VISAVET HEALTH SURVEILLANCE CENTRE

WASTE MANAGEMENT CONSULTANCY IN SAO TOMÉ E PRÍNCIPE

PROPOSAL OF A WASTE MANAGEMENT SYSTEM FOR THE MALARIA ERADICATION PROGRAMME

Lucas Domínguez Lubillo, PhD Candidate at VISAVET

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Table of Contents

Figure List

Table List

1. EXECUTIVE SUMMARY

During the last decade, the United Nations Development Programme (UNDP) as Principal Recipient (RP) of several Global Fund grants, has applied vector control activities in order to alleviate the spread of Malaria in São Tomé and Príncipe. Among others, pyrethroid, carbamate and IGR based pesticides were sprayed during eradication campaigns. As a result of these actions, an important reduction on malaria mortality and morbidity has been registered. On the other hand, the containers and other pesticide wastes remain stored in a warehouse throughout the country. Besides, since the 1990's there are other obsolete pesticide and rodenticide waste, despite attempts to solve the problem.

The objective of the consultancy is to support the government from São Tomé and Príncipe in setting up a strategy and a budget action plan to manage the waste generated as a consequence of the Malaria Eradication Programme. In order to do so, this report has covered firstly a thorough analysis of the current background, namely waste storage and its generation.

Secondly, it has been proposed several solutions for pesticide waste management, referencing always the best available techniques (BAT) according to both national, FAO and WHO regulations (Food and Agricultural Organization and World Health Organization respectively). When it was needed, USA and EU legislation have been cited, in order to establish a reference framework for the implementation of the waste management system in São Tomé and Príncipe.

As reflected in the text of the Convention of Basel on Control of Transboundary Movements of Hazardous Wastes and their Disposal (1), prevention of the waste generation is key (and legally a priority) for its management. Accordingly, the 4th article of Directive 2008/98/EC of the European Parliament and of the Council, of 19 November 2008, on waste and repealing certain Directives (2), the following hierarchy shall apply as a priority order in waste prevention and management legislation policy:

a) Prevention

b) Preparing for re-use

c) Recycling

d) Other recovery, e.g. energy recovery

e) Disposal

Therefore, the first part of the proposal has covered prevention (and consequently environmental impact reduction) in the waste generation. The proposals regarding prevention actions have consisted mainly in changes in the actual pulverisation equipment and pesticide format and packaging. Firstly, it has been recommended to eliminate elements containing polyvinyl chloride (PVC), synthetic rubber and

polycarbonate (PC), which limit significantly the management options for the waste. Secondly, the proposal encourages to maintain a pesticide bought in water dispersible granules (WDG), packaged in paper bags. Although the selection of a pesticide depends on several other parameters, this recommendation should be also taken in account, as it can have a severe impact on the waste management system.

Secondly, reuse and recycling polices have been briefly presented. Nevertheless, this options could be rather implausible due to sanitary problems. Although the Basel Convention (1) approves the exportation of hazardous waste generated from the use biocides phytopharmaceuticals, this could severely endanger the national biosecurity of the importing country, especially in the case of non-classified waste, as the one present in the waste storage facility of *Morro Cargado*.

Lastly, some disposal and recovery alternatives have been discussed. The most basic alternative (and therefore the most economical) proposed covers a dual solution, treating waste by the means of an incinerator and a landfill, both according to national, UE, FAO and WHO regulations. On top of this solution, and in case the project has no further budget limitations, supplementary actions have been proposed, improving the basic option (less air contamination, energy recovery systems, etc.). A cost/benefit analysis has been conducted, in order to shed some light on this issue.

2. INTRODUCTION

2.1. São Tomé and Príncipe

São Tomé and Príncipe, officially the **Democratic Republic of São Tomé and Príncipe**, is a Portuguese-speaking island nation in the Gulf of Guinea, off the western equatorial coast of Central Africa.

It consists of two archipelagos around the two main islands: São Tomé and Príncipe, located about 140 kilometres (87 mi) apart and about 250 and 225 kilometres (155 and 140 mi), respectively, off the north-western coast of Gabon. Both islands are part of an extinct volcanic mountain range. São Tomé, the sizable southern island, is situated just north of the equator. It was named in honour of Saint Thomas by Portuguese explorers who arrived at the island on his feast day on the western shores of the island, a small village called Anobom.

With a census population of 187,356 (2012), São Tomé and Príncipe is the second-smallest African country, behind Seychelles. It is also the smallest Portuguese-speaking country (3).

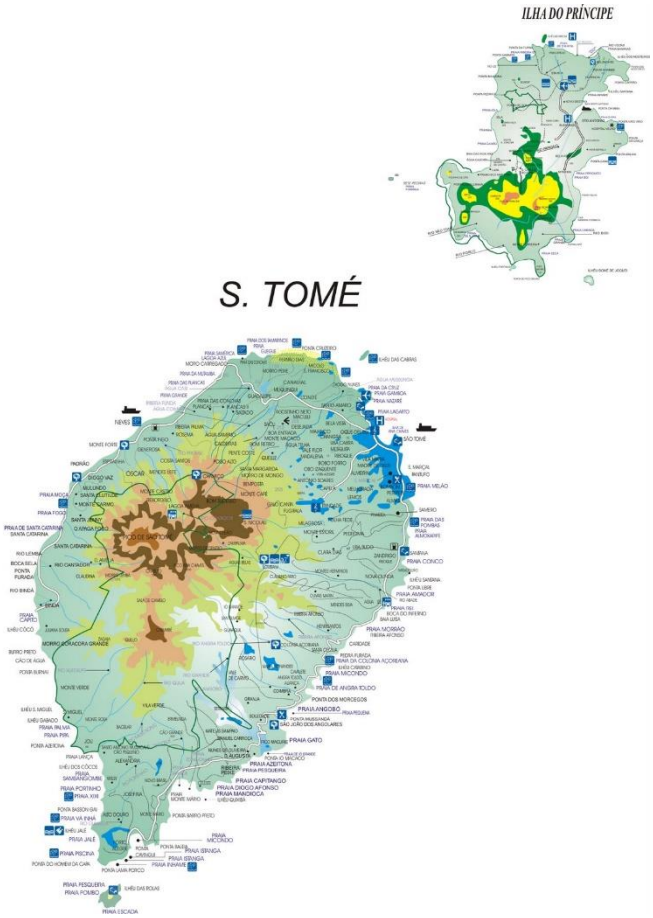

Figure 1. *Map of São Tomé and Príncipe*

2.2. UNDP. The Malaria Eradication Programme

The United Nations Development Programme (UNDP) is the United Nations' (UN) global development network. Its main goal is to partner with people at all levels of society to help build nations that can withstand crisis, and drive and sustain the kind of growth that improves the quality of life for everyone. On the ground in more than 170 countries and territories, it offers global perspective and local insight to help empower lives and build resilient nations (4).

Currently, the task of UNDP in the island of São Tomé is to fight HIV, Tuberculosis and Malaria as Program Coordinator, in the role of Principal Recipient of a Global Fund grant.

