PREVIOUS STUDY OF SOLUTIONS

[REPORT]
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1 Background

1.1 Context of the project

This project aims to improve the sanitation facilities, particularly the management of latrine wastes, designing a sludge treatment plant, in the city of Wukro, Tigray Region, northern Ethiopia.

This is a Final Studies Project in Development Cooperation, in the E.T.S.I. de Caminos, Canales y Puertos of the Universidad Politécnica de Madrid.

The project is framed in the Final Project Department of the E.T.S.I. de Caminos, Canales y Puertos in collaboration with Wukro’s St. Mary’s College and the Mission of Ángel Olarán, that are part of the Ethiopian Catholic Church Diocese of Adigrat (ECCA).

St Mary’s Agricultural College is an institution founded in Wukro by the ECCA more than twenty years ago. This College has two working lines. On one hand, it gives students of all over Ethiopia the opportunity of study agriculture, silviculture and farming. On the other hand, in cooperation with Angel Olarán’s Mission and the Catholic Community of Wukro, it has the purpose of improving life quality in Wukro and the kebeles around, developing agricultural, environmental, and water resource projects to support the farmers and the population.

1.2 Previous situation

The city of Wukro is situated in the north of Ethiopia in Tigray’s Region. The actual city, of about 42000 inhabitants, was founded by the Italians in 1936. Due to its geographic location, that makes the city suitable for industrial and agricultural activities, Wukro is becoming an important administrative and economic center in the region, and its population is growing fast.

But yet urban services in Wukro are not very developed, since there is no urban tradition and low economic resources. Even though, in the last years, big efforts have been done by the Municipality and International Institutions.

The sanitation system of Wukro is deficient. It consists in dry pit latrines situated in the yard of private houses. Some important buildings, as St Mary’s’ Catholic Church have septage tanks, but this is not very significant. When the pit latrines are full, they are covered with soil and another one is constructed if there is enough room.

As it has been mentioned before the population of Wukro is growing fast, and so is the population density as well. Density is increasing because the urban area is limited on the west by the river, the north and the east by mountains and the south by cultivated lands. This fact is causing problems of room for latrines (they are not constructing new ones) and therefore risks to Public Health.

Recently, the Municipality of Wukro has acquired a Vacuum truck of 7500 L for extracting the sludge from the pit latrines.
However, there is currently no scheduled program for cleaning the pit latrines, no place fixed and controlled for disposal of the material, nor a treatment planned for the sludge.

Wastes are being disposed in an uncontrolled manner in the fields, with a high risk of pollution of crops and water resources, and therefore constituting a risk for Public Health as well.

### 1.3 Related studies

There are no previous construction projects or studies of sludge treatment in the region, since there is no urban tradition in the region, and sanitation has not been a priority in this mainly rural area. Sanitation concern usually appears as a priority when the density of the cities grows and it can affect Public Health.

One recent study the “Wukro Integrated Development Plan” of 2008 done by the government of Ethiopia, is a noteworthy reference about the urban situation of the city of Wukro.

As written construction projects recently developed in the region, it can be mentioned the Hizaeti Afras Dam, done together by the AECID, Adigrat Diocesan Catholic Church and Fundació Lleida Solidària.

### 1.4 Needs program

As it is deeply studied in Annex 1 Population Studies, the problems and needs of Wukro are numerous and becoming more severe due to the growth of population that the city is experimenting in the last years and the lack of urban tradition in the region.

The “Wukro Integrated Development Plan” of 2008 done by the government of Ethiopia, with representatives of the community from all kebeles, technicians of the municipality, experts of sectoral offices, the steering committee and the representative forum members, have identified various urban problems. These priorities were: Flood and drainage problem, Water supply problem, Social service (education and health) problem, Unemployment problem, and Infrastructure coverage and coordination problems.

The Municipality and some NGOs are already working on some of these priorities, as the new net of rainfall drainage and some new water wells.

The writer of this project, after the visit to Wukro, has found out big necessities in civil infrastructures and urban services. Related to civil engineering the two principal priorities found were Water Supply and Improved Sanitation Facilities, both of these priorities affect directly to Public Health and Food Security.

### 1.5 General and particular objectives of the project

The overall goal of the project is to collaborate to Universal Access to Basic Services and contributing to ensure Millennium Development Goal 7, Environmental Sustainability (declared by the United Nations in 2000). Improving access to sanitation facilities also contributes indirectly
with Millennium Development Goals 4 “Reducing child mortality rates”, 5 “Improving maternal health”, and 6 “Combating HIV/AIDS, malaria, and other diseases”.

The particular goal of this project is to guarantee a good sanitation treatment that constitutes a barrier to the transmission of pathogens in excreta improving Public Health while giving an added agricultural value to the input material.

It is also pretended that the technical recommendations of design and operative process that result from the project are useful in the future for developing similar projects in the region.

1.6 Petition of the project

This project is framed in the labor of St. Mary’s College and Ángel Olarán in Wukro improving urban and social services in the region, and the improvement of household sanitation facilities.

The initiative of the project begins when the writer of the project gets in contact with the Spanish missionary Angel Olarán, and gets to know the labor that he is developing in the north of Ethiopia. Angel Olarán is specially interested that people from different contexts collaborate and exchange knowledge with his mission. During the visit to Wukro, contact with professionals of St Mary’s College, and knowledge of their work in environmental sustainability, gives birth to the idea of designing a treatment for sludge.
1.7 Location of the project

Wukro is a city located at the north of Ethiopia. It's located at the Eastern zone of the Tigray region. Wukro is the biggest settlement of Kilte Awulaelo woreda.
Wukro is located about 820 kms north of Addis Ababa (the capital of Ethiopia), 40 kms north of Mekele (the regional capital), and 70 kms south of Adigrat (the zonal capital). To accede to the city of Wukro, there is an asphalt road connecting Eritrea with Addis Ababa, the Asmara - Addis Ababa highway, constructed when the Italian occupation.

The landform of Wukro area could be classified in to two broad categories, hilly and flat terrain. The hilly terrain is found at the northern and southern fringe of the town and extends further to the west and east at places where the bed rock is exposed. The urban proper of Wukro (including the built-up and expansion areas) is situated on a landscape that has an elevation between 2140 m.o.s.l and 2250 m.o.s.l.
Sludge treatment system in the city of Wukro (Ethiopia)

The influence area of Wukro is suitable for agriculture, due to the flat terrain and for industrial purposes, since it is endowed with a variety of natural resources. The most important natural resource are known to be construction materials, a potential developing industry.

Wukro is also a center of trade, services and tourism to the neighboring influence area. Agricultural products originating from Hawzen, Seasi Tseadamba, Kilte Awlaelo, and Atsbi Wonberta Weredas are known to be flowed, storage and exchanged in Wukro. As well, out of the 32 tourist attractions so far identified in the Eastern Tigray, 15 (mosque, caves and rock-hewn churches) are found in Eastern Tigray Zone and are located within 50 kms radius of Wukro. This makes Wukro likely to be an important tourist center.

In this context, Wukro is becoming an important administrative and economic center in the region, and its population is growing fast.

Its approximate geographic coordinates are:

39° 37’ East Longitude
13°47’ North Latitude.

Zone UTM 39

2 Object

The object of this document is to develop a project of improvement of sanitation facilities of the city of Wukro, specifically to define a Sludge Treatment.

First step, is doing a Previous Study of Solutions. After this Previous Study, a solution will be defined as detailed as it may be a project with these characteristics.

A numerous quantity of possible alternatives were proposed in the Previous Study of Solutions, in order to justify which of them were the most adequate to the real situation of the city of Wukro. Three of these alternatives that were possible to develop, attending to technical, economic and environmental criteria, were selected. These three alternatives were further studied in greater detail, sized and well defined.

From these three solutions one of them, the one that technically is more adequate, is going to be developed in the Constructive Project.

Nevertheless, it is important not to forget that this project is very subject to variations due to the availability of new data, material and human resources and the possibility of obtaining funding for the construction of it.
3 Reference documents

- *WHO Guidelines For The Safe Use Of Wastewater, Excreta And Greywater*. Excreta and greywater use in agriculture (Volume iv).- World Health Organization, 2006


- *Compendium of Sanitation Systems and Technologies*. Elizabeth Tilley, Christoph Lüthi, Antoine Morel, Chris Zurbrügg and Roland Schertenleib. EAWAG.


- *Composting Manure and Sludge*, John M. Sweeten and Brent W. Auverman, AgriLIFE Extension

- *Sandec Training Tool 1.0 Faecal Sludge Managemente (FSM)*, EAWAG

4 Project Conditions

In this type of project it is very important that the approach to the population is based on knowledge and respect of their culture and there initiatives, trying to develop their abilities because in the future they will have to manage these infrastructures projected. Therefore, the conditionings to take into account in the developing of the project are strongly dependent on the participation of the community, and public authorities.

4.1 Property conditions

The location of the Treatment Plant of feacal sludge is one of the main challenges that a project of these characteristics should deal. The location of the Plant has strong environmental, economic and social consequences that have to be previewed.

But the ultimate choice of the location of the Treatment Plant is a political decision. Appendix B Site Studies describes the requirements of an optimal location for the Treatment Plant, and proposes a possible location.

4.2 Technical performance conditions

The major technical constraints of a project in an area so little developed are based on two inherent assumptions:

- The low level of technical knowledge of the region. Not all the data is available and reasonable assumptions that offer reasonably effective solutions will have to be made. There is many data that has not been taken, and some of them has been taken but it is unknown. Many of this data will be obtained during the project development and the execution of the works.

The characteristics of the sanitation system and the sludge treatment required, widely different from Europeans’, restrained as well the utility of European information. There was neither many information about experiences in treatment plants in contexts like the one of Wukro

- The scarce technical development of the area. Especially regarding to materials and machinery, which is not usually accessible and costly. The training of specialized technicians is not very high, despite the efforts St Marys’ College does.

Based on the above assumptions, the project will have the following technical performance conditions.

1. Appropriate materials will have to be selected. The structures will be the minimum, and the materials prioritized will be limestone, lime, hollow concrete blocks and Eucalyptus wood.

2. The construction method has to be as traditional as possible, manner that avoids the use of heavy or sophisticated machinery. Human work is cheap, although resources are very limited.
3. It has to be projected with low topographic, geological and hydrological precision, so a flexible solution is required.

4. A solution with the lowest dependence on energy or exterior materials will be developed. A solution which needs not energy in construction and operation will be developed.

5. Water is an scarce resource in the area, as it can be further seen in Annex 3- Climatic Studies. The water required for the treatment in the operation step, will have to be harvested from rainfall. This system will also have to be designed.

6. The water required in the construction site must be carried by truck or pickup trucks and must be minimized.

7. An horizon of 5-years for sizing the plant is taken for two reasons:

   - There is no urban tradition, and no experience in programmed and organized public services as Solid Waste or Sludge Treatment in the city. It is better to start with a small scale plant and evaluate the success.

   - The development of the construction industry in the city and surroundings is changing tendencies in house building. It is likely that the sanitation system incorporates more and more septic tanks that produce sludge with less solid material since it is more digested.

8. Manual operation is previewed. A place with a slope of 4 % and a distribution that favors gravity force will be selected.

4.3 Conditions associated to Management of Human Excreta

A treatment of Feacal Sludge, due to the Health Risks associated to this material, has to ensure Public Health.

Risks are to be identified, defined and developed in this project in order to ensure Public Health, and the pertinent measures to minimize health risks have to be described.

The treatment system in study aims to constitute a direct barrier for the first transmission of pathogens from faeces to flies, fields, fluids and human beings. The treatment system projected therefore has to protect public health intervening in potential risk that an infection dose of an excreted pathogen reaches the field or pond, animal or human.

The conditionings associated to the management of Human Excreta are:

1. The treatment plant will need a buffer area, in order to prevent from animal entrance.

2. Make the working-area impermeable, in order to prevent infiltration of lixiviates in the terrain and further pollution of crops or water flows.
3. **Sufficient pluvial drainage system** for run-on water into the plant, to protect from run-off of lixiviates or material.

4. **Drainage of lixiviates and** pertinent further **treatment** of them.

5. **Guarantee health of workers** that operate with the sludge with the pertinent measures.

6. **Control of flies near the sludge**, this can be done by adding lime or other measures.

7. **Controlling the dose of infective pathogens in the final agricultural product** so it doesn’t constitute a health risk for any of the individuals. Any treatment should be followed by the pertinent analyses of final product in order to ensure Public Health.
5 Basic studies

The basic studies done are going to be described briefly in this part of the Report in order to propose the different alternative solutions and the comparison of them. Further information is described in the correspondent Annexes to this Report.

