efficient collection services it may be necessary to increase the productivity of workers. Especially in case of urine collection it is inevitable to process more than 440 kg per day due to the fact that urine barrels are heavy and the collection interval is short.

The duration of collection intervals is based on the waste characteristics, the climate, the collection vehicle and costs [Diaz, 2015].
Long-term storage and high temperatures lead to the formation of unpleasant odors and the breeding of disease spreading insects are increased [Buwuket, 2013]. For this reason, the maximum period between two pick-ups was maximized to one week. In addition, this can be shortened in extremely hot periods. Since the weight of waste per compound generally does not exceed 25kg per week, it is ensured that the trashcans are not too heavy and thus can be transported easily by hand. As already mentioned only one type of waste can be collected and transported by one collection squad since there is separate storage at household level. In addition for improving the workers organization the settlement is divided into three collection areas, which are based on the urban scale.

For the whole planning site we calculated the effort for the disposal as well as the weight and volumes of solid waste. The number of compounds amounting 115, each with 35 inhabitants is taken as a basis. The maximum working time of workers is set to 8 hours. Considering the waste densities, the calculated weight and volume of the waste that should be transported after one week of storage is shown in the following table. According to Diaz (2015) it is advisable to limit the maximum working capacity for the collection of MSW to 440 kg/P*d, whereby over-extortion can be prevented.

Type of waste	**Weight**	**Density**	**Volume**	**Load capacity**	**Charge amount**	**Comp./ trip**	**Trip number**	**Working hours**
	*kg/comp*w*	*t/m³*	*l/comp*w*	*m³*	*kg*	*-*	*-*	*h*
bio	22	0,6	36	2,25	300	15	8,2	15,85
rest	18	0,1; 0,2; 0,5	63	2,25	300	17,0	6,8	14,45

Table 7: Waste Amount and Transport

It can be seen that the total working time for both types of waste amounts to 30,3 hours per week. Thus one collection squad with 2 workers can transport both types of waste within 4 days.

Apart from the residential solid waste it is necessary to plan the collection and transport of **commercial and institutional solid waste**. The rates of generation of this waste are also considered to be low. For this reason all waste can similarly be stored in trashcans, which are picked up regularly by the collection service. Since shops and industries are predominantly located along primary roads, the opportunity arises to plan a separate collection route.

According to Diaz et al. (2005) the use of transfer stations for interim storage of municipal waste is highly recommended if the distance to the location for further treatment is long. Since trucks can transport larger amounts of waste compared to donkey carts, this method can be much more effective. In relation to our project site we decided against it, since the distances to the dumping site and composting plant are short and can be easily accomplished by donkey carts (Figure 54). Other reasons are that the operation and handling of large amounts of waste could be difficult, since further transport is exclusively done by hand. Also in the likely event that the transport cannot be done by trucks, due to technical problems, adversely consequences for the further operation can result.

Fig. 54: Distances to further Treatment and Deposition

Street Cleaning

For the preservation of a tidied and clean settlement it is necessary to clean all streets and roads and collect garbage. Since the inappropriate behavior in developing countries in relation to the discard of garbage is still pronounced, it is essential to provide well-organized street cleaning services [Diaz, 2015]. In addition, it can be assumed that markets and public places in particular show the greatest pollution and therefore should receive more attention. According to Diaz (2015) the main sources of pollution on public spaces are:

Traffic: mud, rubber, soil, spillage, animals
Public: litter, sweeping from residents and commercials

The task of urban cleaning is not transferred solely to small enterprises but also to the inhabitants, which are responsible for cleaning the roads outside their houses, thus ensuring a clean impression in secondary and tertiary roads.
In general it should be ensured that street litter is reduced by regulations and public education. Since the amount of the dirt and waste is difficult to estimate, 4 workers are commissioned for the entire area. Again, simple work equipment, such as shovel, broom and a handcart are provided.

TREATMENT OF ORGANIC WASTE

For further processing of the collected and transported organic waste two variants were discussed at the beginning of our planning. The typical methods for treating organics are **aerobic** composting and **anaerobic** digestion.

The anaerobic treatment technology of organic waste by fermentation in bioreactors has the aim to produce methane gas for energy production, and the use of digestate for agricultural purposes.

Bioreactors are airtight chambers where anaerobic bacteria carry out a fermentation process whereby energy-rich methane gas arises. Digesters can differ in size and can be operated in large scale as well as on household level. While the benefits of anaerobic digestion are attractive, we evaluate it as inappropriate for our planning settlement. Reasons for this are for example the complex operation. In order to run the process optimally, it is necessary to observe a large number of parameters. The temperature must be optimized in a mesophylic range between 37-41 °C or a thermophylic range between 50 and 55 °C. Large temperature fluctuations during the process can lead to the disruption of bacterial cultures and abort of the incomplete fermentation process. A restart of the bioreactor would take a very long time. Thus it can be determined that it is essential to have expertise to control and maintain the anaerobic process and it's components. In relation to the Ethiopian behavior people exclusively cook with wood and coal and not with gas. The change from their traditional cooking to gas powered cooking would be too great. In addition, it is costly to bottle gas in pressure tanks or to build a gas pipeline network. The use of biogas in CHP units for energy is also unrealistic, since this technology is too expensive and maintenance intensive. To support our argumentation a calculus has been prepared which is intended to show that a system with fermentation is not financially viable because yields are far too low.

It has been calculated that the fermentation of organic waste and feces can produce around 45.000m3 biogas per year. At first glance, the amount seems to be a lot, but for an accurate assessment it is necessary to analyze the further use of the gas.
In the case of using a CHP plant, it would be possible to produce 150.000 kwh/a of heat and 95.000 kwh/a of electrical energy by taking the respective efficiencies into account. Unfortunately, for the gained heat energy a purpose can only hardly be found. The electrical energy would obviously be used, but only has a value of 5,680 $/a. As mentioned above, the filling of gas in cylinders or construction of a gas supply network is not economical and suitable for the Ethiopian lifestyle.

For these reasons, the implemantation of anerobic digestion for the treatment of municipal organic waste is not feasable considering social, financial and technical factors.
For the treatment of organic waste we decided to implement composting into our concept. Since composting is highly suitable for the common treatment of municipal organic waste and feces we designed a facility for co-composting. The reason for this is that both materials perfectly complement and thus high quality compost can be made and sold afterwards.
Composting takes place on a large-scale facility, as results have shown that home composting and small scale composting only produce poor quality compost [Kraft, 2015]. Reasons are that the parameters, which are explained in this chapter, are not sufficiently respected by poorly trained users.

Composting

Composting is the controlled microbial decomposition of organic matter. Bacteria and fungi under optimized aerobic conditions do the decomposition. The resulting product called compost can then be easily handled, stored, and used for many applications. [Strauß et al., 2003] The resulting benefit additionally to the treatment of organic matter is the decrease in volume. Since we compost the organic fraction of municipal solid waste together with feces the proces is called co-composting.

For optimal operation and easy adjustment of the process parameters, we decided to pile up the composting materials in heaps, which are called **windrows**. Thereby the necessary mixing, watering and ventilating can easily be accomplished.

Although composting is a simple process, which is ubiquitous in nature, there are a number of process parameters to adjust in order to optimize the process and to speed up. The following parameters are particularly important:

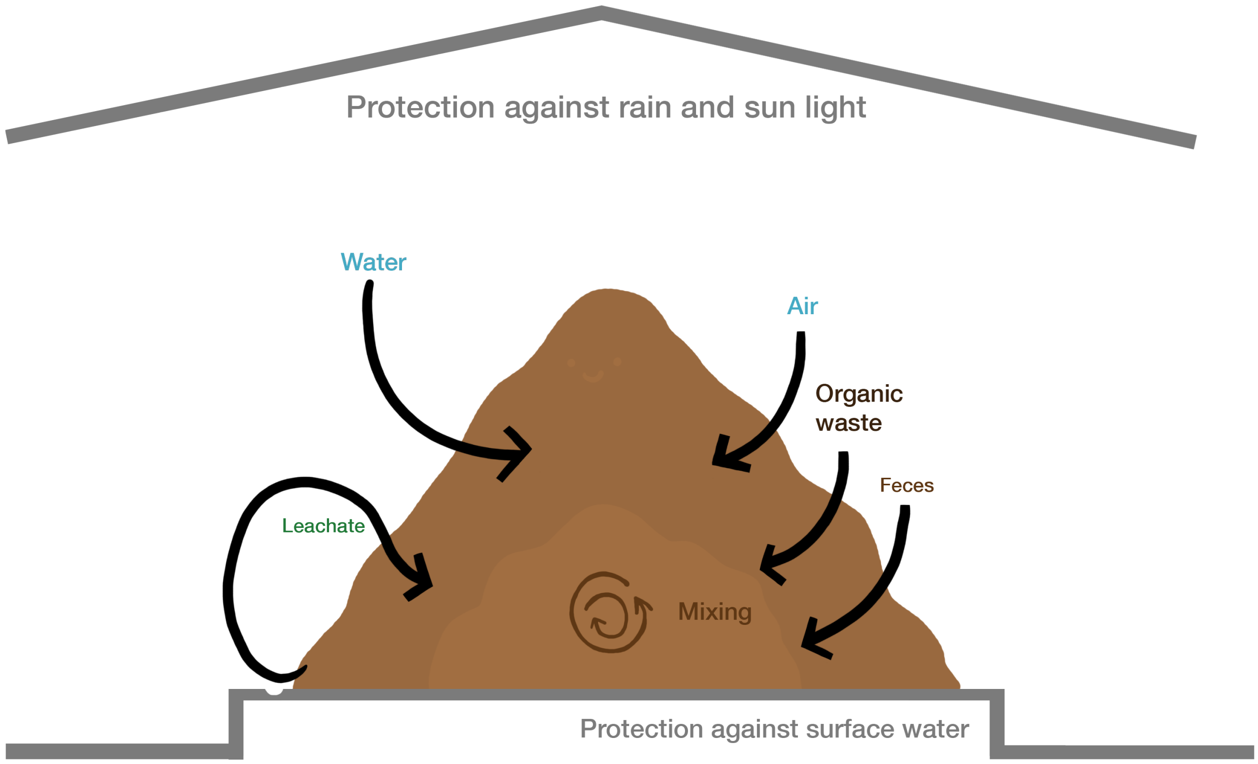

Fig. 55: Operations during Composting

Carbon to nitrogen ratio

As optimal ratio between feces and bio waste 1: 2 is adopted. By the high content of carbon from the waste and nitrogen from feces both materials complement each other perfectly. In order to produce an optimal C/N ratio it may be necessary to add agricultural organic waste in addition to the organic waste from households and commercials, since the proportion of feces may be too large. [26]

Temperature

The temperature must be measured regularly to assess whether the process is running optimally or adjustments have to be made to improve the process. While the entire composting process requires 6 months, the temperature is usually in the mesophilic range between 37-41 °C. This temperature must be maintained in order to guarantee the microbial decomposition. Because of the high load of pathogens, mainly in feces, it is necessary to ensure that the temperature varies in between the thermophilic range of around 55 ° C over a longer period. Thus, the parasite survival particularly helminth eggs is prevented. [26]
The temperature measurement should not necessarily be carried out with thermometers but also by simpler methods like feeling to a metal bar [Diaz, 2015]

Aeration

The oxygen supply is a crucial parameter during the composting. Because aerobic bacteria have a high consumption of oxygen, is to ensure that a sufficient amount of air can enter the windrow. The simplest method of aeration is the manual turning of the compost material. The turning frequency should be between 5-10 days, but it should also depend on other parameters, in particular the temperature. According to Diaz (2015) the performance of a worker is amounted 8-10 tons, which can be turned on an 8h working day. The use of bulky materials is usually the best choice to improve the aeration. For this reason, an adequate amount of bulky materials should always be mixed in.

Coverage and protection against external environmental influences

To protect the windrows it should be assured that a roof is present. This ensures that, in case of the heavy rain, the entering of water into compost material is prevented and thus the washing out of nutrients and the excessive generation of leachate is restricted. It also prevents the accumulation of water in the windrows, which would lead to the disruption of aeration, formation of anaerobic zones and thus to unpleasant odor arising. By protecting the compost material against sunlight possible dehydration is restricted and thereby the consequent watering is not necessary.
During heavy rain in particular rain season it may occur that excessive amounts of water on the surface can enter the space for composting. To prevent this, the surface for composting is set higher. By these measures it should be achieved that all windrows are protected against rainfall as well as surface water.

Leachate

Since leachate is heavily loaded waste waster, which would contaminate the groundwater and soil by entering the ground, the formation should be minimized primarily. On the one hand covering the windrows prevents the excessive formation of leachate. On the other hand in

case of dried out windrows watering should be done in order to minimize the formation of leachate. To restrict the exit of the leachate of the composting plant a variety of measures have been developed, which we call leachate control. The aim is the controlled removal of arising leachate and storing in specially designed tanks. For this reason there are small channels for safe flowing off of leachate into tanks. Since leachate is rich in nutrients, the use for re-watering of the composting material is highly advisable, due to the fact that also nutrients are recycled. To avoid complex biological treatment of excess leachate, we decided to evaporate it a on provided space under the assumption that the amount is very low.
According Hupe et al (1998) to the amount of evaporated leachate is much higher than the drained leachate, which has to be collected. Therefore we assumed a maximum amount of leachate of 60 l/t and thus provided two 1 m^3 tanks to safe storage.

Monitoring

Monitoring is an important part in operation of a composting plant, as it can ensure that all parameters have been set optimally. Therefore, workers must carry out to control moisture content, oxygen supply, odor, temperature and pH-value [Diaz, 2015].
As mentioned before it is essential to maintain the needed temperature. By measuring the temperature with thermometers or metal bars it can be assessed whether the windrow must be turned or not. One sign of an unstable process management is the smell. With unpleasant odor can be assumed that the aeration is not sufficient and the composting material must be supplied with air by turning.
Workers also have to pay attention to the moisture content while they are turning the compost. In case it is too dry it is necessary to add water. PH-value measurements can be performed by easy and inexpensive test-stripes to evaluate whether ashes have to be added to reduce the pH-value. During the whole process of composting it should be ensured that the pH-value is in a neutral range [Sundberg, 2005].

Tools

All works concerning the treatment of organic matter and urine don't require expensive and complex techniques and tools. The whole process and workflow of composting is designed for managing all tasks by effective and convenient performances of the staff only with basic tools like scoops, handcarts, pitchforks and brooms. Although the performance for composting could be multiplied through the use of machines, it is refrained because it is not financially viable.

Composting Plant

This chapter describes the composting plant, its components and the workflow. The facility is placed in the east of the settlement with a distance of 1,6 km and is close to the River Blue Nile. We chose this location because unpleasant odors can occur by the composting process, which would greatly reduce the quality of life within the settlement. The distance should ensure that neither smells nor dusts could reach the settlement. The location is also suitable for the use of water from the Blue Nile, since there is a large demand for the operation of a composting plant. The river water does not have to be clean, because it is only used for irrigation and cleaning. In addition to the composting, the storage and hygenization of urine takes place on the plant. The components of the system are:

The components of the system are:

- *Space for composting (roofed)*
- *Concrete surfaces at locations where waste water arises*
- *Urine tanks*
- *Leachate tanks*
- *Pool for evaporation of leachate*
- *Space for screening and packaging*
- *Place for storing of finished compost (roofed)*
- *Cleaning station*
- *Water tanks*
- *Office / sitting room / workshop / UDDT*

It was ensured that all roads and paths are wide enough so that larger vehicles or oncoming traffic can pass. Also the paths within the composting area and between the windrows as well as the height of the roof have been dimensioned in compliance with the passability.

To provide sufficient space available for all wastes, which have to be composted, it is necessary to do a calculation for the consumption of space. It should be noted that the calculation is based on a composting process of 6 months and triangular windrows with a width and height of each 1.5m. When calculating the total amount of feces, municipal organic waste and ash in consideration of the respective densities and duration of composting of 6 months It results in 252m^3. With a fixed length of windrows of 10 m at least 23 windrows are needed.
In addition to the required area for composting, driveways must be considered with 2.5m width in order to guarantee the passability. This results a total area for composting of 800m^2. In order to simplify the structural design in particular roof, we decided to divide the area into two separate composting areas. After 6 months of composting a volume reduction of up to 50% for MSW, 75% for feces and 0% for ash can be expected, whereby approximately 130m^3 mature compost remain