2.3. Actual Context

During the last decade, vector control activities have been applied in order to alleviate the spread of Malaria. Among others, pyrethroid, carbamate and IGR based pesticides were sprayed during eradication campaigns. As a result of these actions, an important reduction on malaria mortality and morbidity has been registered. On the other hand, the containers and other pesticide wastes remain stored in a warehouse throughout the country. Besides, since the 1990's there are other obsolete pesticide and rodenticide waste, despite attempts to solve the problem.

2.4. Objectives of the Consultancy

The objective of the consultancy is to support the government from São Tomé and Príncipe in setting up a strategy and a budget action plan to manage the waste generated as a consequence of the Malaria Eradication Programme. In order to do so, this report will cover the following points:

- **Analysis of the current background.** In this first section, current storage systems at the Island will be evaluated. Furthermore, generation of new waste will be identified (source of the waste and its nature, generation rate, etc.).
- **Structured solution according to national and international regulations.** Review of best practices for pesticide waste management and their implementation, taking in account the geographical context of the country and its future perspective as tourist destination.
- **Development of a Budget Action Plan** of all the proposed solutions.
- **Conclusions and final recommendations.**

3. CURRENT BACKGROUND

In order to analyse the present situation, a visit to São Tomé was conducted between the 19th July and the 27th July 2014. Due to the tight schedule and the short time, the island of Principe was not visited. Nevertheless, it will be taken in account for the action plan.

The visit had to main goals:

- **On-site data acquisition.** Visit the most significant places regarding the Malaria Eradication Programme, in order to acquire information for the present report.
- **Meeting local authorities.** Some of the local authorities were visited, in order to try to create some synergies between their duties and the future waste management system.

3.1. Schedule

The schedule of the visit was the following:

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
09:00	Official presentation at UNDP			Waste elimination area	
10:00					
11:00			Visit to waste storage at *"Morro Cargado"*	Meeting at Ministry of Agriculture	Consultancy presentation to UNDP
12:00	Visit to the Warehouse	Pulverisation procedure			
13:00			Meeting at National Centre for Endemic Diseases (CNE)*		
14:00					
15:00				Meeting at Ministry of Environment	
16:00	Visit to Taiwanese Malaria Project	Visit to the washing centre			
17:00					

3.2. Location Map

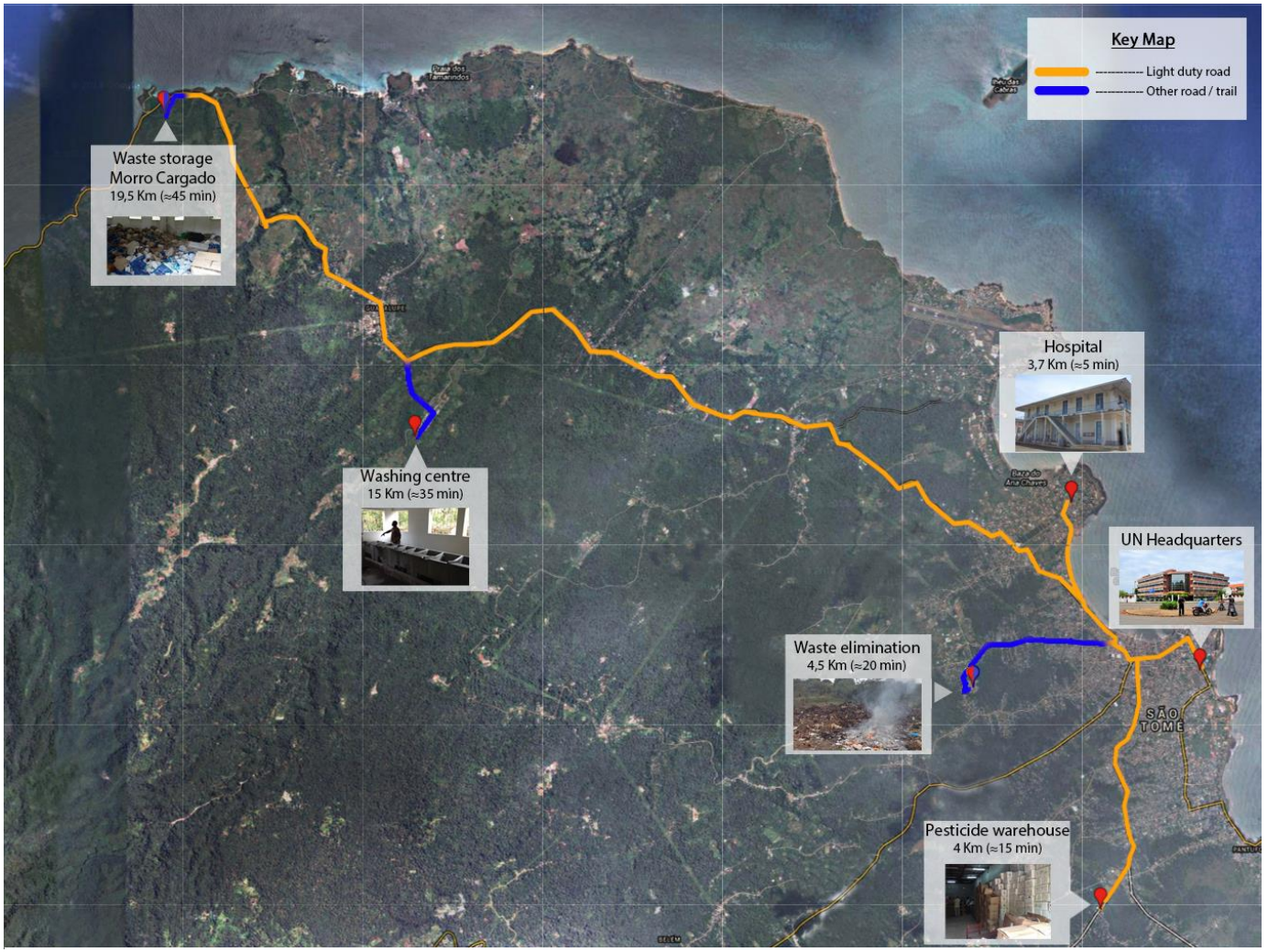

Figure 2. *Map of the north-eastern part of São Tomé Island. All significant facilities are represented in their exact location, as well as the distance and driving time to the UN headquarters.*

3.3. Facilities Overview

All the pictures belonging to this chapter have been moved to Annex I, in purpose of clarity.

3.3.1. Visit to the Pesticide Warehouse

The pesticide warehouse is where all pesticide and pulverising equipment is stored. The Warehouse is not far away from the centre of São Tomé (about 15 minutes), and the road is reasonably good. The warehouse measures 21.7 x 5.7 x 4.7 m (L x W x H).

It has also a section for disposal: pesticide empty containers, boxes, plastics, broken equipment, etc. Beside all the waste stored, the Malaria programme generates approximately **2 to 3 m³/month** of waste, consisting mainly on empty pesticide packages and boxes.

Ventilation conditions of the warehouse are not appropriate for working conditions.

