Research Development and Design of a Simple Solid Waste Incinerator

Department For International Development UK

project to be implemented by

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Summary

Project Goal

To Combat the Degradation of Water Sources

Objective of Research

To research, design, construct, test and monitor a simple incinerator that can be locally constructed at low cost to promote cleaner and more complete combustion of modest volumes of municipal solid wastes with a view to waste volume reduction and amelioration.

Project Outputs

- Proven incinerator design able to safely dispose of ten tons of waste per day.
- Design is affordable and can be locally made, operated and maintained.
- Local manufacturers in partner country are able to design and build incinerator.
- Adoption of unit by local government to promote incineration as an alternative to landfill.

Project Activities

Phase 1 – Research

Phase 2 - Design and Test-Rig

Phase 3 - Pilot Test

Phase 4 - Documentation and Training

Phase 5 - Final Report

Implementing Organisations

The project will be implemented by a team formed through an association between Intermediate Technology Consultants and Integrated Skills Limited.

Intermediate Technology Consultants

ITC is the consultancy wing of Intermediate Technology Development Group based in Rugby, Warwickshire. The group has extensive experience in the design, and development of new products and equipment with partners in less developed countries. IT works closely with partners in the South through a network of country offices in Peru, Sudan, Kenya, Zimbabwe, Nepal, India and Sri Lanka. Recently ITC formed part of a team responsible for developing a low cost incinerator for healthcare waste which is due to be tested in Zimbabwe, India and Nepal.

Integrated Skills Limited

As a network of independent environmental specialists, Integrated Skills combines flexibility of approach with a personal style of Client service and continuity. Due to its integrated, de-centralised structure, Integrated Skills operates with minimal administrative and overhead costs, enabling it to offer Clients very competitively-priced services without in any way compromising on quality. Since formation, the Company has undertaken projects in over 50 countries on behalf of a variety of public and private sector organisations.

The company offers;

- Extensive knowledge and experience of waste management
- Specialist capabilities in strategic analysis
- Experience with waste management contracts in 24 countries
- Substantial experience of incinerator technology

Allocation of Tasks

A multi-disciplinary team has been formed drawing upon the resources of both companies and broad responsibilities will be allocated as follows.

ITC staff and associates will be responsible for;

- Project management
- Technology review
- Detailed design and construction
- Development of training materials

ISL staff and associates will be responsible for;

- Review of needs
- Selection of partner country
- Selection of local partner(s)
- Workshop needs analysis/log frame
- Specialised technical input and advice

Team Members

The individual team members whose CV's are included as an annex are;

Kieron Crawley (ITC) - Project Manager

Nick Crick (ISL) - Strategic analysis

Roberto Vogel (ISL) - Technical specialist

Andy Russell (ITC) - Detailed design and evaluation

Ray Holland (ITC) – Project advisor,

Simple Solid Waste Incinerator

A1 INTRODUCTION

Municipal waste all too often contains unpleasant, potentially dangerous substances, which, if improperly managed, could cause harm to health and the environment, especially if burnt in uncontrolled conditions.

In many less-developed countries, uncontrolled dumping is used for the disposal of solid wastes. These dumps are frequently allowed to burn - either deliberately, as a means of volume reduction, or accidentally. The emissions from this type of uncontrolled burning can be noxious and harmful.

Typical materials found in the waste which contribute to these harmful emissions include certain plastics, batteries, paints, domestic chemicals, pharmaceuticals and many industrial wastes.

Incineration of waste

Properly controlled incineration is an effective means of reducing waste volume. It ensures cleaner and more complete combustion of waste and lends itself well to waste disposal in areas where population density is relatively high and availability of sites for landfill is low. Potential pollutants can be contained within the resulting residue which, if disposed of carefully, reduces the risk of contamination of local groundwater. Consequently, whilst recycling has an important part to play, incineration frequently forms part of an overall strategy for the management of municipal waste. Landfill will always be required for the residue, which typically amounts to about one-third of the initial mass of waste.

There are however, a number of technical, social and environmental problems associated with incineration. These arise from the potential pollutants contained in the emissions and residual solids remaining after from the combustion process.