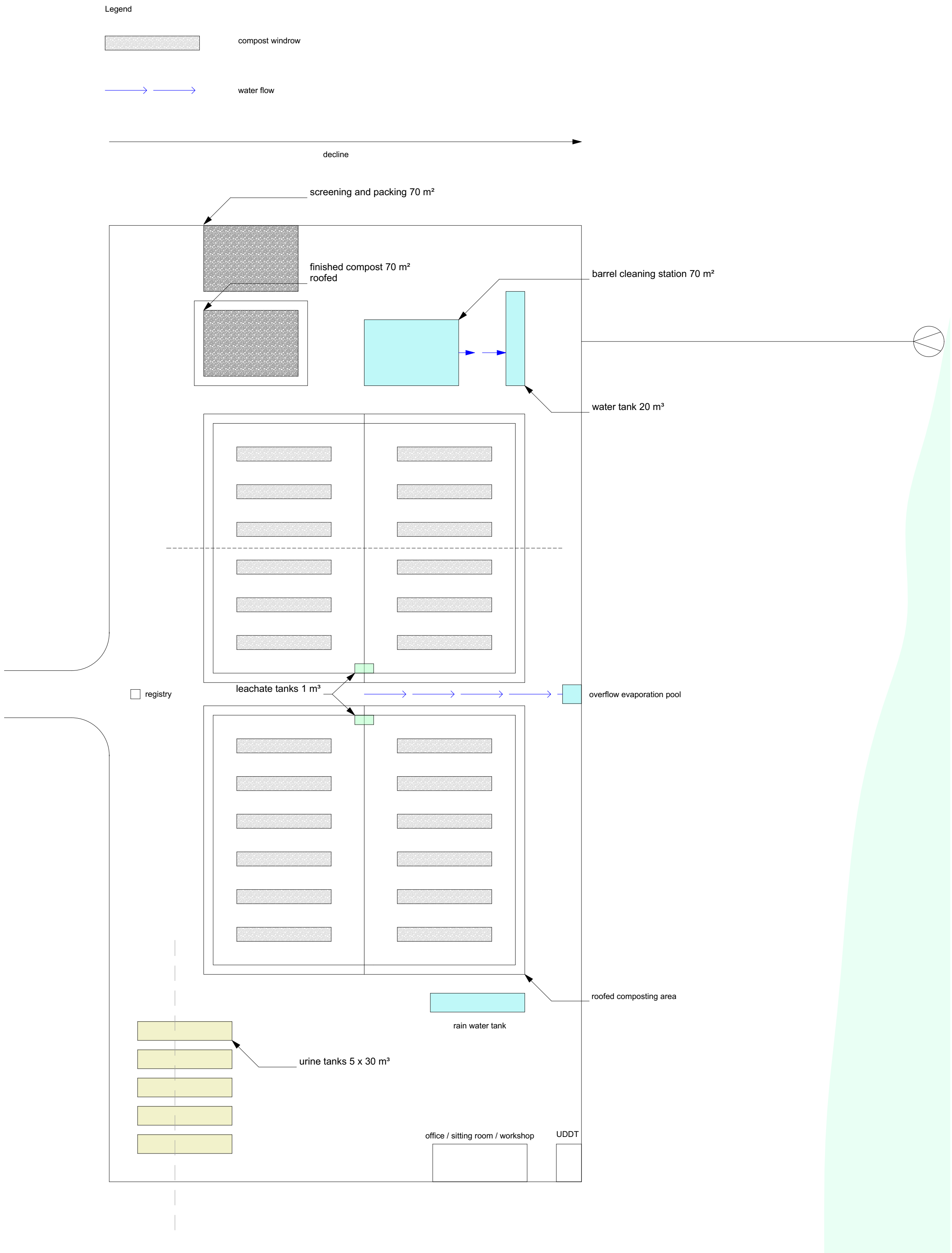

Fig. 56: Composting Plant

Workflow

The sequence of work on the plant should be clearly defined in order to optimize the operation. All carts loaded with organic waste, feces or urine have to be registered when entering the facility by visual counting and estimate of the volume. By this procedure the demand for space for deposition of the composting material can easily be organized. After the registration all materials are brought to the places of their further treatment.

Solid organic waste and **feces** are brought to the composting area. Since these areas are situated higher for protection against water, carts must be driven over ramps. Subsequently, the materials are deposited and piled up in heaps, which are called windrows. In this step it should be ensured that feces and organic waste are mixed and all materials are distributed uniformly. This applies in particular for bulky material to allow a loose storage. The size of windrows was selected to 1.50m x 1.50m, so that they can be easily piled up and manually mixed.
An elaborate treatment is not provided but coarse materials should be screened or crushed by hand. The feces do not require pretreatment, since they are already thickened and not too liquid. Thereafter, the process of composting begins. To optimize this, the previously mentioned parameters and instructions are to observe:

- *Regular mixing of compost material*
- *Regular irrigation*
- *Monitoring*

For the irrigation of the windrows, the wastewater from the cleaning station or water from the River Blue Nile can be used. In case that the pump is not working, water can also be used from rainwater tanks on a transitional basis.
Part of the composting plant is the safe discharge of leachates. In figure 56 it can be seen that the leachate flows over small open channels into two tanks. Overflowing leachate is then passed into a basin where it can evaporate. There is also the opportunity to use leachate water for re-watering, since it is inoculating and high in nutrients.

Since all transport-boxes should be reused, it is necessary to clean them roughly. Therefore a cleaning station is placed on our composting plant. The simplest method is to dry the residue and removing it subsequently by tapping and shaking. However, it is considered better to flush out the boxes with water. A pump from the Blue Nile to the plant pumps the required water. The resulting wastewater is then stored and used for watering of the windrows.
After 6 months of composting the matured compost is processed. On a designated area the screening and packaging can be made. Likewise, there is a roofed area for storing the finished compost. Since also large quantities of compost are sold, trucks can easily drive up to compost stock and charge it. To satisfy the necessities of all costumers there should be a rough screening to classify composts in terms of their quality. Coarse material, which cannot be sold, is recirculated and used as bulky materials for windrows again. There is also the possibility to use coarse materials as mulch, since there will demand by the horticultural sector.
In case there are non-compostable residues screened out, they should be stored in trashcans and transported to the dumping site.

Storage and Hygienization of Urine

The aim of our concept is, that the total amount of urine, produced in the settlement, is stored and sanitized and subsequently sold as fertilizer. As the amount of urine is very large, it must be ensured to provide sufficient storage capacities. For this reason tanks with a total amount for storage of 150m^3 are placed on the facility. In total there are 5 thanks with each a volume of 30m^3, a length of 10m and a diameter of 2m. The placement of the tank allows easy filling and emptying with urine. Since the filling must be made on top of the tanks, there is a plateau to compensate the height difference (Figure 57). Carts can easily pass onto the plateau, whereby the difference in height is low enough allowing workers to fill the tanks with urine. For the removal of urine, the other side can be taken, because the extraction point is attached at the bottom of the tanks.
After the storage of 30 days the sanitized urine can be sold as a high quality fertilizer to the agricultural sector. The urine cycle as described in chapter 6 is shown in figure 58.