In the warehouse, the following waste is being stored:

- **Alphacypermethrine based pesticide.** Left over of former pesticide, due to the fact that the malaria mosquito developed a resistance against it.
    - Expired product (since 09/2013): ALPHACYPERMETHRINE 10 SC, *Gharda Chemicals Ltd.* 80 boxes (100 x100 ml). Content in Alphacypermethrine 10.4% w/w (min). **In total, 800 litres.**
    - Active product (expires 09/2015): ALPHAMOST 10 SC, *Hockley International Ltd.* 20 boxes (4 x 5 ltr.). Content in Alphacypermethrine 10.41% m/m. **In total 400 litres.**
- **Empty plastic bottles.** Approximately **70 m³** of boxes with empty plastic boxes, containing rests of Alphacypermethrine. Material: high-density polyethylene (HDPE).
- **Empty paper packaging.** Approximately **30 m³** with boxes filled with paper packages with rests of carbamate based pesticide.
- **Face masks (used).** Ply fabric. Several boxes.
- **Latex gloves (used).** Several boxes.
- **Synthetic rubber boots (broken).** Several boxes.
- **Pulverising Suits (used).** 40% nylon, 60% PVC. Several boxes.
- **Plastic face-shields (used).** Polycarbonate or similar. Several boxes.

3.3.2. Washing Centre

The washing centre consists of a washing room, where pulverisation suits are washed, and several drying rooms, where clothes and equipment dry. Washing water is stored in a septic tank, situated underground in the nearby of the building.

Each worker uses approximately up to 4 suits weekly.

It is quite far away from Sao Tomé (20 minutes) and access is relatively complicated (last 5 minutes no road and high slope).

3.3.3. Waste Storage at "Morro Cargado"

Situated in the North West part of the island, is approximately 30 minutes from São Tomé. The main role of the waste storage has been completely misused, as can be seen from all the aluminium cans and glass bottles which lie around the site.

The building where the waste is stored is 12 x 6 x 3 m (L x W x H). Litter has been deposited here since its foundation, around the year 2000. A significant amount of noxious, toxic gases is been here generated, as it can be detected from the intense, intolerable smell coming from the building.

There is approximately 10 to 20 m^3 of waste in the building. Although not classified, waste can be broken into the following categories:

- Old rodenticide.
- Old pesticide.
- Pharmacological waste.
- Different types of plastic (mainly packaging and containers).
- Glass bottles.
- Carton and wood boxes (unknown content).
- Metal containers (unknown content).
- Office equipment waste (old toner, printers, etc.).

-

3.3.4. Waste Elimination Site

It is close to São Tome, although the road is tortuous and full of rocks, holes and bumps.

The initial project developed at the site was a waste classification plant. Nowadays, its actual use is as an open area where waste is incinerated. The following waste is brought here for its destruction:

- Municipal solid waste (MSW).
- Hospital waste.
- Wheels.
- All kind of plastic, mainly packaging.
- Others (glass, metal, etc.).

3.4. Meeting with Local Authorities

3.4.1. Visit to the Taiwanese Malaria Project

This Taiwanese NGO has been present in São Tomé and Príncipe for the last 10 years. They have done intensive research in the endemic mosquitoes (different species, resistance to pesticides, etc.). Additionally, they have also implemented important computer programming in the island control mechanisms (warehouse stocking, mapping, statistics, etc.).

3.4.2. Meeting at National Centre for Endemic Diseases(CNE)

This meeting, to be held with Herodes Rampao, Programme Coordinator, was not celebrated.

3.4.3. Meeting at the Ministry of Agriculture, Fishing and Rural Development

This meeting was held with:

- Director of Resources Planning
- Director of Agriculture

During the meeting, both directors presented their duties at the Ministry. Their divisions are in charge of buying and distributing manure and pesticide for local agriculture. Yearly import is approximately **315 Tm/year of manure and 42 Tm/year of pesticides.** There is neither a waste management system nor a plan to implement one in the short term.

3.4.4. Meeting at the Ministry of Natural Resources, Energy and Environment

Meeting held with:

- Arlindo Carvalho, General Director for the Environment

The director for environment is trying to implement actions, to make waste management in São Tomé and Príncipe more sustainable.

- Introduction of the São Tomé in the Convention of Basel on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1).
- Export of non-hazardous waste, such as empty water bottles or batteries, to Portugal for their re-use and recycle.

4. PROPOSAL

In this section several solutions will be proposed to manage the waste of the Malaria Eradication Programme. To do so, firstly a legal framework will be established, beginning at international level.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1) was adopted on 22th March 1989 by the Conference of Plenipotentiaries in Basel, Switzerland, in response to a public outcry following the discovery, in the 1980s, in Africa and other parts of the developing world of deposits of toxic wastes imported from abroad.

The overarching objective of the Basel Convention is to protect human health and the environment against the adverse effects of hazardous wastes. Its scope of application covers a wide range of wastes defined as "hazardous wastes" based on their origin and/or composition and their characteristics.

Accordingly, the 4th article of Directive 2008/98/EC of the European Parliament and of the Council, of 19 November 2008, on waste and repealing certain Directives (2), stablishes a waste hierarchy that shall apply as a priority order in waste prevention and management legislation policies. This legislation is listed below:

a) Prevention

b) Preparing for re-use

c) Recycling

d) Other recovery, e.g. energy recovery

e) Disposal

For purposes of clarity, this report will be structured following this hierarchy.

4.1. Prevention

According to the European Directive on waste management (2), prevention means measures taken before a substance, material or product has become waste. This implies a reduction of:

a) the quantity of waste, including through the reuse of products or the extension of the life span of products;
b) the adverse impacts of the generated waste on the environment and human health; or

c) the content of harmful substances in materials and products.

As reflected in the text of the Convention of Basel (1), prevention of the waste generation is key (and legally a priority) for its management.

Although reducing the waste generated by the Malaria Programme is not possible, as all the materials used are essential for the correct execution of pulverisation campaigns, some changes can be done in order to reduce environmental impact and facilitate the management of disposal.

The prevention plan will cover two points:

- firstly, the recommendation for new equipment which is made of easier disposable materials,
- and secondly, a remark about the packaging format of the pesticide.

4.1.1. Equipment Material Change

It has been detected that some parts of the equipment which is used during the pulverisation campaigns has a high content of certain materials, which can be an issue from a waste management point of view.

- **Polyvinyl chloride (PVC).** PVC is a high quality, cost-effective material due to its mechanical and thermal properties. Nevertheless, it has a very negative environmental impact, due to its high content in chloride, which can represent up to 67% of the total weight for chlorinated PVC (3).
  PVC can be recycled, but although new initiatives such as *Vinyloop*[1] make the process significantly cheaper, it is still expensive and limited (4).
  In the end, an important quantity of the existing PVC is finally burnt in landfills or urban waste incinerators, originating polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). These two combustion by-products are characterised for being very toxic and persistent.
- **Polycarbonate (PC).** Polycarbonates are polymers containing carbonate groups, characterised for being impact and temperature resistant with a high performance.
  Although not as much as PVC, PC is hard to recycle and has a strong environmental impact, due its high toxicity and the fact that it has a very low degradation rate (5).
- **Synthetic rubber.** It is made by the polymerization of a variety of petroleum-based precursors called monomers. The most common synthetic rubber is the styrene-butadiene (SBR).

[1] "Vinyloop" is a process in which PVC is separated from a certain composite by the means of a solvent working in a closed looped.