5.1 Demand Studies

This study is detailed in “Annex 2: Demand Studies”, where the production of sludge of the city of Wukro, in terms of quantity and composition, is analyzed. The object of it is to establish the total quantity of sludge material that needs to be discharged, transported and treated in 5 years.

The actual population of the city of Wukro is 42000 inhabitants. It is expected that the population of Wukro continues growing with a rate of 5 %. In 5 years the population of Wukro is estimated to be 53604 inhabitants. No further projections are done because population is likely to change in this time and so sanitation system, and the plant has to have manageable dimensions.

The household sanitation system of the city of Wukro is based on pit latrines. The material in these pit latrines will be collected with a Vacuum truck of 7500 L.

The estimated characteristics of the sludge of the pit latrines per capita per day are the following:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass TS</td>
<td>90 g/cap.day</td>
</tr>
<tr>
<td>Mass FS</td>
<td>204.7 g/cap.day</td>
</tr>
<tr>
<td>Volume FS</td>
<td>0.20 L/cap.day</td>
</tr>
<tr>
<td>Moisture</td>
<td>56 %</td>
</tr>
</tbody>
</table>

The total sludge to be treated per day is the product of the population in five years and the quantities produced of FS, supposing it is lost 10 % of the material in the collection:

<table>
<thead>
<tr>
<th>Volume FS m3/day</th>
<th>9.65</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS t/day</td>
<td>9.88</td>
</tr>
</tbody>
</table>

And in one year:

<table>
<thead>
<tr>
<th>Volume FS m3/year</th>
<th>3521.78</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS t/year</td>
<td>3604.39</td>
</tr>
</tbody>
</table>
5.2 Topographic Studies

This study is detailed in “Annex 3: Topographic Studies”.

The objects of this study is to describe the general topographic characteristics of the zone of Wukro, give some recommendations for the placement of the Treatment Plant, describe the works to be done for setting-out of the construction, and define an hypothetical topography for the design of the project.

The landform of Wukro area could be classified in two broad categories, hilly and flat terrain. The hilly terrain is found at the northern and southeastern fringe of the town and extends further to the west and east at places where the bed rock is exposed. The flat terrain which covers most part of the town.

Wukro is limited at west by Genfel river and in the east by hilly terrain. Its average altitude is 2195 m.a.s.l, and the altitudinal variation is 110 meter, that has been registered due mainly to the inclusion of hilly landscapes (in the northern and southern peripheries).

Its approximate geographic coordinates are:

39° 37’ East Longitude.

13°47’ North Latitude.

It is located in UTM grid zone 37P.

Since the ultimate choice of the location of the Treatment Plant is a political decision, no parcel was selected for the Treatment Facilities. But however, the location of the Treatment Plant of fecal sludge is one of the main challenges that a project of these characteristics should deal with (Further information is in Appendix B: Site Proposal). In terms of topography, the site will have to take into account:

1. Slope of the terrain of less than 8 %. Slope facilitates labour.
2. A zone where the relief is able to “absorb” the plant without landscape discordance.
3. Avoid points of high wind incidence as saddles, defiles and watersheds.

The principal objective of the setting-out of the construction is to stake out on the terrain singular points of the Treatment Plant. For the case of study, the setting-out will be done in local coordinates, from two setting-out bases. These bases have to be well marked on the terrain and have visibility to the other singular points of the construction. The two bases selected are two corners of the treatment plant with local coordinates (0,0) and (0, 80). These two points will define a reference axe. A precision of ± 2 cm is considered enough for this type of plant, and surveys can be done with an old theodolite or a total station.

For the further correct development of the project, an hypothetical topographic surface has to be considered, and this would be an inclined plane of 4% slope to favor gravity force.
5.3 Climatic Studies

This study is detailed in “Annex 4: Climatic Studies”. The principal object of this document is to gather and analyze qualitative and quantitative data of temperature, rainfall and wind in the city of Wukro in order to choose the best treatment for these climatologic conditions, to size the treatment system in terms of times and volumes, and to protect the treatment system from adverse climatologic conditions as wind and rainfall.

It was found that there are not too many quantitative climate data but mostly qualitative, since there is not a long tradition of urban and rural planning in the city. The only meteorological station in Wukro is located at St. Mary’s College, but only fragmented rainfall data, and temperatures are registered, no wind direction and speed.

The climate of Wukro can be considerate a temperate climate, without big contrasts, with a medium temperature of 17ºC and temperature varies from 12 to 27 ºC in the hottest month and 7º to 22º in the coldest. These values have been obtained from the maximum and minimum average temperatures data registered between (2005-2012).

Rainfall data was obtained for the period from 1992 to 2009, but not for every month. With this data an average year was calculated.

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dic</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,6</td>
<td>2,3</td>
<td>19,7</td>
<td>31,9</td>
<td>26,0</td>
<td>43,0</td>
<td>203,7</td>
<td>211,3</td>
<td>26,0</td>
<td>5,6</td>
<td>3,1</td>
<td>1,1</td>
<td>574,3</td>
</tr>
</tbody>
</table>

The average annual rainfall is 575 mm, which is a sufficient value, but rainfall is concentrated during 3 months, normally between June and September, observing that 75 % of rain fall during July and August. The rest of the year water resources are scarce. For this reason, during the rainy season an open air solution has difficult to work.

The Aridity index of Wukro was estimated by the Bagnouls-Gaussen index (BGI) using the following equation: 
\[ BGI = \sum (2T_i - P_i)*k; \]
where: \( T_i \) is the mean air temperature for month i in °C, \( P_i \) is the total precipitation for month i in mm; and \( k \) represents the proportion of month during which \( 2T_i - P_i > 0 \). The result obtained was a BGI=123. Which means that Wukro has a high aridity climate and, as mentioned before, water resources are very variable and scarce in some periods, and land is more vulnerable to desertification and floods. An area less vulnerable to floods has to be selected in order to reduce lixiviation risks.

According to interviews done in the zone of Wukro, the direction of wind is thought to be southeasterly and northwesterly, but it is also said that it varies with the season. Further interviews or studies about the velocity and direction of the wind are recommended at the moment selection of the site since the direction of the wind affects odours and atmospheric pollution in the city.
5.4 Geologic Studies

The Geologic Studies for this document, enclosed in “Annex 5: Geologic Studies”, aim to describe the geological characteristics of the zone of Wukro, identify the rocks that may be used as construction materials and define the recommended surveys to do at the project site before construction.

5.4.1 Geology of Wukro

The geology of Wukro area is characterized by Precambrian metamorphic rocks and Mesozoic sedimentary rocks.

The Precambrian metamorphic rocks are found at the eastern and north-eastern part of the town. It mainly consists of slates, phylite and carbonates. The slate is exposed forming steep slope and having purple and dark bluish color, while the phylite commonly has light greenish color. The carbonate consists of quartz, limestone and quartzite, depicting whitish color.

The Mesozoic sedimentary rocks are represented by three different rock types of Adigrat sandstone, Hintalo limestone and Agula shale.

- The Adigrat sandstone is exposed forming steep slopes at the south and south eastern part of the town, and it commonly has red and white color and fine grains. It also shows joints, cross bed, vein lets and cross bedding.

- The Hintalo limestone is found overlying the Adigrat sandstone and forming terraced and tilted slopes at eastern and northwestern part of the town, it commonly has rectangular jointing, tilted bedding and grey and yellowish color.

- The Agula shale is characterized by grey color, rectangular joint, thin veins and very soft strength which in some places lead to formation of light green clay soil. It covers extensive flat lying areas and it has 10-20% limestone beds and the rest is either well jointed hard shale or soft powdery shales. It is outcropped at river cut conformably overlying the Hintalo limestone in southern part of the town.

The geological structure of Wukro area is manifested by faults, joints, folds and bedding system. The major fault which demarcates hilly limestone and sandstone beds from flat terrain generally run from northwest to southeast. The joints observed on the sandstone bed are filled with secondary materials while those noticed on limestone beds are longer in size and frequent in number and often filled with secondary materials. The bedding system of the Wukro area is represented by tilted beds of limestone and sandstone showing general northwest-southeast orientation which dip to northeast.

The geology of the area, the nature of the rock and geological structure favor infiltration of rainfall and river water to the ground. The joints and karsts of the limestone, intergranular openings of the sandstone and alluvial soil and the fault lines facilitate easy entrance of water in to the groundwater system. The geology of the area also favors storage and accumulation of water in the groundwater system. Fractures of the Hintalo limestone and joints of the sandstone together with the fault lines that cut these formations create good aquifer for holding of ground water.
Genfel River and its tributaries represent the natural surface water resource of Wukro and the surrounding area. This river has permanent water flows which diminish in size during dry season and drought period. Currently, the river is intensively utilized for agricultural activities. Thus, it is becoming an intermittent river. On the other hand, this river is the major feeder of the ground water system, which is the only source of water for the municipal water supply system.

According to the preliminary assessment made on the water resources of the area, the major water source for recharging of the ground water system comes from direct infiltration of the rainfall and through the continuous flow of Genfel River.

5.4.2 Construction materials

Generally, the geology of Wukro area tell us that there is variety of rock that can be used as construction material (limestone, sandstone, etc.).

Both sandstone and limestone have been used for masonry in traditional construction from ages in the zone. Sandstone is hard, resistant stone, and relatively easy to work.

The most versatile rock in the zone is limestone. Most limestone is crushed and used as a gravel for construction. It is used as an aggregate in concrete. Also it is fired in a kiln with crushed shale, also available in the area, to make cement. Normally, they are strong, dense rocks with few pore spaces. These properties enable them to stand up well to abrasion and freeze-thaw. Although limestone does not perform as well in these uses as some of the harder silicate rocks it is much easier to mine and does not exert the same level of wear on mining equipment, crushers, screens and the beds of the vehicles that transport it.

Lime coming from burning limestone can as well be used directly together with a fine-grained clay soil (25 % passing 74 mm and plastic index > 10) in a proportion of 3 to 6 % by weight, in order to make it resistant and improve the retaining of water conditions of the soil.

There are quarry sites of lime around Wukro and people of the town are practicing the production of lime by burning limestone.

Enterprises like Mesobo cement factory in Mekele exploits materials of the area for its industrial production.

5.4.3 Recommended surveys before construction

For the selection of a site for the treatment plant, in terms of geology and hydrology, it is recommended:

1. Low permeability of the terrain.
2. Far away from permanent water resources, subterranean and superficial. It is important to avoid Genfel river nearby zones that is the main water source of Wukro in order not to pollute it.
3. At a site where flood risk and hydraulic erosion is minimized. Avoid land depressions.
Permeability of the soil is a very important characteristic in the case of study, a Faecal Sludge Treatment Plant, since the material treated is very dangerous for Public Health. It is fundamental to avoid pollution of water resources and crops.

Since information related to permeability in bibliography and geological maps of the zone will not sufficient, when the authorities select a location for the Treatment Plant, two simple geological surveys may be done on the site and are further described in Annex 5 Geologic Studies.

If the permeability rates were specially low, the impermeable surface could be reduced to one layer of lime-soil mixture of 30 cm for economic reasons.
6 Study of Solutions

Once the conditions and the studies done are presented, it has to be explained how it was arrived to the solution for the Feacal Sludge Treatment in the city of Wukro.

Different solutions for the treatment of sludge, adapted to the product that is to be treated, and the particular context of Wukro are presented. The main consideration was the sanitization of the final product while using the minimum quantity of water, energy or other materials that create external dependence.

6.1 Proposal of Solutions

To analyze each solution, a list of indicators for each concept will be taken into account. This will allow us to have a view of the advantages and disadvantages of the proposed solutions in different fields, and to compare them qualitatively to select three of them.

The factors and indicators identified as essential to compare and choose between the different solutions are:

<table>
<thead>
<tr>
<th>FACTORS and INDICATORS EVALUATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
</tr>
<tr>
<td>Society</td>
</tr>
<tr>
<td>Economy</td>
</tr>
<tr>
<td>Technology</td>
</tr>
<tr>
<td>Product</td>
</tr>
<tr>
<td>Environment</td>
</tr>
<tr>
<td>Sustainability</td>
</tr>
</tbody>
</table>

The options proposed for the Sludge Treatment Plant were:

A) Unplanted drying bed

B) Planted drying bed
Sludge treatment system in the city of Wukro (Ethiopia)

C) Co-Composting with organic solid waste plant
   Wind-row composting (turned or passively aerated wind-rows)
   Traditional Bin composting. Long bins.

D) Anaerobic Biogas Reactor

E) Direct burying

From these, the solutions selected were the ones that adequate better to the type of sludge to be treated, the characteristics of the material obtained, and the context of the city of Wukro in terms of economy, climatology, sociology and technology. An accurate description is done in Annex 6 Proposal of Solutions.