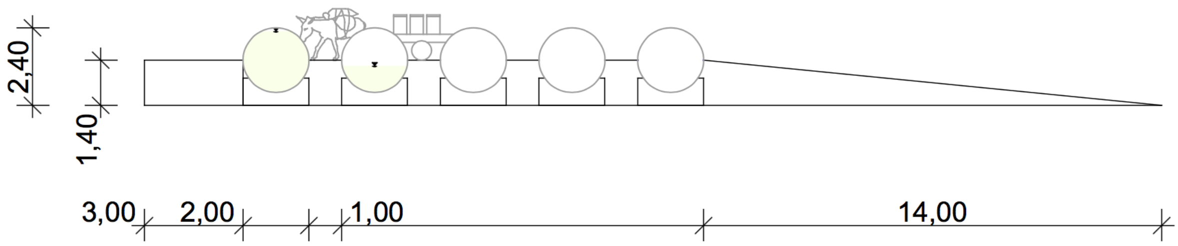

Fig. 57: Storage of Urine in Tanks

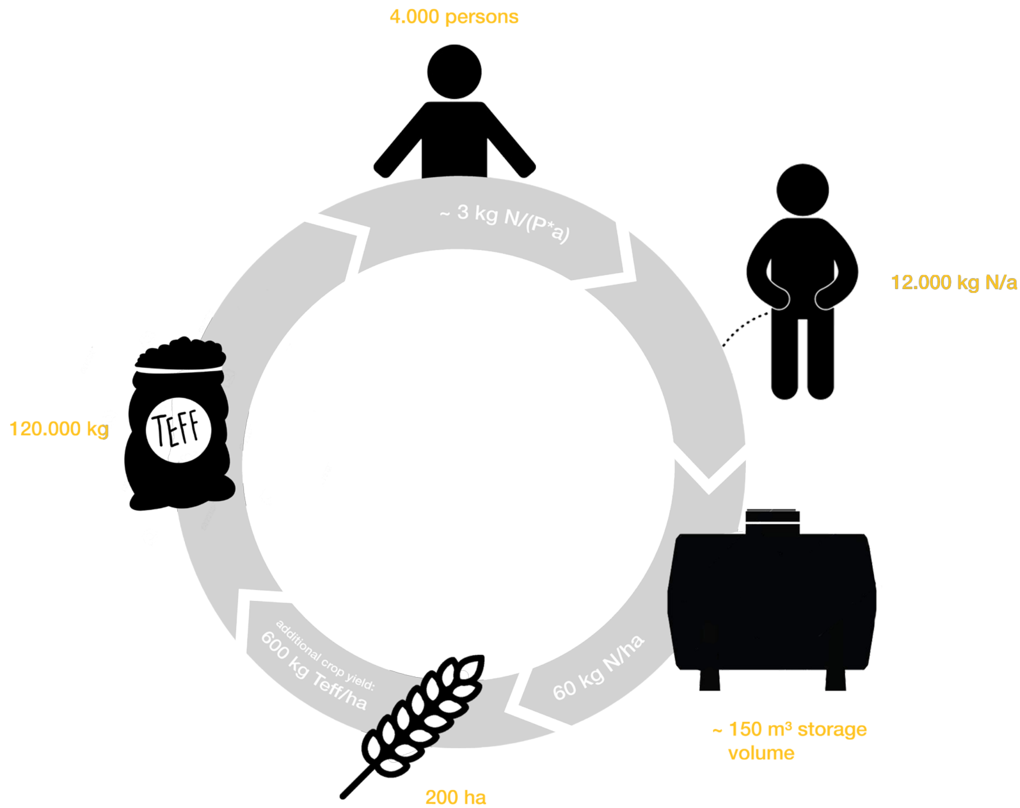

Fig. 58: Urine Cycle

Use of Organic Matter and Urine as a Fertilizer

Since the agricultural sector has the largest share of Ethiopia's economy and provides 85% of the total employment the huge importance is demonstrated. Furthermore the steady population increase and associating growing demand for food illustrates the need for returning nutrients and the use of fertilizers to improve the condition of soil. [Drewko, 2013]
The degradation of soil is not only caused by intensive cultivation but also by natural processes. Natural physical forces of water and wind cause the erosion of soil, which is indicated through the movement and deposition of the top layer of soil. Thereby nutrients, organic matter and soil life of the topsoil are lost respectively and transported to places where they can't be used. [Ritter et al., 2012] For these reasons it is essential to reduce the imports of chemical fertilizers and return nutrients by the use of composted biodegradable solid waste and feces and additionally the use of urine.

With the production of compost and fertilizer we try to prepare well-saleable goods to cover the amount of work financially. We expect a successful marketing if high-quality products can be sold, which causes great interest in **agriculture**, **horticultural**, **landscaping industries** and **private individuals**. In order to achieve this additionally to high quality compost there should be promotion and organization of courses to show customers the benefits in the use of fertilizers.
Depending on the intended use, the compost in terms of quality and packaging may differ. However, for all customers the quality has to be high and the concentration of physical and chemical contaminants should be low.

To enhance the growing conditions of plants the **agricultural sector** needs nutrient-rich, low-loaded, low-salt and medium fine compost. Since we assume that this sector is the biggest consumer, the focus is on the production of compost based on these criteria.

Horticultural and **landscaping industries** require no high-quality compost, because no foods are grown. Similarly, the particle size may be greater than in agriculture.

As it is typical in Ethiopia grow food themselves and all compounds have small gardens **private persons** also are potential customers. Again, the compost must be of high quality, rich in nutrients and low-loaded in terms of contaminations. When selling to individuals it is also necessary to ensure that the compost is packed in sacks for easy transport, since the amounts of sold compost are small [Diaz, 2015].

In the case of covering of the landfill, it would be an excellent opportunity to sell poor-quality compost.

As mentioned before the quality of compost will greatly vary, since the requirements of the costumers are different. This makes it necessary to screen the finished compost and divided into different particle sizes. Fine composts will be required for the use in the agricultural sector and in home gardens. Coarse compost and mulch can be used in landscaping and horticultural industries.
Sieves can easily be made by using a wooden frame and wire mesh in different sizes. It is proposed to perform screenings with a maximum grain size of 13mm for sophisticated gardening purposes and 13-20mm for coarse compost in landscaping and the horticultural sector [Strauß et al., 2003].

Benefits through the Use of Compost and Urine

By the use of compost and urine a large number of advantages in relation to the cultivation of plants arise. In economic terms, the import can be reduced with the substitution of chemical fertilizers by compost and urine. By cost-effective production of these substances can be assumed that the sale prices will be lower than for imported fertilizer. Thereby the investment can be reduced in addition to increasing yields. However, the main reason for the use of fertilizers is the supply of nutrients such as nitrogen and phosphorus, which are necessary for the plant growth. Furthermore compost produces a better plant root environment because the soil structure, porosity and density are improved. In addition, the water holding capacity enhances, whereby the water content in the soil is increased particularly the water loss is reduced. Besides these advantages, the use of compost also promotes the enhancement of aeration and soil permeability, decrease of crusting of soil surfaces and reduction of erosion and compaction. [Strauß et al., 2003]

A Susana project in Kumasi, Ghana shows that with good planning and consistent operation a co-composting facility can be profitable and sustainable. The results after 9 years are promising as it has been achieved that quality compost can be produced and sold through consistent optimization of the composting process. 50kg compost is packaged in sacks and sold for nearly 4$, resulting in a price per ton of $ 80. [Cofie et al., 2009]

However, the difference to our project is that fecal sludge was used as a component for composting. Since fecal sludge has a more liquid consistency through the contained urine a drying is necessary. In case of our project, we avoid to use drying beds as pure feces is collected slightly dried by adding ash. Likewise, the aeration of UDDT contributes to the decrease in volume of feces. The entire amount of water loss, however, is difficult to estimate. We assume a 25% reduction during the storage in boxes and additional 50% after the composting process.

To estimate the potential income from the composting, the selling price of Kumasi was adopted. Based on the quantities produced of up to 260m^3 of compost per year and a density of the finished compost equal to 0.5 t/m^3 can theoretically generate an income of **10,400$**.

Promotion and public education campaign

To maximize sales, it is necessary to promote the products by causing the greatest possible interest for potential customers. The main objective is to attract large customers by delivering less expensive or free products. Thereby it should be achieved to convince the costumers and additionally retain them for a long term. But also small customers should be convinced to use compost and fertilizer for their home gardens. To achieve this, we recommend various methods of public relations work. Via locally available media such as radio it is easy to distribute information and to reach as many people as possible.
Another possibility is to include the topic composting in the school by teaching the advantages of this process there. Since there are many parks and gardens present within the project site, it is to suggest that large amounts of fertilizer and compost are necessary. Thereby the opportunity exists to use glorious and healthy plants as an advertising media and signs referring to the used products. In this way the benefits of the use of compost and fertilizer would be memorable by visual perception. Furthermore events should be organized on the composting plant or within the settlement to show how the products have to be used and what effects they can have if the correct handling is observed.

Material Recovery

Since there is no further separation of waste in the compound it is necessary to introduce subsequent sorting to recycle all useful materials. For this reason, a material recovery facility is planned at the dumping site. Again, opportunities should be created in a simple manner for effective and controlled work.

However, it should be noted that the potential for the recycling of materials is regarded as low because the amounts are very small. Nevertheless, we try to take advantage of the low potential and extract as many recyclable materials from the waste stream.
As mentioned before, recycling is currently done by the informal sector. However, this is not effective, and in addition, the working conditions are not humanely. For this reason, a small plant should be built, in which the recycling can take place.

The facility is located at the edge of the dump and is simple constructed, which protects against external influences such as sun, wind and rain. All transported municipal waste is deposited there and manually sorted by workers. Technical appliances such as air classification are not recommended, as this is too complicated, expensive and maintenance intensive. For this reason, only manual labor is used. Even the equipment is very simple. There are tables for sorting, containers for separate storage, electric light and sanitary facilities available.
However, it has placed great importance in terms of work safety and that clear rules are prevail. All workers must wear protective clothing and are protected from the weather. Since the odor nuisance will be strong, the system must be easy to ventilate. In addition, they must be well trained in order to remain unharmed in the handling of hazardous materials.

Recyclable materials are glass, paper and plastics. Since the amount of glass is very low and most are just broken pieces in the waste, there is the lowest potential. Even paper represents only small amounts and thus it is to be assumed that it is heavily contaminated and torn. The greatest potential we ascribed plastics because they are good to filter out and then can be easily cleaned and processed. All potential recyclables are stored in different containers and can be transported for further processing later. For that, buyers must be found. Since within the settlement manufacturing industries are located, the recyclables are assumed to sell quickly.
For the work on the material recovery facility, it makes sense to integrate the informal sector in particular scavengers as workers. Through the experience of dealing with waste, it can be assumed that they have a great performance and the effectiveness is very high. Additionally proper working conditions particularly better working safety are created, they can receive a payment.

However the possibility of waste separation at the source should not be disregarded. As mentioned earlier, the introduction of waste separation at the source should definitely be done, since it is much more effective than the subsequent sorting.

Occupational Safety

Since the contact with heavily contaminated liquid and solid waste is inevitable, it is necessary to develop a concept for security, and protection of the health of workers. The greatest threats prevail in the collection and transport of waste, composting and in the material recovery. For this reason, we define work instructions to minimize exposure to hazardous substances and thus preserving workers against injuries and illnesses. A basic instruction is the obligatory wearing of protective clothing. This should ensure that the entire body is protected. Also to be hurt by falling objects the risk can be reduced by wearing sturdy footwear.
During the work on the road and in low light conditions, there is a danger of being overlooked by vehicles. For this reason, the stay on the road is to minimize and the wearing of clearly visible clothing and reflectors is recommend. Since all work is done manually, it is important to constantly wear gloves. In case of prolonged dryness it is anticipated that the formation of dust particularly during composting is strengthened. For this reason, it is appropriate to wear masks to protect the airways.
To reduce the risk of diseases of the workers, all plants have sanitary facilities for regular personal care and removal of dirt. In case of injuries, all workers should be trained in order to treat them in the short term. Therefore first aid kits are readily available on each facility.