At the moment, there are three pieces of equipment which are made of one of the described substances, as we can see in the following table:

Table 1. *Description of equipment elements and the material to be changed.*

Equipment element	Material
Pulverisation suits	PVC (60%)
Synthetic rubber boots	Not specified (SBR or similar). May contain PVC.
Plastic face-shields	Polycarbonate

As it can be seen, all the materials listed above complicate significantly the waste management viability, both recycling and disposal activities.

Therefore, several new pieces of equipment will be recommended. The criteria to select the new materials are listed below:

- Low environmental impact (or less than the former equipment)
- Easy, cost-effective recycling process
- Easy for disposal activities

This new materials are:

- **Polypropylene (PP).** PP is a thermoplastic polymer used mainly for packaging applications. Its main advantage in comparison to PVC is the composition of PP, containing only atoms of carbon and hydrogen. The fabrication disposal processes have less environmental impact and it has a shorter decay period (6).

- **Natural rubber.** Also called caoutchouc, it is a material directly extracted from trees. In comparison to synthetic rubber, it has worst thermal properties and can suffer from degradation against biological agents. Nevertheless, the manufacturing process is natural, and disposal process has lower environmental impact (7).

- **Acetate.** Acetate is synthesised from cellulose, present in wood. It is actually considered nature's building blocks. As natural rubber, is a renewable material, and its disposal has a low impact (8).

To conclude, the proposal for equipment substitution is summarised in the following table.

Table 2. *Description of equipment elements and the material to be changed.*

Equipment element	Material
Pulverisation suits	PP (100%)
Rubber boots	Caoutchouc (100%). Sole and exterior
Plastic face-shields	Acetate

4.1.2. Pesticide Packaging Format

Although this point may not seem relevant, the fact is that an important percentage of the waste generated comes from pesticide packaging. Additionally, the Malaria Eradication Programme in São Tomé changes the pesticide approximately every 5 years, due to the fact that the malaria mosquito ends up growing resistant to the active molecule. Therefore, it is important to start considering waste management during the pesticide choosing process.

The actual paper packaging, in comparison to former HDPE bottles, makes disposal of pesticide containers straight forward, as it can be normally disposed with no harm or risk.

Therefore, it is proposed to continue buying pesticide in this packaging format, namely water dispersible granules (WDG), when possible.

Although the selection of a pesticide depends on several other parameters, this recommendation should be also taken in account, as it can have a severe impact on the waste management system.

4.1.3. Prevention Budget Plan (BAP)

The budgeted plan will be elaborated in three different action, namely P.1, P.2 and P.3. Each one of these options refers to the substitution of the former materials for the new recommended ones. The BAP is presented in chapter 5.

4.2. Re-use and Recycle

Once prevention has been analysed, re-use and recycle are the next actions in the waste management hierarchy.

According to the European Directive on waste management (2), reuse and recycle can be defined as follows:

- Waste **re-use** means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.

- Waste **recycling** means any recovery operation by which waste material are reprocessed into products materials or substances whether for the original or other purposes. It includes the reprocessing or organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

4.2.1. Re-use

Analysing the waste that is generated during the Malaria Eradication Programme in São Tomé and Príncipe, it can be seen how the re-use approach of waste is not possible.

- Firstly, all the equipment used for pulverisation campaign becomes waste when its beyond re-use or repair (suits, boots, helmets, plastic face-shields, etc.).
- Secondly, all waste concerning pesticide packaging, namely HDPE bottles containing rests of alphacypermethrine, can neither be used nor recycled according to the manufacturing company (9).

4.2.2. Recycling

Although recycling waste is always a practical option, there is no possibility of doing this directly at São Tomé and Príncipe, as there is no recycling industry.

This means, all waste should be exported to third countries, and once there recycled according to national regulations. This will be hypothetically no problem, as the Ministry of Natural Resources, Energy and Environment is already executing the adhesion of São Tomé e Príncipe to the Convention of Basel (1). According to the Convention:

- hazardous waste can be exported from one party[1] to another, in order to be recycled in the importing country, only when the state of export does not have the technical capacity and the necessary facilities, capacity of suitable disposal sites in order to dispose of the wastes in question in an environmentally sound and efficient manner.
- All hazardous waste must be correctly packaged, labelled and transported in conformity with generally accepted and recognised international rules and standards.

Therefore, the pesticide waste could be exported under the category of "waste from the production, formulation and use of biocides and phytopharmaceuticals (Y4)" (1).

Nevertheless, this may be implausible due to the sanitary risk. By importing the generated waste at São Tomé and Príncipe, the importing country can endanger severely its biosecurity, as waste may contain traces of plagues (mosquito larvae) or infectious diseases (such us HIV or tuberculosis in this case).

Hence, although this option should always be studied, it is also important to look for a sustainable, short-term solution for the waste management at São Tomé and Príncipe.

[1] Party: countries which are members of the Convention of Basel.

4.3. Energy Recovery and Disposal

As mentioned in the above section, due to the increasing problem of waste management at São Tomé and Príncipe, the country needs a sustainable, short-term solution to start solving the problem derived from the waste generation of the Malaria Eradication Programme.

Referring again to the Basel Convention (1), there are several disposal methods available for hazardous waste management.

Table 3. *Operation which do not lead to the possibility of resource recovery, recycling, reclamation, direct re-use or alternative uses*

Code	Disposal action
D1	Deposit into or onto land
D2	Land treatment
D3	Deep injection
D4	Surface impoundment
D5	Specially engineered landfill
D6	Release into a water body except seas/oceans
D7	Release into seas/oceans including sea-bed insertion
D8	Biological treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations in Section A
D9	Physico chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations in Section A
D10	Incineration on land
D11	Incineration at sea
D12	Permanent storage
D13	Blending or mixing prior to submission to any other operations in section A
D14	Repackaging prior to submission to any of the operations in Section A
D15	Storage pending any of the operations in Section A

From the above listed options, it is probably **on land incineration** one of the most cost-effective, sanitarily impeccable and short-term solutions.

4.3.1. On land incineration

According to WHO (10), there has been growing controversy over incineration of health-care waste. Under some circumstances, namely at low incineration temperatures and in the presence of chlorinated substances, such as PVC, dioxins (PCDDs), furans (PCDFs) and other toxic air pollutants may be produced as a result of the incineration process of organic compounds. Exposure to PCDDs and PCDFs may lead to adverse health effects.

The optimal formation of this compounds occurs during a combustion process with a presence of chloride, between 400ºC and 700ºC in reducing atmosphere (namely, with

a low content of O_2). This is the typical situation given in the burning of a building or a forest. In this concrete situation, the flue gases enter in contact with non-burnt organic rests, synthesising dioxin and furan compounds. In such processes, copper can act as a catalyst of the reaction.

Nevertheless, this pollutant air emissions can be avoided by setting adequate combustion conditions. For instance, according to Directive 2000/76/EC of the European Parliament and of the Council, of 4 December, on the incineration of waste (11), when eliminating hazardous waste, if there is a content of more than 1% of halogenated organic substances, expressed as chlorine, the temperature must be raised to 1100ºC for at least two seconds. Additionally, waste must be incinerated in an oxidising atmosphere, having at least a content of 6% O_2 in flue gases (after combustion). This will guarantee that the incinerator fulfils the Protocol on Persistent Organic Pollutants signed by the Community within the framework of the United Nations Economic Commission for Europe (UN-ECE) Convention on long-range transboundary air pollution, which sets legally binding limit values for the emission of dioxins and furans the of 0.2 ng/m³ when burning more than 1 tonne per hour of hazardous waste (12).