The three solutions chosen were:

Solution A. Unplanted Drying Beds

Solution C. Co-Composting With Organic Solid Waste Plant
   C.1. Wind-row Composting
   C.2. Long Bin Composting

6.2 Previous Study of Solutions

The three solutions selected are described below. However, for more detail see Annex 7 Pre-dimensioning of Solutions.

6.2.1 Solution 1. Drying Beds Plant.

This treatment consists in drying open air the sludge from the pit latrines in cycles of 13 days, loading the beds 6 days a week. The plant will be working only during the dry season, approximately 9 months.

The different parts considered for the plant are:

a) 12 drying beds of 3.5 m x 14 m.

b) Access to all drying beds for the Vacuum truck, 5 meters accesses.

c) 510 m² of roofed storage zone of final product 15 m x 34 m.

d) Drainage system to lixiviation pond.

e) Buffer zone and drainage system from run-on water, surrounding the perimeter of the area, about 2 meters wide.
Drying beds need an impermeable surface, in order to inhibit filtration of lixiviates (very contaminant in case of human excreta) to the terrain. This surface will be constituted by 2 layer of 30 cm of soil-lime with a 3 % of lime and between both the layers a layer of 2 cm of clay will be considered. Clay will prevent from percolation of lixiviates if the top layer breaks and as well procures the friction between both layers preventing slipping.

On top of this surface a layer of gravels, 40 cm deep, that permits percolation of lixiviates to a longitudinal perforated pipe that is at the bottom of the bed.

The beds are loaded with 30 cm of sludge. With the action of sun, by evaporation, and drainage the material is dried. The drying of sludge reduces the quantity of pathogens present in it, and as well its volume, so it may be used directly in agriculture. It is estimated a reduction of volume of the 40 %.

6.2.2 Solution 2. Wind-row Co-composting Plant

This solution consist of a termophilic composting treatment done with organic waste (OW) to stabilize the sludge (FS) and get a good product for agriculture. During termophilic composting a temperature more than 55 ºC is achieved and most of the pathogens present in excreta die off. The process it takes part, is an aerobic decomposition, this means it needs oxygen to work out.

Wind-row composting consists on placing on a regular basis the mixture of raw materials in long narrow rows. So it doesn’t need additional constructions and there may not be big differences between composting area and maturation area. These wind-rows are aerated by manual turning operation.

- The wind-row dimension is 2.5 m wide and 1.5 m high, and 4 m length.

Parts of the treatment plant

a) Storage zone for incoming organic waste 30 m x 12 m = 360 m²

b) Active composting area that will consist of 4 buildings of 20 m x 30 m (600 m²) with the same characteristics:

- 20 wind-rows 2.5m x 1.5 m x 4 m.
- An impermeable surface of soil-lime mixture 60 cm thick.
- A hollow blocks wall with for entrances to prevent run-off of lixiviates and entrance of vectors.
- Drainage system for lixiviates, and posterior recollection in a small tank for reuse.
- A metallic roof to prevent water from evaporating due to the arid and hot climate (*detailed in Annex 4 Climatic Studies*), to enable working in the rainy season, and to collect rainfall water.

- Water tank of 30 m³ to remoisten the material during active composting

- Accesses for the Vacuum truck of 5 m.

- Perimeter drainage system for run-on water (rainfall).

c) **Maturation and storage area** will consist on a covered shed of 15 m x 60 m (900 m²).

- An impermeable surface of soil-lime mixture 60 cm thick.

- Drainage system for lixiviates.

- A roof that may be metallic or not, since no water harvesting is required.

d) **Buffer zone** for controlling access of persons and animals, and a perimeter drainage system for run-on rainfall in this buffer zone.

### 6.2.3 Solution 3 Long-bins Co-composting Plant

This solution consist as well on a termophilic composting treatment done with organic waste (OW) to stabilize the sludge (FS) and get a good product for agriculture.

This long bins composting system works similar to wind-row composting system but the composting area consists of bins are open on the top, with four walls made of perforated bricks that permit aeration. The system of bins contains better humidity and temperature, which improves the initial composting stage.

This method previews 3 ways to achieve aeration:

a) Turning operation below 48 ºC in order to boost aerobic decomposition. Every day during the first week.

b) Air supplied through perforated pipes embedded in each bin after the first week. This system has to be controlled and maybe combined with turning when necessary. One set of perforated pipes every 0.75 meters, consisting of three upright tubes. These pipes may be obtained from *Oxytenanthera abyssinica*, an autochthon “bamboo” plant, found near Wukro.

c) The floor of the box is bedded with dry leaves and branches to improve aeration in the lower part of the pile.

A mechanical turning system working with human force could be installed in rails disposed one the walls to facilitate turning operation.

- The bins consist of 4 walls of 1 meter height made of hollow concrete blocks (HCB), with a metallic door 2 meters width on the edges of the bin. Every 0.75 m a set of pipes is disposed.
The difference between the wind-row composting plant and this one is the active composting area:

- The distribution of long bins will be in groups of 5 under a same type building, in order to utilize well the space, facilitate labour, and shorten transport distances. Dimensions are 27 x 19 m (513 m²).
- Water tank dimensions is 25 m³ in each type building.

6.3 Comparison of Solutions

Once the pre-dimensioning is done, it is possible to compare the three solutions. The method that is used for the comparison is ELECTRE II (described in Annex 8 Comparison of Solutions).

According to different concepts and indicators that characterize all of the solutions, one of them is selected. In the following table the different indicators are presented with the weights given to each of them.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Indicator</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functionality</td>
<td>a) Quantity of final product</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>b) Flexibility to demand changes.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>c) Helminthes egg in final product</td>
<td>5</td>
</tr>
<tr>
<td>Climatology</td>
<td>d) Working days</td>
<td>2</td>
</tr>
<tr>
<td>Topography</td>
<td>e) Land requirement</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>f) Earth-works</td>
<td>3</td>
</tr>
<tr>
<td>Sociology</td>
<td>g) Work generation</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>h) Innovation</td>
<td>3</td>
</tr>
<tr>
<td>Economy</td>
<td>i) Construction costs</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>j) Production costs</td>
<td>5</td>
</tr>
<tr>
<td>Environment</td>
<td>k) Exposure of sludge to vectors</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>l) Exposure of workers to sludge</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>m) Vulnerability to natural phenomenon</td>
<td>5</td>
</tr>
</tbody>
</table>

For each solution, a punctuation is given based on these indicators (further details in Annex 7- Pre-dimensioning of Solutions and Annex 8- Comparison of Solutions).

The final table of comparison of solutions is the following.
Sludge treatment system in the city of Wukro (Ethiopia)

<table>
<thead>
<tr>
<th>Concept</th>
<th>Indicator</th>
<th>Weight</th>
<th>Sol 1</th>
<th>Sol 2</th>
<th>Sol 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functionality</td>
<td>a) Quantity of final product</td>
<td>5</td>
<td>25.0</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>b) Flexibility to demand changes.</td>
<td>5</td>
<td>0.0</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>c) Helminthes eggs in final product</td>
<td>5</td>
<td>25.0</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Climatology</td>
<td>d) Working days</td>
<td>2</td>
<td>10.0</td>
<td>20.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Topography</td>
<td>e) Land requirement</td>
<td>2</td>
<td>20.0</td>
<td>8.7</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>f) Earth-works</td>
<td>3</td>
<td>15.0</td>
<td>30.0</td>
<td>29.3</td>
</tr>
<tr>
<td>Sociology</td>
<td>g) Work generation</td>
<td>3</td>
<td>9.0</td>
<td>30.0</td>
<td>24.0</td>
</tr>
<tr>
<td></td>
<td>h) Innovation</td>
<td>3</td>
<td>0.0</td>
<td>15.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Economy</td>
<td>i) Construction costs</td>
<td>5</td>
<td>50.0</td>
<td>22.8</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>j) Production costs</td>
<td>5</td>
<td>50.0</td>
<td>25.0</td>
<td>37.4</td>
</tr>
<tr>
<td>Environment</td>
<td>k) Exposure of sludge to vectors</td>
<td>5</td>
<td>0.0</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>l) Exposure of workers to sludge</td>
<td>5</td>
<td>50.0</td>
<td>16.1</td>
<td>34.6</td>
</tr>
<tr>
<td></td>
<td>m) Vulnerability to natural phenomenon</td>
<td>5</td>
<td>0.0</td>
<td>50.0</td>
<td>50.0</td>
</tr>
</tbody>
</table>

Based on this matrix the solution selected, the one with the highest punctuation is **Solution 3, Long Bin Co-Composting Plant**.
7 Description of the Selected Solution

This solution consist of a aerobic termophilic composting treatment done with organic solid waste (Org. SW) to stabilize the sludge (FS) and get a good product for agriculture. To be classified as a “process to further reduce pathogens,” which is considered equivalent to pasteurization, a temperature of 55 °C must be attained for 7 days being turned at least once a day.

This long bins composting system works similar to wind-row composting system but the composting area consists of bins are open on the top, with four walls made of perforated bricks that permit aeration. The system of bins contains better humidity and temperature, which improves the initial composting stage. So it is planned to be only in this phase, in order to minimize constructions. Since the walls contain the material, this system contains accessibility to animal vectors, and run-off of material in period of heavy rainfall.

Design hypothesis

a) The faecal sludge/organic waste ratio selected is 1:2 in volume.
b) The system will be working the whole year.
c) Composting cycles of 8 weeks (4 for composting and 4 for maturation).
d) Manual labour is previewed.
e) Expected final reduction of volume of the material is 50%.
f) Expected requirement of addition of water to compost of the 5% of the weight of FS.

The scheme of the treatment is the following:

<table>
<thead>
<tr>
<th>Collection of Faecal Sludge</th>
<th>Storage of Organic Material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Active Composting stage</td>
</tr>
<tr>
<td></td>
<td>Maturation Stage</td>
</tr>
<tr>
<td></td>
<td>Storage of Final Material</td>
</tr>
</tbody>
</table>

Around this scheme it is a buffer zone for controlling access of persons and animals, and a perimeter drainage system for run-on rainfall in this buffer zone.

7.1 Collection of Faecal Sludge (FS)

Faecal Sludge Collection is done from pit latrines to the composting plant in a Vacuum truck of a capacity of 7.5 m³ (described in Annex 2 Demand Studies).

It is considered that collection is done 5 days a week with 2 vacuum trucks/day. The arrival of trucks to the plant in one month may be programmed as follows:

<table>
<thead>
<tr>
<th></th>
<th>day 1</th>
<th>day 2</th>
<th>day 3</th>
<th>day 4</th>
<th>day 5</th>
<th>day 6</th>
<th>day 7</th>
<th>Total/week</th>
</tr>
</thead>
<tbody>
<tr>
<td>week 1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>week 2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>week 3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>week 4</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

40 trucks
The plant treats 20 lots (20 days of delivery) of 2 trucks of FS and the correspondent quantity of organic SW.

### 7.2 Storage of Organic Material

The quantity of material to be treated is calculated adding the volume of sludge required to be daily treated (2 trucks: 14 m$^3$/day) and the volume of organic solid waste required (two times the volume of the FS). This quantity constitutes a lot.

<table>
<thead>
<tr>
<th>2 trucks of FS</th>
<th>7 x 2 trucks</th>
<th>= 14 m$^3$ of FS/lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of Organic SW</td>
<td>2 x 14 m$^3$</td>
<td>= 28 m$^3$ of Org SW/lot</td>
</tr>
<tr>
<td><strong>Total Lot of RM</strong></td>
<td>14 m$^3$ of FS + 28 m$^3$ of Org SW</td>
<td>= 42 m$^3$/lot</td>
</tr>
</tbody>
</table>

The organic material for the compost may be obtained from **cereal crops residues**. This type of material is very important for compost mixture, since it performs as a bulking agent giving the material de porosity necessary for a good aeration.

The area to storage this material is previewed to retain the 10% of the material needed during the whole year. If material is only residues from cereal crops, there is no need of covering the area with a roof or doing an impermeable surface. It will be an area of 30 m x 12 m = 360 m$^2$.

### 7.3 Active Composting Area

The active composting stage includes a mesophilic, or moderate-temperature phase, which lasts for a couple of days, and the thermophilic, or high-temperature phase, where bacteria and fungi are activated and die off of pathogens take place. It is programmed to last **1 month**. The volume of the material is reduced in 50% of its volume.