Fig. 59: Safety First

Hazardous waste

Regarding Zurbrügg (2002) particularly healthcare waste from hospitals are the most hazardous substances, because of their chemical, biological and physical nature. The risk of injuries and transmission of diseases and viruses is most caused by needles. But other objects resulting as waste in the operation of a hospital are considered to be dangerous, since scavengers particularly are looking for these products e.g. for needles and syringes to clean and resell them [Diaz, 2015].
Another common method is the incineration of hospital waste, whereby the elimination of dangerous substances is guaranteed. In case of our village incineration is not suitable, since the hospital is centrally located and high smoke generation is expected.
As most appropriate and easiest method we perceive the pouring with cement. Thereby the waste has not to be pre-treated and the possible contact is minimized. The necessary steps are filling a container with waste and then pouring with cement. After the cement has hardened, the container can be deposited hazard-free. [Diaz, 2005]

CONCLUSION

For the treatment and separation of waste we decided for centralized solutions, because we think that only on this way the concept can be operated efficiently and profitable. Although the investment is greater than decentralized treatment methods in the compound, we anticipate that through the professional treatment on a larger scale, high quality compost and fertilizer can be produced and thereby finance a large part of the running costs.
Part of our plannings was to design all jobs and technical procedures as simple as possible and manually practicable. Likewise, this leads to cost-effective operations, since there are no technical complex and high-maintenance parts of the waste management system.
Another advantage of the composting plant is the opportunity for further development. Through the construction of new areas for storage and composting the input can easily be increased.
Even in the case of non-degradable waste, optimizing measures can be carried out at the collection, transportation and recycling. The separation of waste at household level is a measure to increase the effectiveness and improving the recycling rate.

10 Operation & Organisation

For the realization of our plans service providers are required. They have to fulfill all necessary work for the treatment of solid and liquid municipal waste as well as the maintanance of all parts of the infrastructure on well organized, financially structured and goal oriented ways.

Parts of this service are:

- Collection and transport of municipal solid waste, feces and urine by door to door
- Maintenance of all devices like carts
- Material recovery
- Composting and monitoring
- Selling of finished compost
- Hygenization, storing and selling of urine
- Disposal of non-recyclable waste
- Street sweeping
- Cleaning and maintenance of open channels
- Maintenance of water tanks
- Cleaning infiltration areas
- Servicing of drinking water piping network

On the variety of tasks can be stated that for successfully managing a good organization of the service provider is required. In the case of our project, a MSE who is responsible to deal with all tasks is highly suitable.
Since the introduction of a proclamation in 2007, which allows involving the private sector in waste management, it is appropriated to integrate such an organizational form. Since the Local Economic Development Program in cooperation with UNDP supports the introduction of small and micro enterprises, the responsibility is not only transferred to the private sector but also organized through governmental assistance and the help of non-governmental organizations. [Buwuket, 2013, Cheever, 2011]
According to Scheinberg (2001) MSEs can be defined as

"A class of enterprises which start their initiatives with a small amount of capital and fewer employees (micro enterprises capital ranges from $100 to $10,000 and workers 1 to 10, while small enterprises capital ranges from $ 5,000 to $50,000 and workers from 11 to 20 (to 50). They basically relay on low cost technologies and can play a great role in the economies of developing countries."

Following this definition the necessary form of organization would be a small to medium size enterprise in term of the number of workers. Since the maximum number of workers varies in different publications, it is assumed that the total number of workers in this project does not exceed 50 and thus is a small enterprise, according to the European law.

For legally acceptance and formal management MSEs can get a concession, franchise or contract by the local government for the service they are performing. [Bewuket, 2013] According to Scheinberger (2001) privatization allows "external financing, capital equipment and resources" and thus "increasing the capacity of local governments to provide reliable and appropriate service to all their residents." Additionally privatization strategies give the municipality the opportunity to create a more sustainable and integrated approach, since time for adaption of MSEs is short and workers, technology and equipment perfectly fit into the local conditions.

In Bahar Dar most tasks of municipal cleaning, transport, collection and treatment of municipal solid and liquid waste are transferred to a private organization called Dream Light plc., which also could be responsible for the project site, since the distance to Bahar Dar is very low. It's realization, however, is hardly to imagine, since their service only covers a small part of Bahar Dar's urban area. The additional service provision of the project site would be probably higher than the performance of the company and therefore not sufficient.
However, it is not objective of this project to include the activity of an existing enterprise. Our idea is to introduce an independent enterprise, whose activities are optimally adapted to the local conditions of the project site.
For better organization the MSE should be divided into different work areas. A classification in collection and transport, composting, material recovery and street cleaning is the most suitable. This ensures that employees need to be trained only in one service area.

According to Scheinberger there are three types of MSEs:
Service-based MSE, which get their income by performing a service and receiving payments by clients.
Commodities-based MSEs, which get their income by selling products like compost and fertilizers.
Values-based MSEs, which serve a social, religious, environmental or cultural purpose.

In our case, the MSE is both service based as commodities based since recycling and composting products are sold next to the receiving of payments of users. As financing is not covered in this project and revenues are difficult to estimate, the financing can be discussed only superficially. The aim is to cover the investment costs for all parts of the infrastructure concept in a timely manner and subsequently to operate and maintain to cover costs, to pay all workers and possibly provide investments for the expansion of infrastructural components. To achieve this, the payment of a service-fee must be claimed for all consumers in addition to the income that is generated from the sale of compost, fertilizer and recyclables. According to Diaz (2015) the common billing of all services, as well as consumption of water and electricity is a good way to realize the organization of service-fees. Measurable consumption values as the consumption of power can be taken as a basis for the payment of all additional fees. The cost of all other service may be counted proportionately. The basic idea here is that the consumption of electricity and the consumption of other services increases proportionally, which means a higher consumptions of electricity correlates with higher demand for water. With a high consumption of electricity can be assumed that the financial situation of the consumer is better and therefore he has to pay more. Hence the consumption is indirectly made dependent on the income, thus ensuring that even low earners will receive the same service but are not financially loaded too heavily.

However, with the Introduction of the concept, including all components like piping, composting, material recovery etc. it is necessary to deploy further funds. On the one hand there is the possibility to get governmental funds on the other hand, there are NGOs that support the development of sustainable infrastructure projects. In case these stakeholders support the project, we assume that the implementation can be realized.

OVERALL CONCEPT

11 Overall Concept

In our planning process we never considered an isolated aspect, but always regarded its influence on the overall concept. A solution to a problem did not only have to work, but also had to work together with other parts of the infrastructure system. Figure 60 shows the flow chart of all regarded materials. In contrast to the former chapters, where the specific cycles of the materials are shown, in this chapter we focused on the interaction of the different topics. We regarded the use of every flow entering and leaving the settlement and how it could be reduced or reused.

Regarding the rainwater flow we decided to discharge most of the incoming water, in order to reduce the risk of flooding. Nevertheless, we planned to store as much water as feasible in cisterns for a reuse of the rainwater. Water is also infiltrated, which allows not only better flood protection but also leads to groundwater formation instead of surface runoff.

Drinking water supply is achieved by providing tapped water in combination with a following treatment, e.g. boiling, solar disinfection or chlorine dosing. This way, we achieve a compromise between convenient water supply and cost savings

We assumed the greywater amount to be as high as the water consumption as all incoming water has to leave the settlement again. Since greywater highly differs depending on its source, we differentiated between lightly and highly polluted greywater. The lightly polluted water is infiltrated without further treatment, while the highly polluted water is poured into greywater towers, where a filtration and, to a certain extent, biodegradation takes place. This uncomplicated and inexpensive design leads to groundwater formation and allows to grow vegetables in the private gardens.

Safe sanitation and improved hygienic conditions are achieved by UDDTs. These waterless toilets can mostly be built by the users themselves and provide excellent recycling possibilities for the excreta. The faecal matter can be composted together with the organic waste, the urine can be used as fertilizer after one month of storage. We estimated the value of the liquid fertilizer on 0.011 US$. With the urine of the whole settlement a value of nearly 17,000 US$/a can be generated.

By creating a waste management plan, it is possible to regulate the collection, transport, treatment and recycling of municipal solid waste by low-cost and low-tech procedures. The waste management can be seen as the centerpiece of the infrastructure system, as strong interactions with the sanitation-sector exist. In enforcing this system it is possible to promptly and regularly remove all the waste from the settlement and treat, recycle or deposit them as a function of their material suitability. By composting of feces and organic waste, we want to enable a profit-motivated production of high quality compost with a conceivable value of 10.400 US$/a.