Additionally, safe disposal of health-care waste is a priority for human health, as consequences of incorrect manipulation can be tragic. WHO estimates that during 2000 mismanagement of contaminated injection equipment caused:

- 21 million hepatitis B virus infections (32% of all new infections);
- two million hepatitis C virus infections (40% of all new infections);
- at least 260.000 HIV infections (5% of all new infections).

This, according to WHO (10), was propitiated by the fact that between 18% and 64% of the health-care facilities in 22 developing countries did not use proper waste disposal methods (2002).

Therefore, incinerators provide an interim solution, especially for developing countries where options for alternative waste disposal options are limited. Nevertheless, in order to avoid the above listed incineration issues, best incineration practices must be promoted:

1. Effective waste reduction and waste segregation, ensuring that only appropriate wastes are incinerated. Therefore, the following substances should never be incinerated:
    a) Heavy metals (e.g. mercury).
    b) Glass.
    c) Chlorinated substances, such as PVC or alphacypermethrine
2. The incinerator should never stand in a populated area.
3. Properly engineered design, ensuring optimal combustion conditions. According to Directive 2000/76/EC (13):
    a) There is approximately 120 m³ of stored waste which could potentially be incinerated (including the pesticide warehouse, Morro Cargado and waste at the island of Príncipe). Otherwise, the Malaria Eradication

Programme generates nearly 40 m³/year. Therefore, a volume of 1 – 1.5 m³ for the combustion chamber would be enough.

b) The incinerator should never incinerate faster than 50 kg/h, in order to be considered a low capacity incinerator. This limit is established by the the Comission Regulation (EU) Nº 142/2011, of 25 February 2011, on implementing Regulation (EC) Nº 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive (15). According to EU technical reports, this capacity delimits simple, low pollutant incineration systems. Therefore, the approach in São Tomé and Príncipe should be of a low capacity incineration system, in order to generate less environmental impact on the island.
c) The incinerator must have two independent chambers: a combustion chamber and a post-combustion chamber. Waste is to be incinerated in the combustion chamber, while only flue gases continue to the post-combustion chamber.
d) Each combustion chamber must have at least one independent burner.
e) Incineration may not begin until the temperature in the post-combustion chamber has not reached 850ºC (1,100ºC in case there is presence of halogenated organic substances).
f) The temperature of the post-combustion chamber during incineration must always be over 850ºC or 1,100ºC respectively. Additionaly, flue gases must be always over 450ºC and have a fluid velocity of more than 8 m/s, in order to avoid the formation of dioxins and furans at the end of the process.
g) The incinerator must have a secondary air injection, apart from the primary injected through the burners. This secondary injection will guarantee the presence of O_2 inside the incinerator.
h) The combustion must take place in an oxidising atmosphere, in order to avoid formation of PCDDs and PCDFs. For this purpose, the incinerator will be equipped with oxygen sensors and an active control on the air injection.
i) Temperature must be controlled in both chambers in at least one point.
j) Robust design, prepared for adverse weather conditions.
k) The incinerator must be equipped with a control PLC, which makes the incinerator work automatically after start. The PLC must register temperatures during operation, in order to be able to verify in combustion is taking place in appropriate conditions, according to regulations.
l) The programme of the incinerator must guarantee that after completion of the incineration, all waste has been reduced completely to ashes.

4. Easy periodic maintanance, stablished by the manufacturer.
5. Enhanced training and management for incinerator operators.

6. Atteending to local needs, the incineration shoud have several other characteristics:
    a) The system should be conceived to work autonomously, due to often electric power cut. This will guarantee a perfect incineration, independently of the elctric network conditions.
    b) Due to transport difficulties:
        i. the system can be divided into several parts, weighing each part no more than 5 Tm each.
        ii. The whole system should be fitted, if possible, in a 20 feet standard container (recommended).
7. Easy periodic maintenance.
8. Detailed and comprehensive user guide, written in Portuguese and English.

All this characteristics are summarised in Annex II.

4.3.2. Energy Recovery and Flue Gases Filtering

As mentioned above, the incinerator to be acquired for São Tomé, should fall under the category of small capacity incinerator (< 50 kg/h), as it will not be working more than once or twice a week.

On the one hand, as the system is a small capacity incinerator, there is no real need for filtering systems. Pollution derived from the activity will be significantly low, due to the high incineration temperatures and the working schedule.

On the other hand, systems for energy recovery become profitable after long periods of use (above from 7,000 hours/year of use). As in São Tomé and Príncipe the incineration system will never work over 600 hours/year, the profitability of the energy recovery system is not worth the investment.

4.3.3. Landfill

On the other hand, for all the products not suitable for incineration (chlorinated substances, heavy metals and glass) another alternative must be set.

In case the exportation of the hazardous waste is no longer an option, waste could be easily disposed in a landfill.

Landfills are regulated in the EU by the Council Directive 1999/31/EC, of 26 April 1999, on the landfill of waste (13). In order to design a landfill according to this Directive, 3 aspects must be studied and evaluated:

I. General requirements for all classes of landfills.
II. Waste acceptance criteria and procedures.
III. Control and monitoring procedures in operation and after-care phases.

5. BUDGET ACTION PLAN

For the purpose of clarity and uniformity, this budgeted action plan has been developed according to the following:

- The currency used is Euros (€).
- The change from Euros to São Tomé and Príncipe Dobra is set to 24,503.88 DBR/€.
- All budgets are approximately calculated, and so there should be interpreted.

5.1. Ventilation of warehouse budget

Information to compute budget:

- Dimensions Warehouse: 21.7 x 5.7 x 4.7 m (L x W x H). Which means **582 m³.**
- Air renovation needed: 25 renovations/hour.
- Total air flow rate and air speed: 14,534 m³/h ; 0.15 m/s
- **Approximate price: 1,500 €**

5.2. Prevention budget action plan. Material change

The prevention budget is presented as three different options, in order to reflect the budget for each of the proposed actions.

5.2.1. P.1: acetate face-shields

From a personal communication, we know:

- Acetate face-shields covers the same technical characteristics as PC face-shields (EN 166).
- PC face-shields costs 292,500 DBR (11.94 €)
- Acetate face-shields are approximately 40% more expensive than PC face-shields.
- The disposal rate from pulverisation campaigns in São Tomé is 200 face-shields/year.

Table 4. *Budget Action Plan (BAP) for face-shields proposal.*

Materials	Prices	Yearly Units	Yearly budget	P.1 BAP
PC	11.94 €	200	2.388 €/y	**~ 954 €/y**
Acetate	16.71 €	200	3.342 €/y	

5.2.2. P.2: Polypropylene (PP) pulverisation suits

From a personal communication, we know:

- PP pulverisation suits[1] cost approximately 6 €.
- PVC pulverisation suits approximately 5 € (no info about real cost in São Tomé).
- The disposal rate from pulverisation campaigns in São Tomé is 166 pulverisation suits/year.