In Western Europe the standards imposed for incineration are very high, leading to costs of around £30-60 per tonne of waste, depending on economies of scale. This is because the employment of Best Available Technology (BAT) requires the complete destruction of the waste to a completely burned, sterile ash and the control of emissions by gas cleaning techniques to reduce particulates, acid gases and dioxins to the very low levels specified in European legislation.

BAT, however, is clearly not affordable for developing countries. Simple incineration that leads to a dramatic improvement in the quality of air emissions compared to the continuation of open burning dumps, must therefore offer a major environmental amelioration.

Incinerator Technology

Most modern large incinerators operate on the 'starved air' principle, in which the waste is gasified and partially burnt using a support fuel (e.g. gas or fuel oil), in a primary chamber. Gaseous phase reactions are completed in a secondary chamber and the remnant solids are then burned as completely as possible in an air rich zone, or a tertiary chamber, at the discharge end of the incinerator. The gases and airborne particulates are then subjected to complex (and often expensive) 'clean-up' before being emitted to atmosphere.

For the simple incinerator at the focus of this project, optimal emissions will have to be achieved without the use of sophisticated gas cleaning equipment, if costs are to be kept to a reasonable level. Given careful design, construction and operation, however, it should be possible to achieve acceptable levels of emissions without the need for gas cleaning, by using the starved air principle.

A significant proportion of municipal waste has value as fuel, but the waste composition in developing countries is such that it is often very difficult to achieve complete combustion using this alone. It is likely therefore that the incinerator will be designed to operate using a

support fuel such as waste oil, biomass, wood, kerosene, diesel or fuel oil. The selection of a support fuel will depend on its availability and the implications on operating costs.

If oxidation reactions are to occur effectively and lead to the complete combustion of waste, the incinerator must achieve high temperatures, high levels of turbulence and have sufficient combustion chamber volume to achieve an adequate residence time. To achieve this, a high degree of insulation would is required, secondary air should be introduced at relatively high velocity just after gasification has occurred and tertiary air should be added into a chamber with a sufficiently large volume to allow completion of the combustion process.

When present, heavy metals such as lead and cadmium become concentrated in incinerator ash and residue. These must be treated and disposed of in an appropriate way. Other potentially hazardous materials such as gaseous mercury and dioxins resulting from chlorine-containing materials in the waste are difficult to capture and remove, even when using sophisticated gas cleaning plant. The pre-sorting of waste and the removal of as much as possible of the materials which lead to these hazardous contaminants will therefore help to minimise harmful emissions to atmosphere.

Other factors which will directly influence the detailed design of the incinerator include:

- capital, operational and maintenance costs
- current and future quantities of waste
- the waste composition and its calorific value
- the infrastructure of the area chosen for the field trials (roads, electrical power)
- attitudes and legislation relating to emissions control
- public concerns about incineration
- the degree to which an integrated waste management strategy has been prepared and the incinerator's role within it
- locally available materials (refractory bricks or other insulation materials)
- locally available manufacturing skills

Such incineration will undoubtedly have a positive impact on health and the environment at a regional or national level through the reduction of pollution due to current waste disposal practices. However it has the potential to have a detrimental impact on communities situated in its immediate area due to the increase in air pollution, the disposal problems associated with contaminated solid residues, and the increase in traffic bringing waste to the site. With a simple incinerator of this kind the problem may be greater than for a more sophisticated unit as pollutants released with emissions are likely to be greater. Careful siting will therefore be crucial.

To assess these effects an independent local organisation or consultant with relevant experience should undertake an environmental impact assessment (EIA). As with any EIA it is important to assess the impact of the intervention by comparing the current situation (i.e. the "do nothing" scenario) and the impact on the environment of the proposed technology at a local, regional and national level.

This process should involve consultation between the project partners, local and national statutory decision makers, local NGOs and most importantly - local communities. All interested parties should be involved in the scoping process where the issues and the assessable impacts are established. In addition it will be important to create a regular forum where local concerns can be voiced and addressed. The findings from the EIA should formalised and presented as an environmental statement (ES). This should be made available to all interested parties.