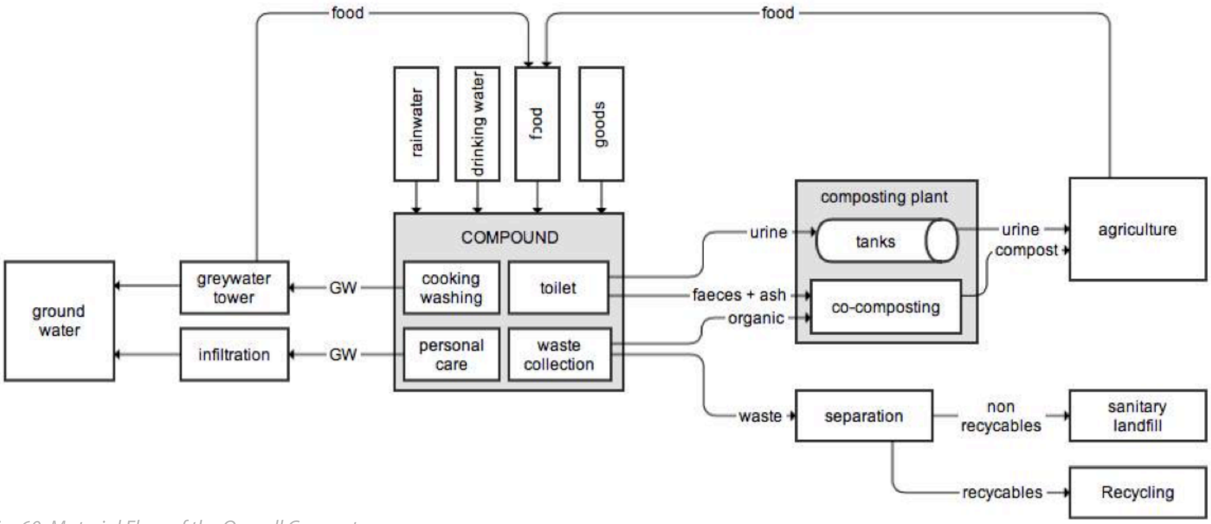

Fig. 60: Material Flow of the Overall Concept

In total, 29 workers are required to maintain the infrastructure system:

- 10 workers for the collection of excreta
- 2 workers for the collection of solid waste
- 4 workers for street sweeping
- 11 workers on the composting plant
- 2 workers for the recovery of the recyclable fraction

Given a monthly salary of 50 US$ per month, which is above Ethiopian average, the labour costs add up to 17,400 US$/a. As stated above, the system can generate an income of 27.400 US$/a. This leaves a surplus of 10,000 US$/a, which could be used for technical maintenance, reinvestment and repayment of the investment costs.

FUTURE OUTLOOK

FUTURE OUTLOOK

After the realization of the settlement's construction and implementation of all infrastructural components there are social and technical aspects still to observe with the objective to ensure the future development and success of the project. Additionally, there is also the chance to develop and improve techniques.
In the following chapter it is explained, how our approach can be continued in the future.
In order to introduce new technical processes or to improve existing systems, however, the integration of people is of great importance. As mentioned often, it is necessary to convince all residents of the project and its benefit. For this reason it is essential to continue and expand training, events, advertising and teaching topics in school in particular when the system is modified. On the basis of monitoring and interviews, it is possible to evaluate the behavior of the residents. Depending on the rate of waste separation, the water consumption and the satisfaction of users, conclusions can be drawn whether the system is well understood or more training is required. If the results are insufficient they can have a negative effect on the concept and therefore the inhabitants' behavior must be changed as soon as possible. In case that the concept works very well, however, the possibility for improvements and developments is offered. For example, the further separation of waste at the source would be an idea that can be realized without much effort and tremendously contributes to the effectiveness of the existing system. In summary it can be said that the participatory operation must definitely be pursued consistently.

At the technical and organizational execution of the infrastructure concept changes are conceivable, which can have a positive effect on the development. For example, the substitution of donkey carts by motorized vehicles would be a step forward in terms of the effectiveness of collection and transportation of municipal solid waste. The use of small-motorized vehicles such as Bajaj could be envisaged, whereby the working pace in particular on routes between material recovery facility, dumping site, composting plant and the settlement will increase. In order to facilitate the unloading, auto tippers would be a great advance, since they not only increase the pace of work but also limit the physical effort of the workers immensely.
Another and equally meaningful change would be the introduction of standardized containers for the storage of all MSW and feces. This would lead to better charging the vehicles, as all containers are the same size and thus are better placeable. A further advantage resulting is the stacking of containers, whereby a lot of space can be saved and the handling of empty containers is simplified. The use of standardized containers offers the chance to have them produced locally within the settlement. As raw materials recycled plastics could be used, whereby another material cycle might be closed.
As already mentioned in the chapter of composting, it is essential to carry out controls of all processes constantly. Only on this way it is possible to specifically influence parameters and to optimize the composting by changing the process conditions. Since composting is highly dependent on the raw materials, and there are no general valid instructions to the mixing ratio, it is necessary to observe and measure the composting process over a longer period and evaluate the resulting data. For improving the C:N ratio it is highly recommended to determine optimal combination between MSW and feces.
Since the accurate monitoring for process optimization can be complicated, it would be advisable to consult specialists. A good option would be the collaboration with the University in Bahar Dar, which may create detailed instructions based on scientific researches.

As already mentioned, it may happen that the presence of bulky materials is limited and thereby the optimal composting conditions cannot be observed. It would be advisable to determine whether bulky material must be additionally retrieved based on the monitoring. In order to compensate the missing quantities of bulky materials collaboration with the agricultural sector is conceivable.
Another way to extend the system would be the cooperation with the Dream Light plc. in Bahar Dar. Since only small amounts of MSW are composted by Dream Light plc. it would be a chance to use the urban organic waste to increase the input of the composting plant.
Although the potential for further development is the highest in the waste management sector there are also changes in other parts of the infrastructure concept conceivable. Since the concept for rainwater drainage and the design of sanitary facilities are created for long-lasting operations, there is only a low potential for further development visible. Fundamental to the change of the existing system, however, is the evaluation of the extent of arising problems during the operation. For this reason, an accurate monitoring is also necessary to determine the explicit need for action. The overload of the rainwater drainage system due to heavy rainfalls is one problem that can occur. Since an enlargement of open channels is difficult to realize, there are only the opportunities to built additional open channels or provide additional areas for infiltration and retention or improve existing areas in terms of their performance.
The waste water treatment and infiltration through seepage areas and grey water towers within the compounds should provide sufficient reserves to disposal of the resulting grey water, but there is still the possibility of overloading. Consequently the increasing of the diameter of the grey water towers or expansion of seepage areas enhance the performance and accordingly prevent arising problems. In any case, it should be avoided that residents dispose their grey water in open channels and thus cause any odor nuisance within the settlement.
By using the UDDT the probability of failure is low. Likewise, the potential for improvement is very limited, since the separation of feces and urine is inevitable.
However, there are proposals to improve the efficiency of the transport and treatment of urine. The enormous amounts of urine cause much effort for transport to the storage tanks at the composting plant. Looking at the amount of work it should be noted that the collection and transport of urine takes by far the largest share of the total working time.
Therefore we suggest a great potential for development in the transport and treatment of urine. However, further investments are necessary for improving the existing system. The easiest way would be to build a transfer station, where the urine can be transferred into a tank lorry. This ensures that large quantities can be transported to the composting plant and frequent commuting of the collection squads is no longer required.
Further development potential exists in the treatment of urine. The current problem is that after sanitization still large quantities have to be transported for its final use in agriculture. A reduction of the volume would be a great opportunity to improve the handling of the fertilizer and to increase the interest of agricultural sector by selling compact products. Struvit precipation with magnesium oxide is an efficient and simple approach to produce granular phosphorus fertilizer. There already are testing facilities in developing countries, which deliver positive results and promise low-cost production of granulated fertilizers. [Etter et al., 2010] Investments are not to be underestimated, as technical units are necessary to ensure optimal precipitation. Likewise the question arises, where magnesium can be obtained inexpensively.
In a long-time view the efficiency of the overall system can be increased, without changing the basic ideas. As presented the system will be sufficient for the next years to come.