Table 5. *Budgeted Action Plan (BAP) for pulverisation suits proposal.*

Materials	Prices	Yearly Units	Yearly budget	P.2 BAP
PVC/Nylon	5.00 €	166	830 €/y	**~ 166 €/y**
PP	6.00 €	166	996 €/y	

5.2.3. P.3: natural rubber boots

From a personal communication, we know:

- Natural rubber boots are certified as valid for working equipment (EN ISO 20345)
- Synthetic rubber boots cost approximately 15.00 €.
- Natural rubber boots cost approximately 17.50 €.
- The disposal rate from pulverisation campaigns in São Tomé is 262 pairs of boots/year.

Table 6. *Budgeted Action Plan (BAP) for boots proposal.*

Materials	Prices	Yearly Units	Yearly budget	P.3 BAP
Synthetic	15.00 €	262	3,930 €/y	**~ 655 €/y**
Natural	17.50 €	262	4,585 €/y	

[1] This Price corresponds to a Cat. 1 suit (EN 340).
- Type 4: protection against toxic hazardous liquids in the form of spray (EN 14605)
- Type 5: protection against hazardous particles (EN ISO 13982-1)
- Type 6: protection against limited splash of lower toxicity liquids (EN 13304)

5.3. Disposal Budget Action Plan. Incinerator and Landfill

5.3.1. D.1: Incinerator

The incinerator includes:

- The incinerator.
- Electric generator.
- Fuel tank.
- Incinerator cottage, included walls and roof (concrete floor not included).
- Setting und starting up.
- Incinerator crew training.

The incinerator has three main costs:

- Initial investment (transport not included).
- Exploitation costs (fuel). Personal not included.
- Maintenance (transport not included).

Average values for exploitation costs calcluation:

- Elimination rate: 1 m³/incineration.
- Incineration cost: 120 € (considering fuel costs 1 €/l).
- Stored waste: approximately 120 m³.
- Waste generation: 40 m³/year.

Table 7. *BAP for incinerator proposal.*

	Year 1	Year 2	Year 3	Year 4	Year 5
Investment	95,000 €	-	-	-	-
Nº incinerations	160	40	40	40	40
Exploitation	19,200 €	4,800 €	4,800 €	4,800 €	4,800 €
Maintenance	-	6,000 €	6,000 €	6,000 €	6,000 €
TOTAL	**114,200 €**	**10,800 €**	**10,800 €**	**10,800 €**	**10,800 €**

5.3.2. D.2: Landfill

In order to prepare a BAP for a Landfill, a thorough study should be carried out, which is not the scope of the present report.

6. CONCLUSIONS AND FINAL RECOMMENDATIONS

A thorough study of the waste management methodology has been carried out. Additionally, several actions, along with their budget, have been proposed, taking in account the context of São Tomé and Príncipe: an island with touristic perspective.

To conclude, São Tomé and Príncipe needs a short-term, cost-effective plan, in order to solve the current waste management problem.

Therefore, the final recommendations are the following.

6.1. Pesticide Warehouse Ventilation

Working conditions at the pesticide warehouse are difficult, due to pesticide concentration in the air. Therefore, a helical fan (or similar) should be placed in the back wall. It should have an air flow rate of 14,534 m³/h, renovating the air approximately 25 renovations/hour. The invest would be around 1,500 €.

6.2. Prevention

It is proposed to assume all prevention proposals (P.1, P.2 and P.3), for being cost-effective and because they will have a significant positive environmental impact on the waste management system of the country. The yearly investment derived from these actions is approximately **1,775 €.**

6.3. Re-use and recycle

As the Ministry of Environment is already going through the process of entering the Convention of Basel it is recommended to export all hazardous waste, as long as it is possible due to sanitary risks.

6.4. Incinerator

It is recommended to acquire an incinerator, according to the characteristics summarised in annex II. This incinerator will be acquired to eliminate all waste generated in the island. This includes:

- Health-care waste, generated in the hospital.
- Municipal solid waste (MSW) taken to the waste elimination site.
- Waste generated in the Malaria Eradication Programme.
- Waste stored at *Morro Cargado* suitable to be incinerated.
- Waste generated from agriculture activities.

Nevertheless, the incinerator will be forbidden for the disposal of the following substances:

- Heavy metals (e.g. mercury).
- Chloride substances, such as PVC or Alphacypermethrine.
- Glass.

As shown in the picture below, the recommended location for the system is the waste elimination site, as most of the waste is already been taken there.

6.5. Landfill

It is proposed to build a landfill, according to international regulations, guaranteeing therefore its correct management, in order to preserve the ecosystem of the island.

It should be located at *Morro Cargado*, providing that all international regulations (e.g. groundwater streams) are fulfilled.

The landfill's purpose will be to store all substances not suitable for incineration.

The design and construction of the landfill would require a complete thorugh study, being it not the scope of the present report.