The area of active composting consists of **4 buildings of 19 m x 27 m** (513 m$^2$) with the same characteristics:

1. **Five long bins of 3 m x 1 m x 15 m**. The bins are formed with 4 walls of 1 meter height made of hollow concrete blocks (HCB) made in the city, and with two metallic door 2 meters width on the edges of the bin in order to facilitate operations.
2. An impermeable surface of soil-lime mixture 60 cm thick. This surface will be constituted by 2 layer of 30 cm of soil-lime with 3 % weight of lime and between both the layers a layer of 2 cm of clay and will be considered. Sand will prevent from percolation of lixiviates if the top layer breaks.

3. **Drainage system for lixiviates**, and posterior recollection in a small tank for reuse.

4. A metallic roof to prevent water from evaporating due to the arid and hot, to enable working in the rainy season, and to collect rainfall water.

5. **Water tank of 25 m³** to remoisten the material during active composting.

6. **Accesses** for the Vacuum truck of 6 m.

7. Perimeter drainage system for run-on water (rainfall).

---

### 7.4 Maturation and Storage Area

After active composting all material will be transferred to the same maturation area where it is piled. The volume of the material is reduces to half its volume. The dimensions of this area will be 15 m x 60 m (900 m²).

1. An impermeable surface of soil-lime mixture 60 cm thick, like the one described before.

2. Drainage system for lixiviates and its correspondent tank.

3. A roof that may be metallic or not, since no water harvesting is required.
7.5 Distribution of the plant

![Graphic 7 Distribution of the Treatment Plant based on long-bin composting]

Total land required (m$^2$) = 80 m x 92 m = 7360 m$^2$

7.6 Final Material Obtained

The quantity of material produced is expected to be the 50 % volume of the raw material. Every 8 weeks (one month), 1 cycle of compost is finished, but every month 20 lots are ready. Then the total final product (FP) in one month will be:

Volume of final product (m$^3$) = 42 m$^3$/lot x 20 lots /month x 50 % = 420 m$^3$/month

Even if the need of compost for crops is lower than the quantity of material produced. This material may be used as well in any land, to improve water retention capacity of the soil.
7.7 Operational requirements

In this type of processes, the primary factors that affect biological activity and composting rates are moisture content, physical structure and consistency, aeration, nutrient balance, pH, and temperature. Factors like aeration, temperature and humidity, are considered in the construction of the long bins. Other factors like nutrient balance, pH, and consistency will have to be studied deeply in situ by experts from St Mary’s College.

This method previews 3 ways to achieve aeration:

- Turning operation below 48 °C in order to boost aerobic decomposition.

- Air supplied through perforated pipes embedded in each bin. One set of perforated pipes every 0.75 meters, each consisting of three upright tubes. These pipes may be obtained from *Oxytenanthera abyssinica*, an autochthon “bamboo” plant, found near Wukro. This plant may be planted in the buffer area of the Treatment Facilities in order to be available over time. Every 0.75 m a set of perforated pipes is disposed.

- The floor of the box is bedded with dry leaves and branches to improve aeration in the lower part of the pile.

A mechanical turning system working with human force could be installed in rails disposed one the walls to facilitate turning operation.

The following activities are considered:

1. Storage of organic material

2. Bedding the bins. To improve aeration the floor the bins is manually bedded with dry leaves and branches to improve aeration in the lower part of the pile.

3. Discharging the material and piling. This operation is done in one day. Sludge is discharged with a hose attached to the Vacuum Truck.
4. Turning during active composting. Aeration of the bins is only done manually until 48 ºC is achieved, in order to boost aerobic decomposition.

5. Control of temperature, moisture and aeration.

6. Tube disposing. Perforated pipes are embedded in each bin to supply

7. Transfer of material. After 4 weeks the material is reduced to half its size and it has to be transferred to the maturation and storage area with a wheelbarrow (or truck if available). No turning is previewed during this phase.

A program of discharge, turning and transfer for each type building is proposed. However, as it was mentioned before, this turning program is based on empiric studies and should be adapted to the requirements observed during the application of the system.

Legend

a, b ,c ,d and e are the names given to lots of 2 trucks arriving each day.

M stays for Making the piles of lot “x”

N stays for turning piles of Lot “x”

T stays for transferring the material of Lot “x” to maturation area.
Proposed Schedule for 1 type building

During the central weeks no big labours have to be done at each bin. Turning is only required at the first weeks in order to make the material boost into thermophilic decomposition.

Attending to this schedule, in order to comply with all the labours, a minimum number of 3 workers may be needed for each 2 type building. Six workers minimum in total plus two that realize the coordinating activities.

Labour needed: 8 workers
Co-Composting Plant in the city of Wukro (Ethiopia)

St. Mary’s College, Wukro

Ana Rubio Gavilán
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1 Background

1.1 Context of the project

This project aims to improve the sanitation facilities, particularly the management of latrine wastes, designing a sludge treatment plant, in the city of Wukro, Tigray Region, northern Ethiopia.

This is a Final Studies Project in Development Cooperation, in the E.T.S.I. de Caminos, Canales y Puertos of the Universidad Politécnica de Madrid.

The project is framed in the Final Project Department of the E.T.S.I. de Caminos, Canales y Puertos in collaboration with Wukro’s St. Mary’s College and the Mission of Ángel Olarán, that are part of the Ethiopian Catholic Church Diocese of Adigrat (ECCA).

St Mary’s Agricultural College is an institution founded in Wukro by the ECCA more than twenty years ago. This College has two working lines. On one hand, it gives students of all over Ethiopia the opportunity of study agriculture, silviculture and farming. On the other hand, in cooperation with Angel Olarán’s Mission and the Catholic Community of Wukro, it has the purpose of improving life quality in Wukro and the kebeles around, developing agricultural, environmental, and water resource projects to support the farmers and the population.

1.2 Previous situation

The city of Wukro is situated in the north of Ethiopia in Tigray’s Region. The actual city, of about 42,000 inhabitants, was founded by the Italians in 1936. Due to its geographic location, that makes the city suitable for industrial and agricultural activities, Wukro is becoming an important administrative and economic center in the region, and its population is growing fast.

But yet urban services in Wukro are not very developed, since there is no urban tradition and low economic resources. Even though, in the last years, big efforts have been done by the Municipality and International Institutions.

The sanitation system of Wukro is deficient. It consists in dry pit latrines situated in the yard of private houses. Some important buildings, as St Mary’s’ Catholic Church have septage tanks, but this is not very significant. When the pit latrines are full, they are covered with soil and another one is constructed if there is enough room.

As it has been mentioned before the population of Wukro is growing fast, and so is the population density as well. Density is increasing because the urban area is limited on the west by the river, the north and the east by mountains and the south by cultivated lands. This fact is causing problems of room for latrines (they are not constructing new ones) and therefore risks to Public Health.

Recently, the Municipality of Wukro has acquired a Vacuum truck of 7500 L for extracting the sludge from the pit latrines.
However, there is currently no scheduled program for cleaning the pit latrines, no place fixed and controlled for disposal of the material, nor a treatment planned for the sludge.

Wastes are being disposed in an uncontrolled manner in the fields, with a high risk of pollution of crops and water resources, and therefore constituting a risk for Public Health as well.

1.3 Related studies

There are no previous construction projects or studies of sludge treatment in the region, since there is no urban tradition in the region, and sanitation has not been a priority in this mainly rural area. Sanitation concern usually appears as a priority when the density of the cities grows and it can affect Public Health.

One recent study the “Wukro Integrated Development Plan” of 2008 done by the government of Ethiopia, is a noteworthy reference about the urban situation of the city of Wukro.

As written construction projects recently developed in the region, it can be mentioned the Hizaeti Afras Dam, done together by the AECID, Adigrat Diocesan Catholic Church and Fundació Lleida Solidària.

On the other hand, the document of the WHO Guidelines for the Safe use of excreta were studied. In the frame of International Development, other projects of sanitation similar to this one were examined, specially the Co-Composting Plant in Kumasi Ghana, done by various agencies of the Sustainable Sanitation Alliance (SuSanA).

1.4 Needs program

As it is deeply studied in Annex 1 Population Studies, the problems and needs of Wukro are numerous and becoming more severe due to the growth of population that the city is experimenting in the last years and the lack of urban tradition in the region.

The “Wukro Integrated Development Plan” of 2008 done by the government of Ethiopia, with representatives of the community from all kebeles, technicians of the municipality, experts of sectoral offices, the steering committee and the representative forum members, have identified various urban problems. These priorities were: Flood and drainage problem, Water supply problem, Social service (education and health) problem, Unemployment problem, and Infrastructure coverage and coordination problems.

The Municipality and some NGOs are already working on some of these priorities, as the new net of rainfall drainage and some new water wells.

The writer of this project, after the visit to Wukro, has found out big necessities in civil infrastructures and urban services. Related to civil engineering the two principal priorities found were Water Supply and Improved Sanitation Facilities, both of these priorities affect directly to Public Health and Food Security.
1.5 General and particular objectives of the project

The **overall goal** of the project is to collaborate to Universal Access to Basic Services and contributing to ensure Millennium Development Goal 7, Environmental Sustainability (declared by the United Nations in 2000). Improving access to sanitation facilities also contributes indirectly with Millennium Development Goals 4 “Reducing child mortality rates”, 5 “Improving maternal health”, and 6 “Combating HIV/AIDS, malaria, and other diseases”.

The **particular goal** of this project is to guarantee a good sanitation treatment that constitutes a barrier to the transmission of pathogens in excreta improving Public Health while giving an added agricultural value to the input material.

It is also pretended that the technical recommendations of design and operative process that result from the project are useful in the future for developing similar projects in the region.

1.6 Petition of the project

This project is framed in the labor of St. Mary’s College and Ángel Olarán in Wukro improving urban and social services in the region, and the improvement of household sanitation facilities.

The initiative of the project begins when the writer of the project gets in contact with the Spanish missionary Ángel Olarán, and gets to know the labor that he is developing in the north of Ethiopia. Ángel Olarán is specially interested that people from different contexts collaborate and exchange knowledge with his mission. During the visit to Wukro, contact with professionals of St Mary’s College, and knowledge of their work in environmental sustainability, gives birth to the idea of designing a treatment for sludge.
1.7 Location of the project

Wukro is a city located at the north of Ethiopia. It's located at the Eastern zone of the Tigray region. Wukro is the biggest settlement of Kilte Awulaelo woreda.
Wukro is located about 820 kms north of Addis Ababa (the capital of Ethiopia), 40 kms north of Mekele (the regional capital), and 70 kms south of Adigrat (the zonal capital). To accede to the city of Wukro, there is an asphalt road connecting Eritrea with Addis Ababa, the Asmara - Addis Ababa highway, constructed when the Italian occupation.

The landform of Wukro area could be classified into two broad categories, hilly and flat terrain. The hilly terrain is found at the northern and southern fringe of the town and extends further to the west and east at places where the bed rock is exposed. The urban proper of Wukro (including the built-up and expansion areas) is situated on a landscape that has an elevation between 2140 m.o.s.l and 2250 m.o.s.l.
The influence area of Wukro is suitable for agriculture, due to the flat terrain and for industrial purposes, since it is endowed with a variety of natural resources. The most important natural resource are known to be construction materials, a potential developing industry.

Wukro is also a center of trade, services and tourism to the neighboring influence area. Agricultural products originating from Hawzen, Seasi Tseadamba, Kilte Awlaelo, and Atsbi Wonberta Wederas are known to be flowed, storage and exchanged in Wukro. As well, out of the 32 tourist attractions so far identified in the Eastern Tigray, 15 (mosque, caves and rock-hewn churches) are found in Eastern Tigray Zone and are located within 50 kms radius of Wukro. This makes Wukro likely to be an important tourist center.

In this context, Wukro is becoming an important administrative and economic center in the region, and its population is growing fast.

Its approximate geographic coordinates are:

- 39° 37' East Longitude
- 13°47’ North Latitude.
- Zone UTM 39

1.7.1 Proposal of location

The location of the Co-composting Plant is one of the main challenges that a project of these characteristics should deal. The location of the Plant has strong environmental, economic and social consequences that have to be previewed.

But the ultimate choice of the location of the Treatment Plant is a political decision. However this document intends also to give some guidelines for the site selection.

In Annex 3 Site Studies the requirements of an optimal location for the Treatment Plant are described. Considering all this aspects, and after the visit done by the redaction of this project in March 2013 to the city of Wukro, a site is proposed to build up the Treatment Facilities.

The area proposed for the location of the Co-Composting Plant is situated four kilometers south east of the city, next to the Solid Waste Treatment System. The site is beside the main road that goes from Mekelle to Wukro with good access from the road.

It is located at the bottom part of a small reforested hill in an almost flat terrain, that is not cultivated with irrigation crops. It is located far away from the principal river, the Genfel River, and the irrigation crops, in order to reduce the risks of pollution of the waters.