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APPENDICES

Tables A1: Solid Waste Management & Sanitation

Generation of Solid Waste, Feces and Urine per Person and per Compound

Type of waste	Organic waste	Plastics	Paper	Other waste	Faeces	Urine	Ash
Amount kg/p*a	31,8	4,7	3,6	14,3	36,5	365	10,95
Amount kg/comp*a	1113	164,5	126	500,5	1277,5	12775	383,25
Amount kg/p*d	0,09	0,01	0,01	0,04	0,1	1	0,03
Amount kg/comp*d	3,05	0,45	0,35	1,37	3,50	35,00	1,05
Density in t/m3	0,6	0,1	0,2	0,5	1	1	0,3
Amount per week/comp	21,35	3,15	2,42	9,60	24,50	245,00	7,35
Volume per week/comp	35,58	31,55	12,08	19,20	24,50	245,00	24,50

Transported Amount of Solid Waste, Feces and Urine

Material	Amount [l/(w*C]	Density [t/m³]	Amount [kg/(w*E)]	Inhabitants/ compound [-]	Containers/ compound [-]	Amount/ week*compound [l/w]	Collecion [1/w]	Amount per collection [kg]	Amount per collection [barrels]
Faeces + Ash	49,00	0,5 ; 0,3	1,4	35	3	49	1	49	3
Urine	245,00	1	7,00	35	3	245	3,5	70	3
Organic waste	35,58	0,6	0,61	35	1	21	1	21	1
Other waste	62,83	0,1; 0,2; 0,5	0,51	35	1	18	1	18	1

	Load quantity donkey cart [m³]	Load quantity [barrels]	Load quantity [kg]	Compounds per trip [-]	Number of compounds	Trips [-]	Time [min/compound]	Driving time [min]	Working time [h]	Weekly working time
Faeces+Ash	2,25	10	300	3,33	50	15	5	60	19,17	19,17
Urine	2,25	10	300	3,33	50	15	5	60	19,17	67,08
Organic waste	2,25		300	14,1	50	3,6	4	60	6,89	6,89
Other waste	2,25		300	17,0	50	2,9	4	60	6,28	6,28

Table A2.1: Hydraulic Verification of RW Channels Part I

Legende	
abbreveation	
MC	Main Collector
BS	Branch Sewer
Ψ	discharge coefficient
Q	discharge
l/s	liter per second
min	minutes
b	breadth
h	height
r	hydraulic radius
S	slope

design rainfall: [l/(s*ha)]	**300**
roof area per house: [m²]	40
Manning-Strickler-Coefficient: [-]	50
ditch shape:	rectangular

ditch	catchment		buidlings			
identifier	area	ditch	houses	Ψ	sanitary facilities	Ψ
				[-]		[-]
MC 1	1		12	1	0	1
MC 1	2		12	1	2	1
MC 1	3		11	1	0	1
MC 1	4		9	1	1	1
MC 1	5		3	1	0	1
MC 1	6		6	1	1	1
BS 2.1	7;8		28	1	3	1
MC 2	10		9	1	2	1
MC 2	11		10	1	2	1
MC 2	12		8	1	2	1
MC 2	13		3	1	0	1
MC 2	14		0	1	0	1
MC 2	9	2.1	10	1	0	1
BS 3.1	19;20;21		17	1	2	1
MC 3	15		0	1	0	1
MC 3	16;17	3.1	21	1	2	1
MC 3	18		15	1	0	1
BS 4.1	24;25		10	1	2	1
BS 4.2	26;27		10	1	2	1
MC 4	22		12	1	2	1
MC 4	23		6	1	2	1
MC 4		4.1	0	1	0	1
MC 4	28	4.2	19	1	0	1

Table A2.2: Hydraulic Verification of RW Channels Part II

ditch	buidlings				area				precipitation		storage	
identifier	houses	Ψ	sanitary facilities	Ψ	ground area	Ψ	street area	Ψ	Q	sum Q	inflow	volume
		[-]		[-]	[m²]	[-]	[m²]	[-]	[l/s]	[l/s]	[l/s]	[m³]
MC 1	12	1	0	1	920	0,7	0	0,9	33,72	33,72		
MC 1	12	1	2	1	1050	0,7	0	0,9	38,55	72,27		
MC 1	11	1	0	1	340	0,7	0	0,9	20,34	92,61		
MC 1	9	1	1	1	600	0,7	0	0,9	24,45	117,06		
MC 1	3	1	0	1	380	0,7	0	0,9	11,58	128,64		
MC 1	6	1	1	1	485	0,7	0	0,9	18,44	**147,08**		
BS 2.1	28	1	3	1	994	0,7	0	0,9	57,62	57,62		
MC 2	9	1	2	1	970	0,7	80	0,9	35,43	35,43		
MC 2	10	1	2	1	1230	0,7	130	0,9	43,44	78,87		
MC 2	8	1	2	1	1010	0,7	130	0,9	36,42	115,29		
MC 2	3	1	0	1	588	0,7	100	0,9	18,65	133,94	79,44	50
MC 2	0	1	0	1	880	0,7	320	0,9	27,12	81,62		
MC 2	10	1	0	1	960	0,7	0	0,9	32,16	**171,4**		
BS 3.1	17	1	2	1	1250	0,7	0	0,9	48,75	48,75		
MC 3	0	1	0	1	400	0,7	320	0,9	17,04	17,04		
MC 3	21	1	2	1	2090	0,7	0	0,9	71,19	136,98	82,48	45
MC 3	15	1	0	1	1600	0,7	200	0,9	57	**111,5**		
BS 4.1	10	1	2	1	730	0,7	0	0,9	29,43	29,43		
BS 4.2	10	1	2	1	630	0,7	0	0,9	27,33	27,33		
MC 4	12	1	2	1	450	0,7	0	0,9	25,95	25,95		
MC 4	6	1	2	1	410	0,7	0	0,9	17,91	43,86		
MC 4	0	1	0	1	0	0,7	0	0,9	0	73,29		
MC 4	19	1	0	1	940	0,7	0	0,9	42,54	**54,5**	88,66	50

Table A2.3: Hydraulic Verification of RW Channels Part III

ditch	precipitation		storage			ditch characteristics				
identifier	Q	sum Q	inflow	volume	filling time	b	h	r	S	discharge
	[l/s]	[l/s]	[l/s]	[m³]	[min]	[cm]	[cm]	[m]	[-]	[l/s]
MC 1	33,72	33,72				40	40	0,13	0,004	129,84
MC 1	38,55	72,27				40	40	0,13	0,004	129,84
MC 1	20,34	92,61				40	40	0,13	0,004	129,84
MC 1	24,45	117,06				40	40	0,13	0,004	129,84
MC 1	11,58	128,64				40	40	0,13	0,004	129,84
MC 1	18,44	**147,08**				40	40	0,13	0,004	129,84
BS 2.1	57,62	57,62				30	30	0,1	0,004	61,32
MC 2	35,43	35,43				40	40	0,13	0,004	129,84
MC 2	43,44	78,87				40	40	0,13	0,004	129,84
MC 2	36,42	115,29				40	40	0,13	0,004	129,84
MC 2	18,65	133,94	79,44	50	10,49	40	20	0,1	0,004	54,5
MC 2	27,12	81,62				40	40	0,13	0,004	129,84
MC 2	32,16	**171,4**				40	40	0,13	0,004	129,84
BS 3.1	48,75	48,75				30	30	0,1	0,004	61,32
MC 3	17,04	17,04				40	40	0,13	0,004	129,84
MC 3	71,19	136,98	82,48	45	9,09	40	20	0,1	0,004	54,5
MC 3	57	**111,5**				40	40	0,13	0,004	129,84
BS 4.1	29,43	29,43				30	30	0,1	0,004	61,32
BS 4.2	27,33	27,33				30	30	0,1	0,004	61,32
MC 4	25,95	25,95				40	40	0,13	0,004	129,84
MC 4	17,91	43,86				40	40	0,13	0,004	129,84
MC 4	0	73,29				40	40	0,13	0,004	129,84
MC 4	42,54	**54,5**	88,66	50	9,4	40	20	0,1	0,004	54,5

Table A3: Rough Calculation Biogas Plant

		Inhabitants:	4000	
Waste water			**Organic Waste**	
Specific gas yield [l/(p*d)]	20		Amount of organic waste[kg/(p*a)]	31,8
Gas yield [Nl/d]	80000		Amount of organic waste [kg oDM/(p*a)]	7,95
Gas yield [m^3/a]	29200		Specific gas yield [m^3/kg oDM]	0,5
			Gas yield [Nm^3/a]	15900

Total gas yield [Nm^3/a]	45100
Calorific value biogas [kWh/m^3]	6
Total heating value [kWh/a]	270600
Energy conversion efficiency (thermal) [-]	0,55
Energy conversion efficiency (electric) [-]	0,35
Generated Heat [kWh/a]	148800
Generated electric power [kWh/a]	94700
Electricity price [US $/kWh]	0,06
Value of produced Electricity [US$ /a]	**5682**