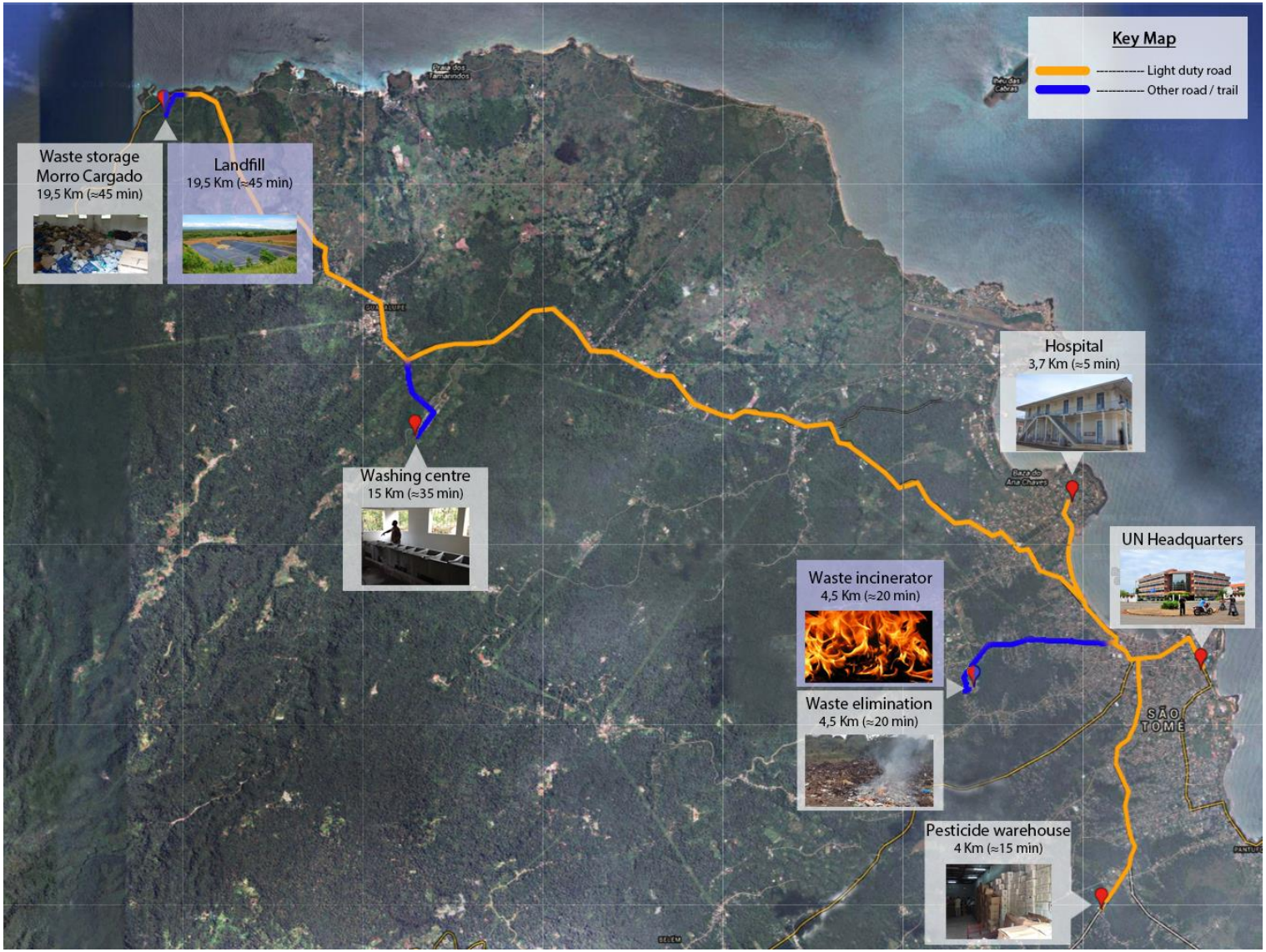

Figure 3. *Map of the north-eastern part of São Tomé Island. Possible location for incinerator and landfill arepresented. Additionally, all significant facilities are represented in their exact location, as well as the distance and driving time to the UN headquarters.*

ANNEX I: FACILITY PICTURES

1. Pesticide Warehouse

Figure 4. *Pesticide Warehouse*

Figure 5. *Alphacypermethrine 5 lt. packaging*

Figure 6. *Waste stored at the Warehouse.*

Figure 7. *Waste stored at the Warehouse.*

Figure 9. *Paper packaging FICAM VC*

Figure 8. *Small bottle packaging Alfacypermethrine*

Figure 11. *PC face-shield*

Figure 10. *Disposable gloves*

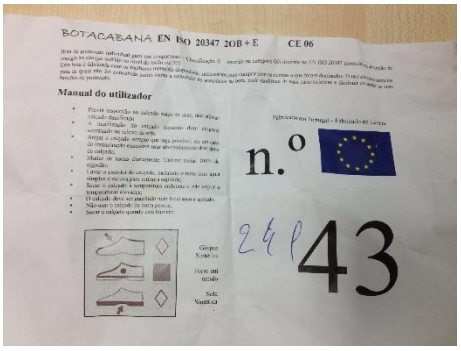

Figure 14. *Synthetic boots description*

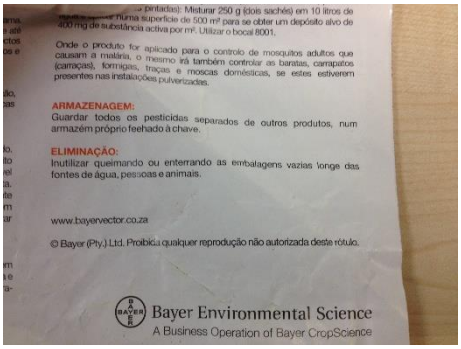

Figure 13. *Disposal description of FICAM VC*

Figure 12. *Pulverisation suit description*

Figure 17. *Pulverising nozzle*

Figure 16. *Pulverising bottle*

Figure 15. *Pulversisation equipment*

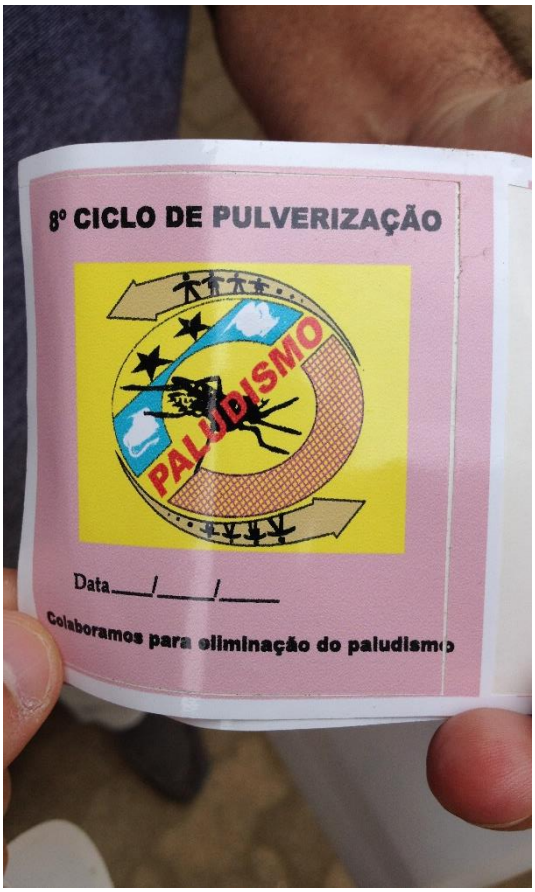

Figure 18. *Pulverisation campaign sticker*

2. Washing Centre

Figure 22. *Washing centre*

Figure 21. *Septic tank*

Figure 19. *Washing room*

Figure 20. *Drying room*

3. Incineration site

Figure 23. *Municipal Solid Waste*

Figure 24. *Dogs eating health-care waste*

4. Waste Storage *Morro Cargado*

Figure 25. *Waste at Morro Cargado.*

Figure 26. *Waste at Morro Cargado.*

ANNEX II: CHARACTERISTICS OF THE PROPOSED INCINERATOR

As metioned in chapter 4.3.1., the recommended system for waste disposal is an incinerator. According to the listed needs, the incinerator must fullfil the following:

- **Propperly engineered design, ensuring that combustion conditions are appropriate.**
    a) The incinerator should never incinerate faster than 50 kg/h, in order to be considered a low capacity incinerator.
    b) The incinerator must have two independent chambers: a combustion chamber and a post-combustion chamber. Waste is to be incinerated in the combustion chamber, while only flue gases continue to the post-combustion chamber.
    c) Each combustion chamber must have at least one independent burner.
    d) Incineration may not begin until the temperature in the post-combustion chamber has not reached 850ºC (1,100ºC in case there is presence of halogenated organic substances).
    a) The temperature of the post-combustion chamber during incineration must always be over 850ºC or 1,100ºC respectively. Additionaly, flue gases must be always over 450ºC and have a fluid velocity of more than 8 m/s, in order to avoid the formation of dioxins and furans at the end of the process.
    e) The incinerator must have a secondary air injection, apart from the primary injected through the burners. This secondary injection will guarantee the presence of O_2 inside the incinerator.
    f) The combustion must take place in an oxidising atmosphere, in order to avoid formation of PCDDs and PCDFs. For this purpose, the incinerator will be equipped with oxygen sensors and an active control on the air injection.
    g) Temperature must be controlled in both chambers in at least one point.
    h) Robust design, prepared for adverse weather conditions.
    i) The incinerator must be equipped with a control PLC, which makes the incinerator work automatically after start. The PLC must register temperatures during operation.
    j) The programme of the incinerator must guarantee that after completion of the incineration, all waste has been reduced completely to ashes.
- **The system should be conceived to work autonomously.** It will therefore be equipped with a fuel electric generator, for all its electric consumption.
- **Transport issues.**
    a) the system can be divided into several parts, weighing each part no more than 5 Tm each.
    b) The whole system should be fitted, if possible, in a 20 feet standard container (recommended, not mandatory).
- **Easy periodic maintenance.** A periodic maintenance must be set by the manufacturer, distinguishing between basic maintanace (done by the

incinerator crew at São Tomé and Príncipe) a professional maintanance (specialised maintance done by manufacturer).