As it can be observed in the map, the zone is also far away from touristic sites in the mountains near Wukro (churches marked in the map), so it doesn’t affect the landscape.
2 Object

The object of this document is to develop a project of improvement of sanitation facilities of the city of Wukro, specifically to define a Sludge Treatment.

After the Previous Study of Solutions, the solution will be defined as detailed as it may be a project with these characteristics.

A numerous quantity of possible alternatives were proposed in the Previous Study of Solutions, in order to justify which of them were the most adequate to the real situation of the city of Wukro. Three of these alternatives that were possible to develop, attending to technical, economic and environmental criteria, were selected. These three alternatives were further studied in greater detail, sized and well defined.

From these three solutions one of them, the one that technically is more adequate, is going to be developed in the Constructive Project.

Nevertheless, it is important not to forget that this project is very subject to variations due to the availability of new data, material and human resources and the possibility of obtaining funding for the construction of it.
3 Reference documents


- *Compendium of Sanitation Systems and Technologies*, Elizabeth Tilley, Christoph Lüthi, Antoine Morel, Chris Zurbrügg and Roland Schertenleib. EAWAG.


- *Composting Manure and Sludge*, John M. Sweeten and Brent W. Auverman, AgriLIFE Extension

- *Sandec Training Tool 1.0 Faecal Sludge Managemente (FSM)*, EAWAG

4 Project Conditions

In this type of project it is very important that the approach to the population is based on knowledge and respect of their culture and there initiatives, trying to develop their abilities because in the future they will have to manage these infrastructures projected. Therefore, the conditionings to take into account in the developing of the project are strongly dependent on the participation of the community, and public authorities.

4.1 Property and legal conditions

The location of the Treatment Plant of faecal sludge is one of the main challenges that a project of these characteristics should deal. The location of the Plant has strong environmental, economic and social consequences that have to be previewed.

But the ultimate choice of the location of the Treatment Plant is a political decision. Annex 3 Site Studies describes the requirements of an optimal location for the Treatment Plant, and proposes a possible location.

4.2 Technical performance conditions

The major technical constraints of a project in an area so little developed are based on two inherent assumptions:

- The 
  
  low level of technical knowledge

  of the region. Not all the data is available and reasonable assumptions that offer reasonably effective solutions will have to be made. There is many data that has not been taken, and some of them has been taken but it is unknown. Many of this data will be obtained during the project development and the execution of the works.

  The characteristics of the sanitation system and the sludge treatment required, widely different from Europeans’, restrained as well the utility of European information. There was neither many information about experiences in treatment plants in contexts like the one of Wukro

- The 
  
  scarce technical development

  of the area. Especially regarding to materials and machinery, which is not usually accessible and costly. The training of specialized technicians is not very high, despite the efforts St Marys’ College does.

Based on the above assumptions, the project will have the following technical performance conditions.

1. Appropriate materials will have to be selected. The structures will be the minimum, and the materials prioritized will be limestone, lime, hollow concrete blocks and Eucalyptus wood.
2. The construction method has to be as traditional as possible, manner that avoids the use of heavy or sophisticated machinery. Human work is cheap, although resources are very limited.

3. It has to be projected with low topographic, geological and hydrological precision, so a flexible solution is required.

4. A solution with the lowest dependence on energy or exterior materials will be developed. A solution which needs not energy in construction and operation will be developed.

5. Water is a scarce resource in the area, as it can be further seen in Annex 3- Climatic Studies. The water required for the treatment in the operation step, will have to be harvested from rainfall. This system will also have to be designed.

6. The water required in the construction site must be carried by truck or pickup trucks and must be minimized.

7. An horizon of 5-years for sizing the plant is taken for two reasons:

   - There is no urban tradition, and no experience in programmed and organized public services as Solid Waste or Sludge Treatment in the city. It is better to start with a small scale plant and evaluate the success.

   - The development of the construction industry in the city and surroundings is changing tendencies in house building. It is likely that the sanitation system incorporates more and more septic tanks that produce sludge with less solid material since it is more digested.

8. Manual operation is previewed. A place with a slope of 4% and a distribution that favors gravity force will be selected.

4.3 Conditions associated to Management of Human Excreta

A treatment of Faecal Sludge, due to the Health Risks associated to this material, has to ensure Public Health.

Risks are to be identified, defined and developed in this project in order to ensure Public Health, and the pertinent measures to minimize health risks have to be described.

The treatment system in study aims to constitute a direct barrier for the first transmission of pathogens from faeces to flies, fields, fluids and human beings. The treatment system projected therefore has to protect public health intervening in potential risk that an infection dose of an excreted pathogen reaches the field or pond, animal or human.

The conditionings associated to the management of Human Excreta are:

1. The treatment plant will need a buffer area, in order to prevent from animal entrance.
2. Make the **working-area impermeable**, in order to prevent infiltration of lixiviates in the terrain and further pollution of crops or water flows.

3. **Sufficient pluvial drainage system** for run-on water into the plant, to protect from run-off of lixiviates or material.

4. **Drainage of lixiviates and** pertinent further **treatment** of them.

5. **Guarantee health of workers** that operate with the sludge with the pertinent measures.

6. **Control of flies near the sludge**, this can be done by adding lime or other measures.

7. **Controlling the dose of infective pathogens in the final agricultural product** so it doesn’t constitute a health risk for any of the individuals. Any treatment should be followed by the pertinent analyses of final product in order to ensure Public Health.
5 Basic studies

The basic studies done are going to be described briefly in this part of the Report in order to propose the different alternative solutions and the comparison of them. Further information is described in the correspondent Annexes to this Report.

5.1 Demand Studies

This study is detailed in “Annex 2: Demand Studies”, where the production of sludge of the city of Wukro, in terms of quantity and composition, is analyzed. The object of it is to establish the total quantity of sludge material that needs to be discharged, transported and treated in 5 years.

The actual population of the city of Wukro is 42000 inhabitants. It is expected that the population of Wukro continues growing with a rate of 5 %.

The treatment system is planned to be constructed in modules, with the capacity to treat the expected sludge of Wukro for 45000 inhabitants. When one module arrives to its maximum capacity a new one can be built up.

This modular design is chosen for two reasons:

-There is no urban tradition, and no experience in programmed and organized public services as Solid Waste or Sludge Treatment in the city. It is better to start with a small scale plant and evaluate the success.

-The development of the construction industry in the city and surroundings is changing tendencies in house building. It is likely that the sanitation system incorporates more and more septic tanks that produce sludge with less solid material since it is more digested.

The household sanitation system of the city of Wukro is based on pit latrines. The material in these pit latrines will be collected with a Vacuum truck of 7500 L.

The estimated characteristics of the sludge of the pit latrines per capita per day are the following:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass TS</td>
<td>90</td>
<td>g/cap.day</td>
</tr>
<tr>
<td>Mass FS</td>
<td>204.7</td>
<td>g/cap.day</td>
</tr>
<tr>
<td>Volume FS</td>
<td>0.20</td>
<td>L/cap.day</td>
</tr>
<tr>
<td>Moisture</td>
<td>56</td>
<td>%</td>
</tr>
</tbody>
</table>

The total sludge to be treated per day is the product of the population in five years and the quantities produced of FS:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume FS m3/day</td>
<td>9.00</td>
</tr>
<tr>
<td>FS t/day</td>
<td>9.21</td>
</tr>
</tbody>
</table>
And in one year:

<table>
<thead>
<tr>
<th>Volume FS m³/year</th>
<th>3285</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS t/year</td>
<td>3361.65</td>
</tr>
</tbody>
</table>

5.2 Topographic Studies

This study is detailed in “Annex 3: Topographic Studies”.

The objects of this study is to describe the general topographic characteristics of the zone of Wukro, give some recommendations for the placement of the Treatment Plant and described the proposed area, describe the works to be done for setting-out of the construction, and define an hypothetical topography for the design of the project.

The landform of Wukro area could be classified in two broad categories, hilly and flat terrain. The hilly terrain is found at the northern and southeast fringe of the town and extends further to the west and east at places where the bed rock is exposed. The flat terrain which covers most part of the town.

Wukro is limited at west by Genfel river and in the east by hilly terrain. Its average altitude is 2195 m.a.s.l, and the altitudinal variation is 110 meter, that has been registered due mainly to the inclusion of hilly landscapes (in the northern and southern peripheries).

Its approximate geographic coordinates are:

39° 37’ East Longitude.

13°47’ North Latitude.

It is located in UTM grid zone 37P.

Since the ultimate choice of the location of the Treatment Plant is a political decision, no definitive area for the Treatment Facilities is available. However, in Annex 3 Site Studies, an area for the construction of the plant is proposed in order to further develop the studies and to give a performance guideline.

With the means available in terms of cartography and topographic equipment before the construction, it is not enough to characterize the terrain. For the correct development of the project, it has to be considered an hypothetical topographic surface. For simplicity the surface will be considered an inclined plane with a slope of 4 %. This slope is hypothesized in order to facilitate the works in the plant, favoring gravity action.

The principal objective of the setting-out of the construction is to stake out on the terrain singular points of the Treatment Plant. For the case of study, the setting-out will be done in local coordinates, from two setting-out bases. These bases have to be well marked on the terrain and have visibility to the other singular points of the construction. The two bases selected are two corners of the treatment plant with local coordinates (0,0) and (0, 80). These two points will de-
fine a reference axe. A precision of ± 2 cm is considered enough for this type of plant, and surveys can be done with an old theodolite or a total station.

5.3 Climatic Studies

This study is detailed in “Annex 4: Climatic Studies”. The principal object of this document is to gather and analyze qualitative and quantitative data of temperature, rainfall and wind in the city of Wukro in order to choose the best treatment for these climatologic conditions, to size the treatment system in terms of times and volumes, and to protect the treatment system from adverse climatologic conditions as wind and rainfall.

It was found that there are not too many quantitative climate data but mostly qualitative, since there is not a long tradition of urban and rural planning in the city. The only meteorological station in Wukro is located at St. Mary’s College, but only fragmented rainfall data, and temperatures are registered, no wind direction and speed.

The climate of Wukro can be considerate a temperate climate, without big contrasts, with a medium temperature of 17ºC and temperature varies from 12 to 27 ºC in the hottest month and 7º to 22º in the coldest. These values have been obtained from the maximum and minimum average temperatures data registered between (2005-2012).

Rainfall data was obtained for the period from 1992 to 2009, but not for every month. With this data an average year was calculated.

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dic</th>
<th>Annual Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,6</td>
<td>2,3</td>
<td>19,7</td>
<td>31,9</td>
<td>26,0</td>
<td><strong>43,0</strong></td>
<td><strong>203,7</strong></td>
<td><strong>211,3</strong></td>
<td>26,0</td>
<td>5,6</td>
<td>3,1</td>
<td>1,1</td>
<td><strong>574,3</strong></td>
</tr>
</tbody>
</table>

The average annual rainfall is 575 mm, which is a sufficient value, but rainfall is concentrated during 3 months, normally between June and September, observing that 75 % of rainfall during July and August. The rest of the year water resources are scarce. For this reason, during the rainy season an open air solution has difficult to work.

The Aridity index of Wukro was estimated by the Bagnouls-Gaussens index (BGI) using the following equation:  \[ BGI = \sum (2T_i - P_i)k; \] where: \( T_i \) is the mean air temperature for month \( i \) in ºC, \( P_i \) is the total precipitation for month \( i \) in mm; and \( k \) represents the proportion of month during which \( 2T_i - P_i > 0 \). The result obtained was a BGI=123. Which means that Wukro has a high aridity climate and, as mentioned before, water resources are very variable and scarce in some periods, and land is more vulnerable to desertification and floods. An area less vulnerable to floods has to be selected in order to reduce lixiviation risks.

According to interviews done in the zone of Wukro, the direction of wind is thought to be southeasterly and northwesterly, but it is also said that it varies with the season. If the wind dominant direction was northwesterly (from northwest to south east), then for the site selected for the Plant, which is located south east of the city, the main winds will not affect the city. And also a reforested hill protects the city from the wind.
However, further interviews or studies about the velocity and direction of the wind are recommended at the moment selection of the site since the direction of the wind affects odours and atmospheric pollution in the city.

5.4 Geologic Studies

The Geologic Studies for this document, enclosed in “Annex 5: Geologic Studies”, aim to describe the geological characteristics of the zone of Wukro, indentify the rocks that may be used as construction materials and define the recommended surveys to do at the project site before construction.

5.4.1 Geology of Wukro

The geology of Wukro area is characterized by Precambrian metamorphic rocks and Mesozoic sedimentary rocks.