Table A4: Excursion Schedule

EXCURSION SCHEDULE

Time	Saturday 18. April 2015	Sunday 19. April 2015	Monday 20. April 2015	Tuesday 21. April 2015	Wednesday 22. April 2015	Thursday 23. April 2015	Friday 24. April 2015	Saturday 25. April 2015	Sunday 26. April 2015	Monday - Friday 27.4. - 1.5.15
					5:30 Pick-up from Hotel					
7:00 AM	Recommended arrival in Addis Ababa									
7:30 AM					**7:50 Departure AA - BJR**					
8:00 AM										
8:30 AM					8:50 arrival in Bahir Dar					
9:00 AM			**Meeting at Hotel/ Pick-up**	**Meeting at Hotel/ pick-up**		**Meeting at Hotel/ Pick-up**	**Meeting at Hotel/ Pick-up**			
9:30 AM					**Check-In Hotel Bahir Dar**					
10:00 AM			**Tour of EiABC Campus SICU/ SECU/ MACU**							
10:30 AM					Breakfast					
11:00 AM				**Walking Tour** Piazza and site visit condominiums / Walking Tour Merkato / Tour Teklehaimanot		**Site Visit/ Workshop**				
11:30 AM							**Workshop**	**Lake Tana**		
12:00 PM										individual:
12:30 PM					**11:30 AM Meeting at Hotel**					
1:00 PM										Option A - workshop in Bahir Dar
1:30 PM										
2:00 PM	individual	individual							individual	
2:30 PM										
3:00 PM			**Mid-term critique Master Course EiABC**	alternatively or parallel "WALK OF PAIN"						Option B - individual travelling
3:30 PM										
4:00 PM							**Workshop**			
4:30 PM					Tour Bahir Dar and Bahir Dar University	**Workshop**		individual		
5:00 PM										
5:30 PM							**Final Discussion**			
6:00 PM										
6:30 PM										
7:00 PM										
7:30 PM			**Common Night**	**Trad. Dinner**						
8:00 PM										
8:30 PM										
									21:30 Recommended departure Bahir Dar 1:00 Recommended departure AA	

mandatory, 20. - 24.4.15

individual, 18. + 19.4. and 25. + 26.4.5.

recommended travelling dates

individual extension possible, 27. - 3.5.15

SS 2015 | Prof. Dr.-Ing. Dirk Donath | Prof. Dr.-Ing. Jörg Londong
Dipl.-Ing. Lukas Veltrusky | Dipl.-Ing. Jürgen Städel | Dipl.-Ing. Nicole Baron

Travel Journal

DAY ONE

Date: Monday, 20th April 2015
Place: Addis Ababa, Ethiopia

It was the first official day of our project in Ethiopia, starting in the capital Addis Ababa. After having breakfast on the terrace of Taitu-Hotel, the students from Bauhaus-University and three students from EiABC met up with Professor Donath, Mr. Veltrusky and Mr. Stäudel for briefing on site. On this day much was scheduled. Divided into different groups, the team went to the lower region of Entoto Mountain by car. While moving back into the city on foot, our task was to make contact with the local inhabitants and the traders at Shiro Meda market, asking for lifestyle habits, living conditions and costs for items and living.

Fig. A1: View fromn the Entoto Mountains

Our first destination was a typical compound near the main road. The compound was fenced by metal sheets. An old woman opened the door and invited us to enter and study their property. The Ethiopian students helped us with the translation. There were a few houses built of eucalyptus, clay and straw, some apiaries, a hen house and a goat run. The current supply was well installed and they had working satellite dishes for TV. To get daily water, they had to move to a nearby water tank. They told us that the price for 25 litres of freshwater is 0,50 Birr (0,03€). The water is filled and transported in yellow cans and used for cooking and washing, but not for drinking.

Fig. A2: Drinking Water Storage on Entoto Mountains

After moving on, we arrived at Shiro Meda market. Shops in this market mainly offered traditional Ethiopian items, souvenir items and in particular Ethiopian scarfs. Lots of people and pupils were on their way. A few poor people asked for money or food. Sometimes the way they were dressed was terrifying. At some market stalls we inquired the prices for goods and items: a goat cost 2000 Birr (90€), a dress 400 Birr (18€) and a hammer 160 Birr (7€).

Fig. A3: Way down from Entoto Mountains to Addis Ababa Centre

Arriving back in the city centre, we visited the building site of the Flintstone warehouse. It was an awesome structural work including escalators and lift shafts. The big staircase was built like a helix. Otherwise the scaffold of bamboo looked and seemed to be instable and many electrical installations were badly and loosely laid. I can't imagine feeling save there as a worker!


Fig. A4: Flintstone Warehouse Building under Construction


Fig. A5: Team Members on the Roof of Flintstone Building

In the early evening we moved to the condominiums, an area of the Ethiopian low-income housing. Professor Donath explained structure and design and how to get such a flat. The procedure works like a lottery. While checking and analyzing the housing area and infrastructure, our group was surrounded by excited children wanting to play with us. This eventful day ended with some glasses of beer near the St. George brewery und a pretty good traditional diner in Finfine restaurant. We had a tasteful dish of Ferfer and delicious honey wine called 'Touch'.


Fig. A6: Visiting Condominiums

Travel Journal

DAY TWO

Date: Wednesday, 22th April 2015
Place: Addis Ababa,Bahar Dar, Ethiopia

Wednesday, the third day of our project in Ethiopia and the one we were leaving Addis Ababa and heading over to Bahar Dar. After a great night with traditional food and some drinks and unfortunately only a few hours to sleep we went to the airport. At this time there was a state of emergency in Addis because of demonstrations. Only a few days earlier 20 Ethiopians were killed in Lybia. For this reason the government expected unrest and tried to secure the city. Although uncountable soldiers and police men blocked off the main roads we got to the airport. Arrived in Bahar Dar everybody overcame the feeling to be in a totally different world. In comparison to Addis it is a much more peaceful place. Less traffic, nice people, palm trees and much less hectic are reasons why I really like this city. Although we are all very tired we had a lot of stuff to do this day. But before the work we enjoyed a great breakfast at a beautiful place next to Lake Tana.

Afterwards we met an Ethiopian architect and admire her great work. In her project she researches how local materials can take place in traditional buildings. I've never seen something like this before and I have to admit that she is doing a great job. With materials like mud and straw she is not only preparing constructions materials and buildings that are fitting perfectly into the Ethiopian culture but also elaborate and long lasting products. All houses are optimally designed for Ethiopian needs. There is an enjoyable climate, traditional kitchens and a lot of space to stow things inside these buildings. She also designed a great concept for watering their huge garden by using nutrient rich sewage. I really think she is doing a great job.

Fig. A7: Meeting with Eminet


Fig. A8: Gaze in Amazement of Traditional Ethipian Ways of Construction

I can imagine every architect dreams about these freedoms and the opportunity to realize its ideas just like she is doing.

Afterwards we took a little tour through Bahar Dar and earned many impressions of this beautiful place.

Travel Journal

DAY FOUR

Date: Thursday, 23th April 2015
Place: Bahar Dar, Ethiopia

Today has been a long, exhausting and last but not least interesting day. We started with a trip to Bahir Dar University. The campus we visited is somewhere outside the city in the middle of nowhere. As I was told by some of the students later on, this is the case for four of Bahir Dar's six campuses. It doesn't seem like the government wants the students to be integrated into city life. The whole campus is surrounded by fences and we had to wait at the guard post for quite some time before we could finally enter. Besides the lecture rooms and administration buildings the campus includes dormitories and living houses for the teachers but no recreation areas whatsoever. I expected there should be some trees, benches or similar places to enjoy your leisure time.

Fig. A9: Campus of the Bahar Dar University

In the following lecture by Professor Donath, about pattern language and architecture and stuff, the Ethiopian students tried to look interested as much as we tried. We did not have much time to get to know them afterwards. Instead we headed to our next appointment: Buranest.
The Buranest project of ETH is an attempt to build a new town in a rural area. As soon as we arrived we were surrounded by curious children who've probably never seen that many ferenjis (=foreigners) at once. Unfortunately we couldn't find any project officials to explain their ideas to us. We also lacked a translator. So all we could do was indeed: look. It turned out that this wasn't enough to understand all the details of the few demonstration objects, including a school, which had already been built. Especially the sanitation system, which was already out of order, stayed a riddle to us.

Fig. A10: Visiting Buranest

In the meantime even more children had gathered around us and constantly asked us for pens. It seemed like "pen" was the only English word they knew. I do not know how it is possible to build a school in Ethiopia but not provide enough pens for the pupils. The only other thing the children wanted as much as pens were empty plastic bottles. A partly filled water bottle we gave them was immediately spilled – doesn't seem like they are short of water.
We then drove back to Bahir Dar, only to leave it southwards again. There, next to the old road to Addis Ababa (if this stony, bumpy dirt track which doesn't allow any speed beyond 30km/h deserves the name "road") we found the location for our own project. We also found the students from Bahir Dar University who had been waiting for us for about two hours. But in general the Ethiopian are relaxed people and so no one was angry with us for coming late. Together we explored how people really live in the Ethiopian hinterland.
Stone-carving men and injera-baking women told us of their daily struggles. Despite the lack of jobs, the missing technical infrastructure and the general difficulties to make a living in this barren area, people told us that their life is easier now than it had been in the past. And they also seemed confident that their living conditions would keep improving. This optimistic attitude towards the future is something a sour German should try to learn from the Ethiopian.

Fig. A11: Children Struggling for some Pens