- **Enhance training and user guide.** After delivery and start-up, the manufacturer will be in charge of training personal for the use of the incinerator. Only this personal will be allowed to use the equipment. Additionally, a comprehensive and detailes user guide in Portuguese and English will be prepared.

Specifically, the main incinerator characteristics should be the following:

Table 8. *Incinerator main characteristics*

Characteristics of the waste incinerator	
Waste to be incinerated	- Health-care waste - Pesticide waste (mainly plastics) - MSW
Dimensions	Parts no longer than 20 feet, as them to fit in a container
Incineration speed	50 kg/h
Maximum weight	Modules of maximum 5 Tm
Volume combustion chamber	1.0 – 1.5 m^3
Autonomy	Completely autonomous (with 5 kW fuel electric generator)
Flue gases residence time in post-combustion chamber	> 2 seconds (1,100ºC)
Maximum post-combustion temperature	1,300 ºC
Fuel	Diesel fuel
Nominal electric power	5 kW
Nominal thermal power	150 – 300 kW
O_2 in flue gases	> 6%

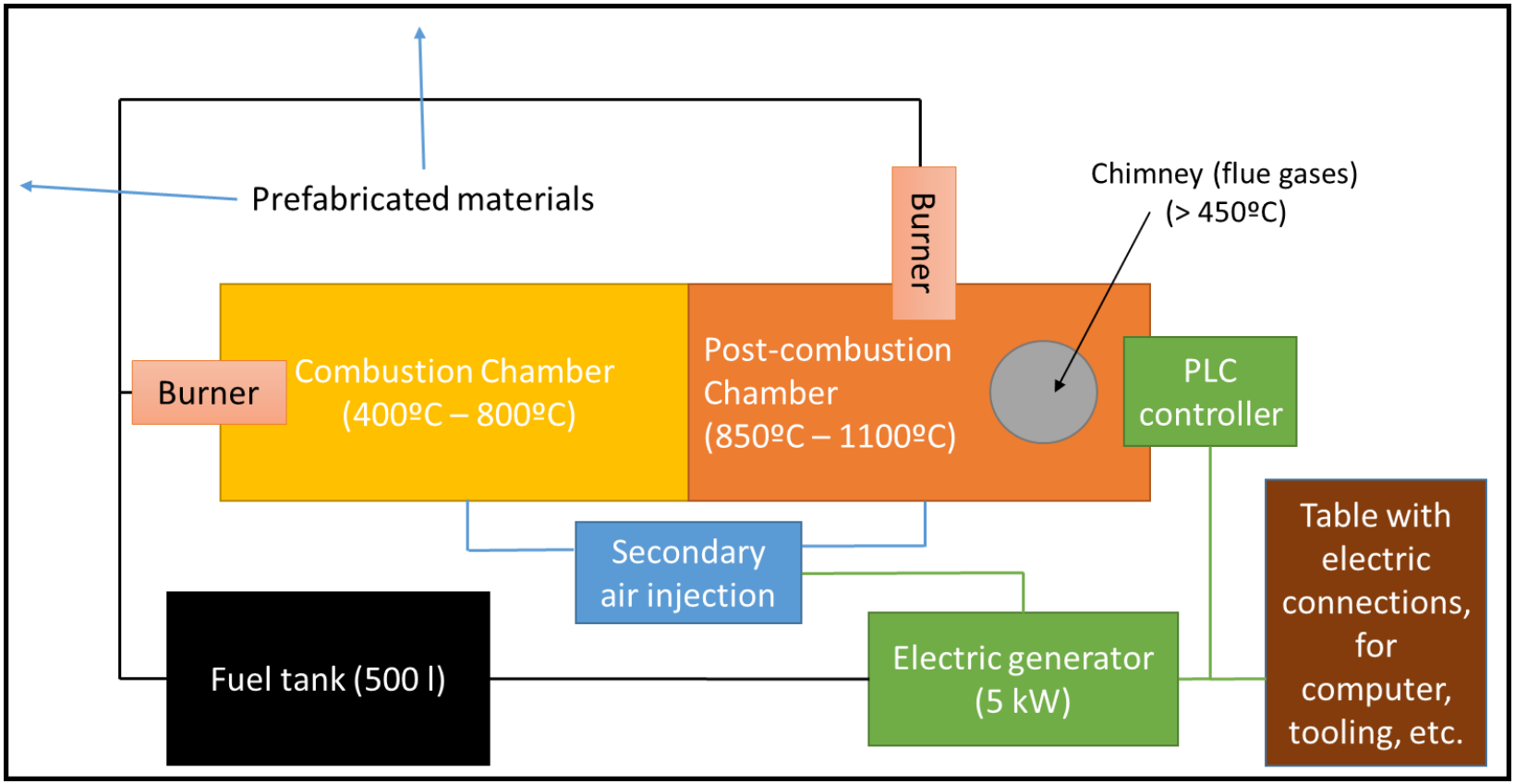

Figure 27. *Chart of incinerator and housing*

References

1. **The Basel Convention.** The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. January 2011.

2. **The European Parliament and the Council.** Directive 2008/98/EC of the European Parliament and of the Council, of 19 November 2008, on waste and repealing certain Directives.

3. *Poly(Vinyl Chloride)*. **Allsopp, M. W. and Vianello, G.** s.l. : Ullmann's Encyclopedia of Industrial Chemistry, 2012, Vols. Wiley-VCH, Weinheim.

4. **Dr. Tukker, A. (TNO-STB), et al.** *Chemical Recycling of Plastics Waste.* s.l. : TNO Institute of Strategy, Technology and Policy, 1999.

5. **Serini, V.** *Polycarbonates.* s.l. : Ullmann's Encyclopedia of Industrial Chemistry, 2000. Wiley-VCH, Weinheim.

6. **Maier, C. and Calafut, T.** *Polypropylene: the definitive user's guide and databook.*

7. **Heinz-Hermann, G.** *Rubber, 2. Natural.* s.l. : Ullmann's Encyclopedia of Industrial Chemistry, 2000. Wiley-VCH, Weinheim.

8. **March, J.** *Advanced Organic Chemistry.* s.l. : Ed. J. Wiley and Sons, 1992.

9. **Ltd., Hockley International.** Personal communication. 2014.

10. *Health-care waste management* . **World Health Organization (WHO).** 2011, Vol. Fact sheet nº281.

11. **The European Parliament and the Council.** Directive 2000/76/EC of The European Parliament and the Council, of 4 December 2000, on the incineration of Waste.

12. **United Nations Economic Comission for Europe (UN-ECE).** The Protocol on Persistent Organic Pollutants. Convention on long-range transboundary air pollution.

13. **The Council of the European Union.** Council Directive 1999/31/EC, of 26 april 1999, on the landfill of waste.