The Precambrian metamorphic rocks are found at the eastern and north-eastern part of the town. It mainly consists of slates, phylite and carbonates. The slate is exposed forming steep slope and having purple and dark bluish color, while the phylite commonly has light greenish color. The carbonate consists of quartz, limestone and quartzite, depicting whitish color.

The Mesozoic sedimentary rocks are represented by three different rock types of Adigrat sandstone, Hintalo limestone and Agula shale.

- The Adigrat sandstone is exposed forming steep slopes at the south and south eastern part of the town, and it commonly has red and white color and fine grains. It also shows joints, cross bed, vein lets and cross bedding.

- The Hintalo limestone is found overlying the Adigrat sandstone and forming terraced and tilted slopes at eastern and northwestern part of the town, it commonly has rectangular jointing, tilted bedding and grey and yellowish color.

- The Agula shale is characterized by grey color, rectangular joint, thin veins and very soft strength which in some places lead to formation of light green clay soil. It covers extensive flat lying areas and it has 10-20% limestone beds and the rest is either well jointed hard shale or soft powdery shales. It is outcropped at river cut conformably overlying the Hintalo limestone in southern part of the town.

The geological structure of Wukro area is manifested by faults, joints, folds and bedding system. The major fault which demarcates hilly limestone and sandstone beds from flat terrain generally run from northwest to southeast. The joints observed on the sandstone bed are filled with secondary materials while those noticed on limestone beds are longer in size and frequent in number and often filled with secondary materials. The bedding system of the Wukro area is represented by tilted beds of limestone and sandstone showing general northwest-southeast orientation which dip to northeast.

The geology of the area, the nature of the rock and geological structure favor infiltration of rainfall and river water to the ground. The joints and karsts of the limestone, intergranular
openings of the sandstone and alluvial soil and the fault lines facilitate easy entrance of water in to the groundwater system. The geology of the area also favors storage and accumulation of wa- ter in the groundwater system. Fractures of the Hintalo limestone and joints of the sandstone together with the fault lines that cut these formations create good aquifer for holding of ground water.

Genfel River and its tributaries represent the natural surface water resource of Wukro and the surrounding area. This river has permanent water flows which diminish in size during dry season and drought period. Currently, the river is intensively utilized for agricultural activities. Thus, it is becoming an intermittent river. On the other hand, this river is the major feeder of the ground water system, which is the only source of water for the municipal water supply system.

According to the preliminary assessment made on the water resources of the area, the major water source for recharging of the ground water system comes from direct infiltration of the rainfall and through the continuous flow of Genfel River.

5.4.2 Geological and Hydrological Description of the Proposed Site

The area is constituted predominantly by Agula shale, as it can be observed in Annex 5 Geological Studies. This shale from the Jurassic is characterized by its grey color, rectangular joint, thin veins and very soft strength which in some places lead to formation of light green clay soil. It is outcropped at river cut conformably overlying the Hintalo limestone in southern part of the town. These shales have poor permeability and according to the experience with other works in the area good strength to support small engineering structures. At first sight, previous to any geo- logical “in situ” studies, and based on written and graphic documents, no big fractures or joints are identified in the area.

The site is far away from the Genfel River, and any other permanent surface water source that could be polluted. But it is near an intermittent river, that only takes water in the rainy sea- son. Some measures to protect this river from possible runoff or pollution should be taken.

According to the preliminary assessment there are no groundwater sources in the area, which is nor rare since the unit Agula shale is classified as an aquifer of low productivity.

5.4.3 Construction materials

Generally, the geology of Wukro area tell us that there is variety of rock that can be used as construction material (limestone, sandstone, etc.).

Both sandstone and limestone have been used for masonry in traditional construction from ages in the zone. Sandstone is hard, resistant stone, and relatively easy to work.

The most versatile rock in the zone is limestone. Most limestone is crushed and used as a gravel for construction. It is used as an aggregate in concrete. Also it is fired in a kiln with crushed shale, also available in the area, to make cement. Normally, they are strong, dense rocks with few pore spaces. These properties enable them to stand up well to abrasion and freeze-thaw. Although limestone does not perform as well in these uses as some of the harder silicate rocks it
is much easier to mine and does not exert the same level of wear on mining equipment, crushers, screens and the beds of the vehicles that transport it.

Lime coming from burning limestone can as well be used directly together with a fine-grained clay soil (25 % passing 74 mm and plastic index > 10) in a proportion of 3 to 6 % by weight, in order to make it resistant and improve the retaining of water conditions of the soil.

There are quarry sites of lime around Wukro and people of the town are practicing the production of lime by burning limestone.

Enterprises like Mesobo cement factory in Mekele exploits materials of the area for its industrial production.

5.4.4 Further Recommendations

Permeability of the soil is the most important characteristic in the case of study, a Feacal Sludge Treatment Plant, since the material treated is very dangerous for Public Health. It is fundamental to avoid pollution of water resources and crops.

Since information related to permeability in bibliography and geological maps of the zone are not sufficient, when the authorities select the definitive location for the Treatment Plant, two simple geological surveys may be done on the site and are further described in Annex 5 Geologic Studies.

If the permeability rates were specially low, the impermeable surface could be reduced to one layer of lime-soil mixture of 30 cm for economic reasons.

6 Environmental Studies

A project of these characteristics is thought to give a solution to environmental and public health problems. The need for safe, responsible, and sustainable management of wastes is vital in order to eliminate health hazards and adverse ecological effects.

Since there is no formal legislation of Environmental Issues in Ethiopia, other sources had to be studied for developing this document. This EIA study was conducted according to the guidelines set WHO Guidelines For The Safe Use Of Wastewater, Excreta And Greywater and other institutions recommendations as well as other observed similar projects.

Two documents for this purpose were written, the Environmental Impact Studies, where any potential environmental impacts result from the construction and operation of the plant were identified and evaluated, and the Managemente Mitigation Plan, with mitigation and monitoring schemes for the potential impacts.
6.1 Summary of Impact Mitigation Measures

The identification and analysis of potential negative impacts indicated that significant impacts would occur during construction and operation phases, thus implying the necessity of implementing mitigation measures recommended for the project design, construction, and operation. With respect to the project design, the following considerations should be included: a drainage system for leachate and runoff management, appropriate paving of the facility site and storage places, and fencing around the facility or site. With respect to the construction phase, dust and noise generation, waste production, and health and safety hazards are the most significant impacts and they are minimized by ensuring safety regulations, working during daytime and proper site paving and closure.

However, impacts related to the operation phase are the most significant since they have long-term effects, especially impacts related to the application of contaminated compost.

Mitigation measures to prevent the production of contaminated compost include appropriate operation of the facility according to the specified standards and considerations.

All these measures will be taken into account in the design of the compost facility, the composting operations and process, and the construction phase.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Recommended mitigation measure</th>
<th>Responsibility</th>
<th>Feasibility and cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DESIGN PHASE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Odor production</td>
<td>Include a buffer zone around the facility</td>
<td>PM</td>
<td>Feasible/ no cost</td>
</tr>
<tr>
<td>Resources contamination</td>
<td>Paving of storage and operation areas, drainage control system, covering areas where wastes are stored (incoming wastes and maturing compost), and lixiviates collection and reuse.</td>
<td>PM</td>
<td>Included in design</td>
</tr>
<tr>
<td>Landscape esthetics and visual amenity</td>
<td>Native plants and trees species already present in the area around the perimeter of the plant.</td>
<td>PM</td>
<td>Costs of plantation</td>
</tr>
<tr>
<td>Public hazards</td>
<td>Facility site fencing (2 m height)</td>
<td>PM</td>
<td>Included in design</td>
</tr>
<tr>
<td>Litter</td>
<td>Fencing and providing a closed depression pit for unloading waste</td>
<td>PM/Contractor</td>
<td>Included in design</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CONSTRUCTION PHASE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction waste</td>
<td>Waste transport and disposal in quarries for re-use or in sanitary landfills.</td>
<td>Contractor</td>
<td>Included in construction</td>
</tr>
<tr>
<td>Health and safety</td>
<td>Provide protective clothing, follow general safety regulations, prevent un-authorized access to the construction site by fencing and night security guard.</td>
<td>PM/Contractor/ Municipality</td>
<td>Health and Safety cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>OPERATION PHASE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Litter</td>
<td>Unloading waste only in the designated covered area.</td>
<td>Municipality/ facility operators</td>
<td>Cost of textile to cover storage area.</td>
</tr>
<tr>
<td>Odor production</td>
<td>Proper process operation, maintaining aerobic conditions, and storing waste in designated areas</td>
<td>Facility operator</td>
<td>No extra cost</td>
</tr>
</tbody>
</table>
6.1.1 Summary of Costs of Impact Mitigation

<table>
<thead>
<tr>
<th>Concept</th>
<th>Unit. Cost (Birr)</th>
<th>Quantity</th>
<th>Cost (Birr)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Oxytenanthera abyssinica</em> 1 every 2.5 m only on one side of the parcel</td>
<td>12</td>
<td>40</td>
<td>480</td>
</tr>
<tr>
<td>m² Textile to cover storage area</td>
<td>120</td>
<td>1000</td>
<td>120,000</td>
</tr>
<tr>
<td><strong>TOTAL IN BIRR</strong></td>
<td></td>
<td></td>
<td><strong>120,480</strong></td>
</tr>
</tbody>
</table>

6.2 Summary Of Monitoring Plan

The Municipality of Wukro with the technical support of the contractor will be responsible for the environmental monitoring activities during the operation of the facility, whereas, during the construction phase, St Mary’s’ Mission would undertake monitoring with the collaboration of the Municipality.

Environmental monitoring will be carried out during both the construction and operation phases to ensure appropriate operation of the facility, the implementation, and effectiveness of the recommended mitigation measures, the production of good quality and safe compost, and the response to unanticipated environmental impacts.

6.2.1 Construction Phase

During the construction phase, the contractor and St Mary’s Mission will be responsible for monitoring health and safety hazards along with the proper implementation of the construction operation. The following parameters will be continuously monitored at the construction site:
6.2.2 Operation Phase

During the operation phase, quarterly monitoring of some critical parameters is necessary, and will be the responsibility of the facility operation manager in collaboration with the Municipality of Wukro. The parameters that will be monitored at the facility site include water quality of surface runoff (Intermittent River), noise level, odor generation, compost quality, health and safety, and landscape esthetics. Environmental parameters to be monitored with their frequency, duration, and responsible body are summarized in the following table.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Samples</th>
<th>Frequency</th>
<th>Location</th>
<th>Responsibility</th>
<th>Estimated cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction phase</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landscape</td>
<td>Visual inspection</td>
<td>Weekly</td>
<td>Construction Site and Surroundings</td>
<td>PM/Contractor</td>
<td>No extra cost</td>
</tr>
<tr>
<td>Health and Safety</td>
<td>Visual inspection</td>
<td>Continuous</td>
<td>Construction Site</td>
<td>PM/Contractor</td>
<td>Health and Safety cost</td>
</tr>
<tr>
<td><strong>Operation phase</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise</td>
<td>Inspection</td>
<td>Daily</td>
<td>Vacuum truck</td>
<td>Municipality and truck operatives</td>
<td>No extra cost</td>
</tr>
<tr>
<td>Odor</td>
<td>Inspection</td>
<td>Monthly</td>
<td>Facility</td>
<td>Municipality and facility operatives</td>
<td>No extra cost</td>
</tr>
<tr>
<td>Compost Quality</td>
<td>Inspection</td>
<td>Monthly</td>
<td>Facility</td>
<td>Municipality and facility operatives</td>
<td>100 $/month</td>
</tr>
<tr>
<td>Health and Safety</td>
<td>Visual inspection</td>
<td>Continuous</td>
<td>Facility</td>
<td>Municipality and facility operatives</td>
<td>No extra cost</td>
</tr>
<tr>
<td>Landscape</td>
<td>Visual inspection</td>
<td>Continuous</td>
<td>Construction Site and Surroundings</td>
<td>Municipality and facility operatives</td>
<td>No extra cost</td>
</tr>
<tr>
<td><strong>Total Cost per year</strong></td>
<td>1200 $/month</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7 Description of the Selected Solution

This solution consists of a **aerobic thermophilic** composting treatment done with organic solid waste (Org. SW) to stabilize the sludge (FS) and get a good product for agriculture. The plant will have the capacity to treat 48 m³ of raw material each day.

The site where the composting facilities will be built up has a gentle slope, about the 4%. The land parcel, 110 x 110 m of 12,100 m², will be fenced off with a metal fence in all its perimeter (buffer zone) and it will be bushed in one side.

At the parcel three different areas will be distinguished: the storage of organic material area, the active composting area, and the maturation and storage area. These areas and the different systems that constitute the construction of the plant are described separately.