To ensure that the final incinerator design is the most appropriate for its purpose, we believe that the project should be broken down into five phases which are described in the following section.

Technical Response

Phase 1 – Research

1.1.1 Inception meetings with DFID

A series on inception meeting will take place between the team members and DFID to discuss and negotiate the project budgets and schedules.

1.1.2 Team Meeting

Following the discussions with DFID a team meeting will be convened to define detailed roles and responsibilities, set out work packages, agree inputs, activities and outputs. The output from this activity will be a detailed project specific reference guide.

Whilst it is possible to make an initial recommendation of a partner country, we believe that different countries will have different needs. If the project is to have relatively universal applicability, it would seem to be wise to review the needs of countries

The review will take the form of a desk-study in two parts. The first will look at socio-economic and environmental issues and the second will look at technical issues

1.1.3 Socio-Economic Desk Research

The socio-economic review will take the form of a telephone and internet review of the potential for this technology in an large number of countries. It will focus on country characteristics in the following areas:

- Population density
- Waste composition
- Rainfall (which may affect the former)
- Proportion and composition of industrial wastes
- Land availability
- Waste regulatory infrastructure
- Priority attached to air pollution control
- Priority attached to improving waste management standards

Countries that will form part of the study will include, Zimbabwe, Kenya, The Gambia, Sri Lanka, Bangladesh, India, Peru, and a number of Island communities. The output from the study will be a short list of 4 countries, ranked in order of merit.

1.1.4 Technical

A similar exercise will be completed to investigate the technical background to the technology. Library searches and visits to historical sites within the UK (a former leader in incinerator technology) will also form part of the study. In particular the survey will;

- review and evaluate former technologies in this area
- review and evaluate existing proven incinerator technology
- review and evaluate incinerator projects in or for developing countries
- identify technical opportunities and constraints in local manufacture, operation and maintenance of the technology in those areas of high potential
- appraise current technical facilities and skills available in project areas

1.1.5 In-country research

As a result of the desk based surveys we will initiate local research in four of the promising countries. Local consultants will be used to confirm details of the desk-based studies and to set up meetings with potential stakeholders during the country visits.

1.1.6 Country Selection visits

We propose to visit four countries in Africa, Asia and an island community for a period of three days, in order to obtain sufficient information to assess their needs for incineration facilities of the kind proposed and to identify their characteristics against the criteria mentioned above.

One of the factors, which will determine the overall success of the project, will be the commitment of the selected country to take ownership. Thus the degree of interest and willingness to co-operate will be a key factor in selecting the partner country. This will be established by holding meetings with the authorities during the country visits.

Well engineered landfill will almost always be more cost effective and environmentally sound than low technology incineration. The selected country should therefore have a perceived need for incineration. This is prevalent in areas where land available for landfill is scarce (eg. in areas where there is a local high density of subsistence farming).

The technology selected in this project is unlikely to be suitable for large waste volumes. Hence it will only be applicable in smaller towns.

We recommend that the main criteria for selection should be:

- Willingness to take ownership
- Degree of existing reliance on open burning dumps
- Existence of a refuse collection service in smaller towns producing 10 - 100 tonnes per day of waste
- Existence of a suitable and reliable local partners
- Scarcity of available land for developing engineered landfills

Each of these criteria will be weighted and a selection made from the countries visited.

The results of the country visits will be formulated as a report with each country given a ranking. The report will be presented at a meeting with team members and DFID. This stage will also give an opportunity to revise and refine the logical framework for the project.

Stage Two

1.2.1 Field Studies in Country

Having selected a partner country, a more detailed field study will be carried out by members of the project team. The objectives of this study will be to gather important information in two areas.

Waste assessment and analysis

The selection and composition of the wastes to be incinerated will be a crucial factor. Municipal wastes will clearly be one waste stream, which will require to be analysed for its composition, preferably at different times of year. There may also be other waste types which are required to be managed by means of incineration and these will require careful assessment - in terms of their suitability for incineration and their availability. These are likely to be industrial wastes and might, for example, include waste oils - from garages and DIY motorists as well as from industry. Waste oils present a major disposal problem in most less well-developed countries and would provide a useful source of calorific value. This may be particularly important if the municipal waste has a high organic content, which is likely. It will be important, however, to assess whether a suitable collection system for these materials exists or can be established.