In order that this scheme of activities flows correctly, the distribution proposed for the plant is the following:

![Graphic 6 Distribution of the Treatment Plant based on long-bin composting](image)
7.1 The Co-composting Process

This system is justified in Annex 10 Composting Process.

The scheme of the treatment is the following:

<table>
<thead>
<tr>
<th>Collection of Feecal Sludge</th>
<th>Storage of Organic Material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Active Composting stage</td>
</tr>
<tr>
<td></td>
<td>Maturation Stage</td>
</tr>
<tr>
<td></td>
<td>Storage of Final Material</td>
</tr>
</tbody>
</table>

Around this scheme it is a buffer zone for controlling access of persons and animals, and a perimeter drainage system for run-on rainfall in this buffer zone.

The input raw material results from the combination of feacal sludge and organic material in volume in a proportion 1:3. In each lot (unit arriving in one day of delivery) the quantity of material that enters the process is 2 trucks of FS (filled approximately with 6 m$^3$) and the correspondent quantity of organic material, in total 48 m$^3$/lot. The expected characteristics of this material is 45 % of moisture and C:N ratio of 21.30.

Aerobic compost process includes two stages, composting stage and maturation stage. Each of them have different requirements and therefore different activities associated. The two main factors of aerobic composting are aeration and moisture.

Composting stage will take part in long bins made of hollow concrete blocks, that contain better material, humidity and temperature. Each lot of raw material will be contained in one long bin. The material in each bins is forming a pile, 3 meters width, 1.2 meter height and 20 m length. This way, the composting area will be formed by 20 long bins, regrouped in 4 type buildings further described below.

To form the pile, first of all, the floor of the bin is bedded with dry leaves and branches, and the pile is formed on top by the alternation of layers of sludge (10 cm) and organic material (30 cm). Then biological stabilization is to be ensured by turning and remoistening.

The first turn should be made about the 3rd day and thereafter it is recommended to turn at 3-day intervals with 3 to 4 turns until the temperature doesn’t descend down 55 ºC. During the days were the material is not being turned, perforated pipes are disposed embedded in the material. This involves inserting a set of bamboo poles, approximately one every 0.75 meters, deep into the pile and withdrawing them a day later, leaving the pile with ventilation holes.

On the other hand, moisture levels should be maintained for that materials are thoroughly wetted without being waterlogged or dripping excessive water. This activity requires experience skills of the operators. This remoistening will be done manually with a sprinkler. Remoistening operations with lixiviates will be done only during composting phase, before temperature descends definitely under 55 ºC.

During all the process temperature should be monitored and recorded daily with a dial thermometer with a 1 m stem, with a temperature range of approximately 0-90°C.

The end of composting stage is identified when turning no longer reheats the pile or when temperature of the material descends to a value under 50°C, approximately after one
month. At this moment, the material is transferred with wheelbarrow or trucks to the maturation area.

Maturation phase will last approximately one month, and it is required to allow the compost to finish the process and to develop the desired characteristics.

In this stage, the material will be piled in the maturation area forming wind-rows separated 1 meter, with an approximate trapezoidal section, of 2.5 m bases and 1.5 m high, and a length of 12 m. With the material maturing and half of the production of the previous month 40 piles will be formed (an area of 1550 m²).

This maturation stage has no activities associated, except from odor control, that should be done once a week, in order to detect anomalies in aerobic composting.

At last, every month 480 m³ of compost is obtained, and its quality is to be studied through the “level of pathogen kill of the process” (monitoring temperatures), PSRP or PFRP, the exclusion of *Salmonellae* (65 º during 7 days), the seed germination rate, and its maturation grade. These tests and a graduation of the different materials obtained and its uses are further described in *Annex 10 Composting Process*.

### 7.2 Composting Areas

#### 7.2.1 Storage of Organic Material Area.

The organic material for the compost may be obtained from *cereal crops residues*. The area to storage this material is previewed to retain the 25 % of the material needed during the whole year. If material is only residues from cereal crops, there is no need of an impervious surface, but in order to prevent putrefaction of the material the area is covered with a textile over an eucalyptus structure.

This area will occupy a surface of 25 m x 40 m = 1000 m².

#### 7.2.2 Active Composting Area

The long bins composting system works similar to wind-row composting system but the composting area consists of bins that are open on the top, with four walls made of perforated bricks that permit aeration. The system of bins contains better humidity and temperature, which improves the initial composting stage. Since the walls contain the material, this system contains accessibility to animal vectors, and run-off of material in period of heavy rainfall.

The area of active composting consists of 4 buildings of 25 m x 28 m (700 m²) with the same characteristics, each of them will consist of an impermeable pad, five long bins and a metallic roof. As well, each of the buildings will have their own water harvesting system, their lixiviates drainage and collection system and a perimeter drainage system for run-on water (rainfall).
Impervious pad

The impermeable surface will be made of a soil-lime mixture 60 cm thick, it will be constituted by 2 layer of 30 cm of soil-lime with 3 % weight of lime and between both the layers a layer of 2 cm of clay and will be considered. Sand will prevent from percolation of lixiviates if the top layer breaks.

Long bins

The dimensions of the bins will be 3 m x 1 m x 20 m. The bins will be formed by 4 walls 1 meter high made of hollow concrete blocks (HCB) manufactured in the city, and with two metallic door 1 meters width on the edges of the bin in order to facilitate operations. The hollow blocks will be disposed in a way that air may pass through the holes and maintain the aeration of the mixture.

The walls have a foundation 1.8 m deep, made of HCB, 0.6 the longitude between the walls. This foundation walls confine the soil under the long bins and ensure that the soil will bear the weight of the piles of compost.

Roof

The function of the roof is to prevent water from evaporating due to the arid and hot climate, to minimize odour and leachate generation, to enable working in the rainy season, and to collect rainfall water.

The roofs will be constructed with eucalyptus piers (ᶲ12 cm) and beams (ᶲ10 cm), and galvanized steel sheet (0.5 mm), as it is common in local building. Piers will be disposed every 5 m, with a maximum height of 3.5 m and a minimum, on the edges of the roof, of 3 m.

The foundation of the piers will be done by excavating a pit 0.4 m deep and the pier will be embedded in the terrain, in a length of 3ᶲ, and the pit will be conveniently backfilled with a soil-lime mixture.

7.2.3 Maturation and Storage Area

After active composting all material will be transferred to the same maturation area where it is piled. The volume of the material is reduced to half its volume. The dimensions of this area will be 20 m x 65 m (1625 m²). This area needs an impermeable surface of soil-lime mixture 60 cm thick, like the one described before, as well as a roof.

7.3 Lixiviates Drainage and Collection System (Run-Off Drainage).

All drainage from the composting and maturation area shall be collected for return to the process and function year round.
The surface of the bins will have a transversal slope of 1% to the center of the bin and, since the terrain has an inclination of the 4%, the lixiviate will divert on the lower part, due to gravity effect. In the lower part a 200 mm chute (profiled on the terrain and lined with soil-lime mixture) with a slope of 1% will collect the lixiviate to a tank placed in a lower part.

Due to the absence of similar plants in the zone, it is not possible to know how much lixiviate the mixture will produce, so it is not possible to dimension accurately the collection tank for lixiviates. Initially, a lixiviates tank of galvanized steel with a capacity of 3 m$^3$ for each area is previewed, this tank will be installed in a manhole of masonry 2 m x 2 m x 1 m covered with a concrete slab.

7.4 Water Harvesting System

The rainwater is collected in guttering placed around the eaves of the building. The guttering will be made up from 0.65 mm galvanized steel sheeting, bent to form a ‘V’ and suspended by galvanized wire stitched through the sheeting every meter.

For water storage along the time, each building of the active area will be provided of one tank of about 10 m$^3$ capacity. The approximate dimensions of each cylindrical tank will be 2.5 m diameter per 3 m height. The provision of the storage tank is the most costly element of a rainwater harvesting project. Since the 4 tanks are not required for drinking purposes, there is no important requisites of the materials, but impermeability. In the moment of building the plant, the most economic tank type will be chosen. The watering of the mixture is previewed to be done with a sprinkler, so no other facilities are designed.

7.5 Vehicular Accesses

Accesses to all buildings, for delivery purposes are previewed. The entrance to the plant will be done through a metallic door 4 meters wide, situated at one corner of the parcel.

Access roads are been planned to accommodate all types of vehicles that will be entering and leaving the site. This includes providing sufficient area for vehicles (delivery trucks) to back out, turn around or turn without interfering with composting equipment.

The largest vehicle entering the area will be the vacuum truck of 250 cm width and 760 cm length. The roads will need a width of 6 m, in order to allow the vacuum to turn an angle of 90º.

The surface of earth roads should be graded and compacted to provide a durable and level running surface for traffic and the road surface should have a minimum camber of 4% to ensure water runs off the surface and into the side drains, and a normal crown height over the natural ground level is 35 cm.

7.6 Pluvial Drainage System

This system is justified in Annex 9 Drainage.
For the dimensioning of this system, Ethiopian Manual for Low Volume Roads Construction was studied.

a) Exterior Run-On Drainage System.

Around the perimeter of the parcel, a continuous perimeter ditch will be built up to divert run-on away from the composting plant, decreasing the stormwater runoff that needs to be controlled. This ditch will have an approximate trapezoidal section, dug up manually and not lined. These ditches should be kept clean along de year.

The ditch of the upstream part of the parcel (perpendicular to the local reference axe) has a longitudinal gradient of 2% descending to the local east of the parcel, and the ditches of the sides of the parcel (parallel to the reference axe), as well as the terrain, have a slope of 4%. All drainage system will outflow in the local south east of the parcel in order to not disturb the entrance through the unpaved roads to the facilities.

These gradients are above the minimum of 0.5% required. This exterior ditches are shallow but wide (3 m and 2.5 m wide), with a trapezoidal section of slopes 2:1 and 3:1. To control erosion, the 4% slope ditches will have every 15 m a scour check of gravels 0.20 m high and with a slope up-stream and down-stream 2:1 (H:V).

The intersection of this drainage with the Plant Accesses will be solved with a lined ditch 1.5 m width.

b) Interior Run-On Drainage

All curing areas shall be protected from rainfall water. The perimeter of the buildings will be surrounded by a trapezoidal ditch. The purposes of this ditches are to divert surface and storm water from the active areas; control erosion, sedimentation, siltation, and flooding; and minimize the generation of leachate.

There will be two types of different ditches. The ditches perpendicular to the local reference axe, which protect water from entering to the composting buildings, have a longitudinal gradient of 2% and a circular section of diameter 0.50 m. These ditches will have beside a small dike 20 cm wide to prevent water from entering the composting pad, as it seen at the following graphic.

And the collector ditches, that drain water from the previous ones and the accesses. These ditches that are parallel to the reference axe, have a slope of 4% like the terrain. They are the same as the previous ones, but they will enlarge to 1.5 m wide when crossing an access because trucks will have to be able to pass above the ditches, and this enlargement will be lined.
8 Economic Justification

The calculus of unit prices (for each item) for the construction of the project are done considering direct and indirect costs adapted to the context of Wukro in Ethiopia.

Direct costs will be considered:

- Manpower that directly intervenes in the execution of the constructive item.
- Materials, including transport to the construction site.
- Machinery

The indirect costs are the costs of technique personal and administrative that is exclusively working in the construction, communication and unexpected costs.