Assessment of local manufacturing capabilities

Capability to build and maintain the incinerator will be dependant on locally available skills and capabilities. This part of the field study will seek to identify locally available technologies and fabrication methods that can be exploited.

1.2.2 Inception meetings

Having selected the partner country, a series of inception meetings will be held in-country to:

- hold negotiations with Government Authorities to obtain their firm commitment to the project
- identify a broad location for the project
- identify potential local partners including local authority officials, with capabilities in general construction, mechanical and electrical engineering, metal fabrication and waste management
- identify any other interested and affected parties, e.g. NGOs, community groups, other Government departments in country

1.2.3 Preliminary Environmental Impact assessment

At this stage we will commission an independent EIA to assess the current impact to the environment of the existing waste strategy (the “do nothing” scenario). This will provide a valuable document for discussion in the Participative Planning Workshop.

1.2.4 Participative planning workshop

A problem analysis workshop will be held with all parties identified above. The purposes of this workshop will be to identify and define clearly the problems associated with existing solid waste management systems which the project will address. A hierarchy of cause and effect relationships for the negative features of the existing systems will be established.

Having identified and defined the problems they will be transposed into a set of well-defined Strategy Objectives, linked within a hierarchy of means-ends relationships.

The identification and definition of problems is likely to be the main focus of discussion and debate during the workshop. Often, a negative feature or effect of an existing wastes management system is perceived to be a problem but, on closer examination, may in fact only be a symptom of the true or "core" problem which ultimately gives rise to the effect. For this reason, it will be important for Workshop participants to consider carefully the nature of the "cause-and-effect" relationships for what are generally perceived to be the problems associated with the existing solid wastes management systems, in order to identify a set of well-defined and interrelated "core" problems.

By contrast, the process of defining and linking a set of specific objectives should be straightforward, as the objectives are normally the inverse or "mirror image" of the problems which have been identified and defined. The first output of the Workshop would therefore be a set of carefully defined and agreed strategic priorities and objectives for the project, which would be expressed by means of a structured problem tree.

Other outputs from the workshop will be;

- A revised time schedule for building and testing the incinerator
- A draft memorandum of understanding between stakeholders and project partners which would include assignment of roles and responsibilities and a detailed plan of action.

Phase 2 – Technical Development

2.1 Test-Rig Design

It is anticipated that no single design will be capable of covering the range of waste streams compositions that may be encountered in developing country environments. As a result of the field surveys and waste stream analysis, the consultants will undertake the design of a test rig incinerator which is capable of simulating conditions to include a variety of waste stream profiles and operating conditions. Areas of focus during the design of the test rig will include the likely need for gas cleaning in terms of settlement chamber or cyclone technology.

Provision has been made in the budget for specialist consultancy input during this stage to look at specific technical elements of the design such as fluid dynamics, material analysis (refractories) and biological analysis of waste inputs and emissions from the incinerator.

2.2 Test-rig build and operate

The incinerator test rig will be built in UK to allow straightforward testing, monitoring and modification. Efforts will be made to forge an alliance with a local authority to negotiate the use of existing waste disposal sites. In the event that this co-operation is not forthcoming, provision has been made for the extra costs of complying with local environmental agency legislation which may require the building of shelters for waste, fencing etc.

Provision has been made in the budget for gas monitoring equipment which will be used both in UK and in-country to monitor emissions from the incinerator.

2.7 Incinerator Design and write up.

As a result of the build and test stage, a single design for a full scale incinerator will be produced, based on the rig configuration which most closely matches the technical requirements for the actual in-country site. The results from the testing of alternative configurations will be available for use at a later stage and could form the basis for a “family” of incinerator designs.

The output from this stage will include

- all technical drawings
- material specifications
- bill of quantities
- construction notes

Issues of health and safety will feature prominently in the detailed design work at this stage.