Detailed prices are given in Birr, and relevant values are transformed as well in USD and Euro, with the conversion:

<table>
<thead>
<tr>
<th>1 $</th>
<th>20 Birr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 €</td>
<td>24 Birr</td>
</tr>
</tbody>
</table>

The cost of all work-units is summarized in the following table, obtained from the direct and indirect costs (5 % of the direct costs) and the measuring of each unit:

<table>
<thead>
<tr>
<th>WORK UNITS</th>
<th>Unitary Price (Birr)</th>
<th>U. Price (€)</th>
<th>Measuring</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Preparation of the parcel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1. m COLLOCATION OF NET WIRE FENCE</td>
<td>762.24</td>
<td>31.76</td>
<td>440</td>
<td>335,385.60</td>
</tr>
<tr>
<td>1.1. m² THINNING AND CLEARING OF TERRAIN</td>
<td>2.74</td>
<td>0.11</td>
<td>12,100.00</td>
<td>33,154.00</td>
</tr>
<tr>
<td>2. Earthworks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1. m³ GENERAL EXCAVATION</td>
<td>18.28</td>
<td>0.76</td>
<td>1,327.50</td>
<td>24,266.70</td>
</tr>
<tr>
<td>2.2. m³ DRAINAGE EXCAVATION</td>
<td>21.4</td>
<td>0.89</td>
<td>267.09</td>
<td>5,715.77</td>
</tr>
<tr>
<td>2.3. m³ FOUNDATION PITS EXCAVATION</td>
<td>31.68</td>
<td>1.32</td>
<td>988.74</td>
<td>31,323.28</td>
</tr>
<tr>
<td>2.4. Unit. SCOUR CHECK OF GRAVELS</td>
<td>13</td>
<td>0.54</td>
<td>10</td>
<td>130.00</td>
</tr>
<tr>
<td>2.5. m³ LINING OF DITCHES WITH GRAVELS</td>
<td>85.09</td>
<td>3.55</td>
<td>83.55</td>
<td>7,109.44</td>
</tr>
<tr>
<td>3. Composting pad</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Sludge treatment system in the city of Wukro (Ethiopia)

| 3.1. | m$^2$ SOIL-LIME LAYER OF 30 cm | 292.61 | 12.19 | 8850 | 2,589,598.50 |
| 3.2. | m$^2$ CHUTES LINED WITH SOIL-LIME | 34.04 | 1.42 | 55.04 | 1,873.59 |

#### 4. Long bins

| 4.1. | m$^3$ HOLLOW CONCRETE BLOCK (HCB) WALL | 81.6 | 3.40 | 2832 | 231,091.20 |
| 4.2. | m$^3$ BACKFILL OF FOUNDATION PITS | 900 | 37.50 | 671.00 | 603,903.20 |

#### 5. Roof And Water Harvesting System

| 5.1. | m EUCALYPTUS PIER | 445.75 | 18.57 | 736 | 328,072.00 |
| 5.2. | m EUCALYPTUS BEAM | 214.93 | 8.96 | 1,150.00 | 247,169.50 |
| 5.3. | m$^2$ CORRUGATED IRON SHEET FOR ROOFING | 88.11 | 3.67 | 4,779.00 | 421,077.69 |
| 5.4. | m EAVES GUTTERING | 111.23 | 4.63 | 600.7 | 66,815.86 |
| 5.5. | m DOWN PIPE | 43.29 | 1.80 | 216.00 | 9,350.64 |
| 5.6. | Unit. CYLINDRICAL WATER TANK (10 m$^3$) | 21,448.20 | 893.68 | 4 | 85,792.80 |

#### 6. Lixiviates Drainage

| 6.1. | Unit. GALVANIZED SHEET TANK (3 m$^3$) | 6499.46 | 270.81 | 6 | 38,996.76 |
| 6.2. | Unit. MANHOLE OF MASONRY | 915 | 38.13 | 6 | 5,490.00 |

#### 7. Vehicular Accesses

| 7.1. | m$^2$ GRADING AND COMPACTATION OF NATURAL TERRAIN | 32 | 1.33 | 3,285.80 | 105,145.60 |

#### 8. Others

| 8.1. | m$^2$ CLEANING OFF THE SITE | 3.24 | 0.14 | 12,100.00 | 39,204.00 |

**TOTAL in Birr**  
5,210,666.13

**TOTAL in €**  
217,111.09

This costs are the construction costs. To this costs it has to be added the amount correspondent to Environmental Impact Mitigation and Health and Safety procurement.

The total budget of the construction activities of the Co-Composting Plant in Wukro (Ethiopia) is then disaggregated:

<table>
<thead>
<tr>
<th>Concepts</th>
<th>Total Cost Birr</th>
<th>Total Cost $</th>
<th>Total Cost €</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Preparation of the parcel</td>
<td>368,539.60</td>
<td>18,426.98</td>
<td>15,355.82</td>
</tr>
<tr>
<td>2. Earthworks</td>
<td>68,545.19</td>
<td>3,427.26</td>
<td>2,856.05</td>
</tr>
<tr>
<td>3. Composting pad</td>
<td>2,591,472.09</td>
<td>129,573.60</td>
<td>107,978.00</td>
</tr>
<tr>
<td>4. Long bins</td>
<td>834,994.40</td>
<td>41,749.72</td>
<td>34,791.43</td>
</tr>
<tr>
<td>5. Roof And Water Harvesting System</td>
<td>1,158,278.49</td>
<td>57,913.92</td>
<td>48,261.60</td>
</tr>
<tr>
<td>6. Lixiviates Drainage</td>
<td>44,486.76</td>
<td>2,224.34</td>
<td>1,853.62</td>
</tr>
<tr>
<td>7. Vehicular Accesses</td>
<td>105,145.60</td>
<td>5,257.28</td>
<td>4,381.07</td>
</tr>
<tr>
<td>8. Others</td>
<td>39,204.00</td>
<td>1,960.20</td>
<td>1,633.50</td>
</tr>
<tr>
<td>9. Safe and Security</td>
<td>7,500.00</td>
<td>375.00</td>
<td>312.50</td>
</tr>
<tr>
<td>10. Environmental Impact Mitigation</td>
<td>120,480.00</td>
<td>6,024.00</td>
<td>5,020.00</td>
</tr>
<tr>
<td>TOTAL WITHOUT TAXES</td>
<td>5,338,646.13</td>
<td>266,932.31</td>
<td>222,443.59</td>
</tr>
<tr>
<td>TAXES (15 % VAT)</td>
<td>800,796.92</td>
<td>40,039.85</td>
<td>33,366.54</td>
</tr>
<tr>
<td>TOTAL CONSTRUCTION BUDGET</td>
<td>6,139,443.05</td>
<td>306,972.15</td>
<td>255,810.13</td>
</tr>
</tbody>
</table>
The budget of the construction activities of the Co-Composting Plant in Wukro (Ethiopia) is six million one hundred thirty-nine thousand four hundred forty-three Birr and five cents (255,810.13 € two hundred fifty-five thousand eight hundred ten Euro and thirteen cents).
9 Construction Program

The timelines and means of production required for the construction works were determined, as well as it was previewed the manpower and equipment needed in the execution of the Co-Composting Plant facilities.

It was considered as an average value for the realization of the Construction Program a total of 20 working-days a month, with standard workday of 8 hours, which makes 160 working-hours a month.

For the different activities that have to be done, it was detailed their measuring, budget, tasks that include, technical resources assigned and expected performance. The activities considered the most relevant, due to their conceptual importance or their high size or cost, were the following:

1. Preparation of the parcel
   a) General Setting-out
   b) Fencing the area
   c) Thinning and clearing of the parcel
2. Execution of the impervious surface
   a) Excavation for the different impervious areas
   b) Stabilization of the terrain with lime
3. Roofs
   a) Positioning piers of roof
   b) Collocation of beams and steel sheet
4. Long bins and lixiviation drainage
   a) Execution of the walls of the bins
   b) Execution of the lixiviates tank and water storage tank.
5. Pluvial drainage
   a) Excavation and profiling of ditches and execution of scour checks
6. Accesses
   a) Profiling and consolidation of the accesses
   b) Cleaning off the site and finishing activities

After elaborating the Program of the Construction (attached in Annex 12 Construction Program), it is estimated an approximate duration of the construction activities of 20 weeks (5 months).
10 Documents that Constitute this Project

DOCUMENT I. REPORT AND ANNEXES

REPORT

ANNEXES TO THE REPORT

ANNEX 0. PREVIOUS STUDY OF SOLUTIONS
ANNEX 1. POPULATION STUDIES
ANNEX 2. DEMAND STUDIES
ANNEX 3. SITE STUDIES
ANNEX 4. TOPOGRAPHIC STUDIES
ANNEX 5. CLIMATIC STUDIES
ANNEX 6. GEOLOGIC STUDIES
ANNEX 7. ENVIRONMENTAL IMPACT
ANNEX 8. ENVIRONMENTAL MANAGEMENT PLAN
ANNEX 9. DRAINAGE
ANNEX 10. COMPOSTING PROCESS
ANNEX 11. JUSTIFICACION OF COSTS
ANNEX 12. CONSTRUCTION PROGRAM
ANNEX 13. QUALITY CONTROL

DOCUMENT II. PLANS

II. 1 Situation Plan
II. 2 General Plan of Co-Composting Plant
II. 3.1 Drainage 1
II. 3.2 Drainage 2

DOCUMENT III. TECHNICAL SPECIFICATIONS

DOCUMENT IV. BUDGET

DOCUMENT V. HEALTH AND SAFETY
11 Technical Summary of the Project

GENERAL INFORMATION

<table>
<thead>
<tr>
<th>Country</th>
<th>Ethiopia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>Tigray</td>
</tr>
<tr>
<td>City</td>
<td>Wukro</td>
</tr>
</tbody>
</table>

CHARACTERISTICS OF THE TREATMENT

<table>
<thead>
<tr>
<th>Service</th>
<th>45,000 inhabitants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of treatment</td>
<td>TERMOPHILIC AEROBIC COMPOSTING</td>
</tr>
<tr>
<td>Material to treat</td>
<td>Feacal Sludge : Cereal residues (1:3)</td>
</tr>
<tr>
<td>Treatment Capacity</td>
<td>48 m³/day of input material</td>
</tr>
<tr>
<td>Production of compost</td>
<td>480 m³/month</td>
</tr>
<tr>
<td>Types of Compost produced</td>
<td>Grades A, B, C depending on sanitation</td>
</tr>
</tbody>
</table>

CHARACTERISTICS OF THE PLANT

Storage area for Organic Material

<table>
<thead>
<tr>
<th>Capacity</th>
<th>25% annual necessities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>25 m x 40 m = 1000 m²</td>
</tr>
<tr>
<td>Covered with textile</td>
<td></td>
</tr>
</tbody>
</table>

Composting Area

<table>
<thead>
<tr>
<th>System</th>
<th>Long bins</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Type Building</td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>25 m x 28 m (700 m³)</td>
</tr>
<tr>
<td>Number of long bins</td>
<td>5</td>
</tr>
<tr>
<td>Dimensions of long bins</td>
<td>3 m x 1 m x 20 m</td>
</tr>
<tr>
<td>Impervious pad</td>
<td>60 cm soil-lime treatment</td>
</tr>
<tr>
<td>Roof</td>
<td>2 pitch metallic roof with eucalyptus beams and piers. Maximum height of roof 3.5 m in the center.</td>
</tr>
</tbody>
</table>

Maturation and Storage Area

<table>
<thead>
<tr>
<th>System</th>
<th>Wind-rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Building</td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>25 m x 65 m (1625 m²)</td>
</tr>
<tr>
<td>Impervious pad</td>
<td>60 cm soil-lime treatment</td>
</tr>
<tr>
<td>Roof</td>
<td>2 pitch metallic roof with eucalyptus beams and piers. Maximum height of roof 3.5 m in the center.</td>
</tr>
</tbody>
</table>

Lixiviates Drainage and Collection System (Run-Off Drainage).
Transversal slope of bins | 1 % to the symmetry axe
---|---
Chutes | Semi-cylindrical 200 mm, 1% slope
Collection tank per building | 3 m³ metallic cylindrical tank in masonry manhole
Masonry manhole | 2 m x 2 m x 1 m covered with a concrete slab.

Water Harvesting System

<table>
<thead>
<tr>
<th>Gutters</th>
<th>Galvanized steel sheet 0.5 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collection tank per building</td>
<td>10 m³ metallic cylindrical tank</td>
</tr>
</tbody>
</table>

Vehicular Accesses

<table>
<thead>
<tr>
<th>Width</th>
<th>6 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camber</td>
<td>4 %</td>
</tr>
<tr>
<td>Total Area</td>
<td>3,285.8 m²</td>
</tr>
</tbody>
</table>

Exterior and Interior Run-On Drainage System.

<table>
<thead>
<tr>
<th>Exterior</th>
<th>Trapezoidal Ditches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>2:1</td>
</tr>
<tr>
<td>Gradients</td>
<td>2 %</td>
</tr>
<tr>
<td>Width</td>
<td>3 m</td>
</tr>
<tr>
<td>Length</td>
<td>220 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interior</th>
<th>Circular Perimeter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>50 cm</td>
</tr>
<tr>
<td>Gradients</td>
<td>2 %</td>
</tr>
<tr>
<td>Width</td>
<td>50 cm</td>
</tr>
<tr>
<td>Length</td>
<td>64.8 x 3</td>
</tr>
</tbody>
</table>
12 Conclusions

The work covered by this "Construction Project of the Co-composting Plant in the city of Wukro" constitute a proposal of sanitation solution for the city of Wukro in Ethiopia. This document tries to define all the elements that are required for the use of the Co-composting Facilities but further surveys of chemical composition and treatment will have to be done previous to the opening of the plant.

However, it is estimated sufficiently justified the construction project of the Co-Composting Facility. Therefore, it is left to whom it may concern the approval of this project.

Madrid, 28th October 2013

The Engineer Author of the Project

Ana Rubio Gavilán