2.8 Construction project plan

A construction project plan will be formulated to provide a basis upon which to audit the building work. This will form an important document for the works supervisor who will take on the day to responsibilities for co-ordinating the construction work in-country. The construction project plan will include;

- procedure and schedule for building one incinerator design in-country
- outlines for contracts with local suppliers and manufacturers
- plans for obtaining local licenses and permits

Depending on the site chosen for the incinerator, there may be a need for some civil works. Preparation of the site may be necessary to cater for waste delivery, pre-sorting, storage (which may require shelter), feeding into the incinerator and then the removal, cooling and disposal of ash. At present we would expect that the cost of this work would be met by the local partner and that it would form part of their contribution to the project. No provision in the budget has been made therefore for this work.

Phase 3 - Pilot Project

3.1 Formulate Pre Build agreement

Before any building work can start it will be necessary to reaffirm commitment from the various stakeholders and project partners. This will take the form of a memorandum of understanding and will define clearly roles and responsibilities with respect to;

- ownership of waste
- ownership and access to site
- contracts for local manufacturers and sub contractors
- local environmental health agencies and compliance with local legislation
- operating personnel/agency
- terms of “hand-over” of incinerator

3.2 Construction in country

The construction in-country will take place using local manufacturers and suppliers and will be overseen by a works supervisor. Technical support to the works supervisor will be provided by the rest of the team through preliminary meeting in UK and periodic on-site visits to the in-country site.

The works supervisor will be responsible for selecting and contracting local manufacturers and fabricators, supervising construction and subcontracted work, providing regular feedback to other team members on construction progress. The output of this activity will be a working incinerator completed and integrated with local waste management strategy.

3.3 Operational testing and monitoring

After the incinerator has been fired up there will follow a period of continuous operational monitoring and testing. During this period the incinerator will be monitored to measure;

- performance and efficiencies over actual range of operating conditions and cycle patterns
- quantities and compositions of emissions and residues
- reliability of materials and components

The results of the operational testing and monitoring will be compiled as a technical report.

3.4 Ongoing monitoring (3 mth, 6 mth)

It will be important to monitor the operation of the incinerator over an extended period in order to appraise it’s overall performance. Visit’s after three and six months will be arranged to;

- appraise the incinerator and it’s components in terms of material degradation,
- identify any problems in operation and maintenance

evaluate the effectiveness of the technology as part of the overall waste management strategy for the district

Phase 4 - Training Package

4.1 Design and Document

Information gathered throughout the operational monitoring and testing stage will form the basis of a training package for potential operators of the incinerator. The training package will cover both the operation and maintenance of the plant and will also focus on important issues regarding health and safety.

4.2 Delivery of training

The training package will be delivered to both the institution responsible for operating the incinerator and the in-country manufacturer.

4.3 Information Video

Intermediate Technology has found that audio visual materials are one of the most effective ways of disseminating information about appropriate technologies and sustainable development practice.

Building on its partnership with Television Trust for the Environment (TVE) an international organisation which has produced and distributed more than eight hundred hours of film in environment and development issues to broadcast and non-broadcast audiences world wide, the partners propose a short ten minute video which would enable policy makers and potential practitioners to understand the importance of incinerator technology.

TVE would also hope to edit a five-minute piece for its Earth Report series on BBC World TV based on the ten minute production and if this was possible it would insure an audience of 100 million world wide.

The video would be produced to coincide with phases 2,3 and 4 of the project.

Phase 5 - Reporting

5.1 Final report

A final report will be compiled to document the project experience and highlight the lessons learnt. It will also include recommendations and an appraisal of the opportunities for the future application of this technology in other countries of the South. The main body of the report will be broken into two parts.

Part 1 Socio-economic and environmental

This section of the report will cover;

- pilot project implementation experience
- ownership and access issues for incinerators as part of local waste management strategies
- checklists of financial, economic, environmental issues that should be examined when replicating the technology
- assessment of market opportunities for local manufacturers of incinerators
- environmental statement.

Part 2 Technical report

This section of the report will include;

- drawings and construction notes for test-rigs
- drawings and construction notes for in-country design
- details of tests and modifications carried out
- assessment of market opportunities for local manufacturers of incinerator
- recommendations for construction training package
- technical manual for the operation and maintenance of the incinerator

Simple Waste Incinerator

Project Activity Flow Chart