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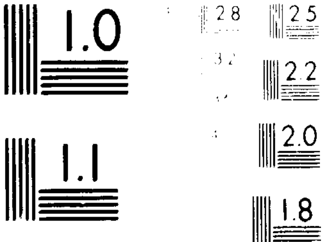
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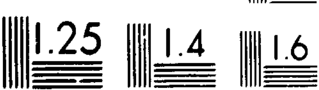
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12 June 1980
English

TECHNO-ECONOMIC EVALUATION OF A COMPOSTING PILOT PLANT FOR MUNICIPAL GARBAGE, FREETOWN

SI/SIL/79/801

SIERRA LEONE

Technical report: Composting pilot plant for municipal garbage

Prepared for the Government of Sierra Leone
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Robert Gillet, expert in
production of compost from municipal wastes

United Nations Industrial Development Organization
Vienna

80-40898

Explanatory notes

References to dollars ($) are to United States dollars, unless otherwise stated.

The monetary unit in Sierra Leone is the leone (Le). During the period covered by the report the value of the leone in relation to the United States dollar was $US 1 = 1.1 Le.

A full stop (.) is used to indicate decimals.

References to "tons" are to metric tons.

References to "gallons" are to British imperial gallons; one British imperial gallon equals 4.545 litres.

Besides the common abbreviations, symbols and terms, the following have been used in this report:

1 acre	0.4 hectare (ha)
C/N	carbon/nitrogen ratio
IHP	installed HP
IKW	installed KW
kVA	kilovolt-ampere
NPK	nitrogen, phosphorus, potassium
WHO	World Health Organization

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ABSTRACT

In the last five years, in Freetown, the capital city of Sierra Leone, sanitation has deteriorated mostly due to financial constraints.

According to an estimate from the World Health Organization, 7,000 tons of household wastes are produced annually in the greater Freetown area.1/ Since the garbage collection system started deteriorating, more than 30,000 tons of waste materials have accumulated on the streets. Rodents and flies have proliferated and parasitic diseases are rife. Since 1977, two cholera outbreaks have taken place in Freetown with a significant death toll.

The Government has obtained assistance for refuse collection trucks, and wishes to organize garbage collection and processing of compost for the dual purpose of improving public sanitation and returning organic material to the soil to improve its fertility.

Compost is a good organic complement to chemical fertilizers, which the country has to import at a substantial cost.

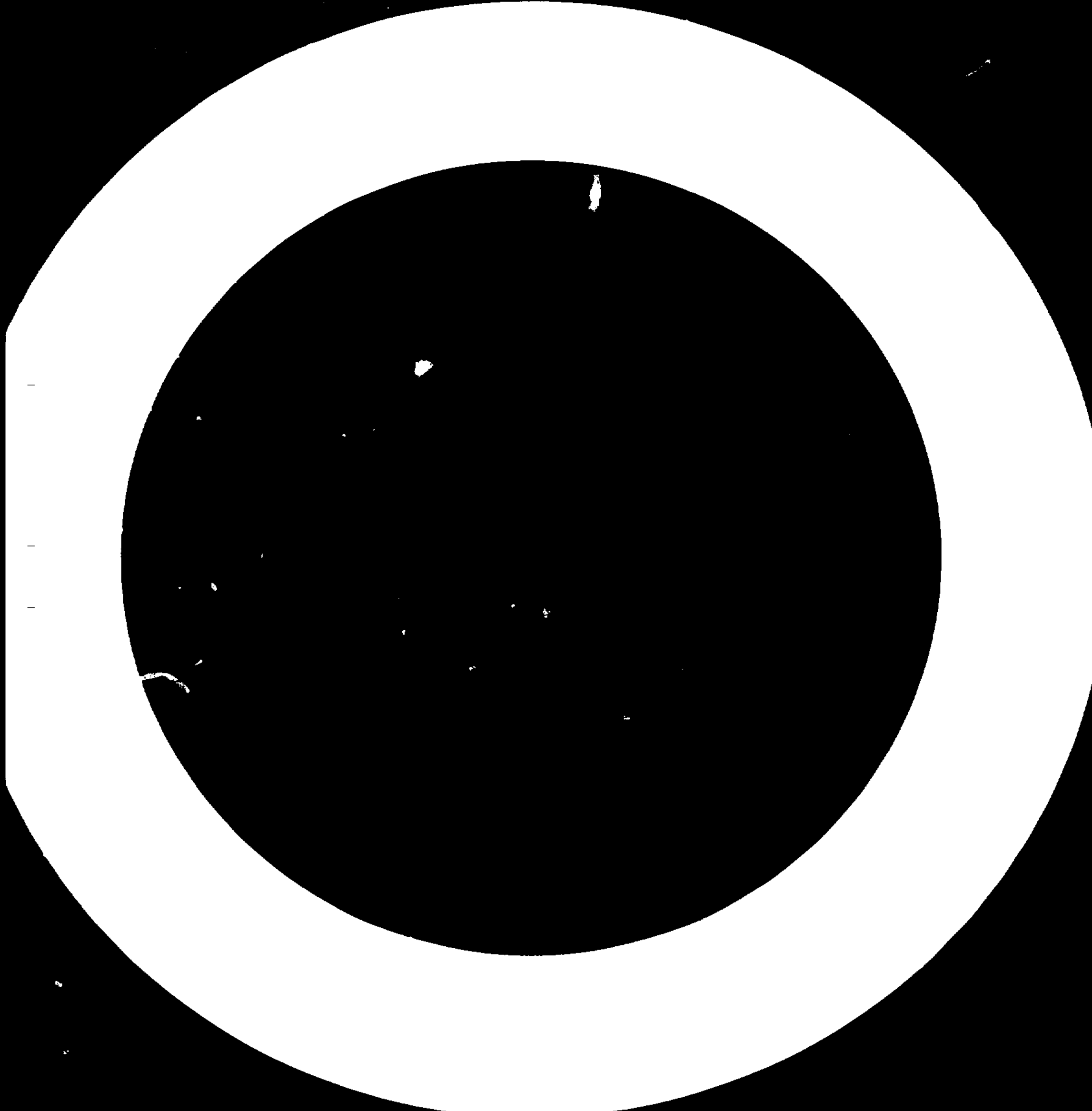
The Government requested the technical assistance of UNIDO to evaluate the feasibility of a pilot plant for the manufacture of compost. The purpose of the mission was to assess the technical and economic feasibility of establishing a pilot plant, or the smallest technically and economically operative plant, for the production of compost from the municipal garbage of Freetown.

The sanitation project, which includes household refuse removal and destruction, is organized by the Ministry of Health. To implement a composting plant requires a significant investment and the composting process, as a way of destroying garbage, is more expensive than using sanitary dumping.

The compost generated would mainly, or solely, benefit Western area market gardeners. Therefore, if the Ministry of Agriculture decides to implement a composting plant that produces compost acceptable to market gardeners, it should sell the compost at a price that covers the difference between the composting process and sanitary dumping.

The aim of the first part of this six-month split mission, from 26 February to 14 March 1980, was to help the Government to decide whether the composting plant project would meet the general interest or not, and if it would, to recommend the further assistance of UNIDO in the plant design preparation and implementation.

1/ Henceforth referred to as Freetown.



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INTRODUCTION

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I. THE GENERATION AND DISPOSAL OF SOLID WASTES IN FREETOWN

WHO Project "Immediate measures on solid wastes disposal for the greater Freetown Area" (SIL/SHS/001)

For various reasons, shortage of garbage collection trucks, lack of spare parts, shortage of funds, indiscriminate and uncontrolled refuse spread all over the city etc., solid wastes collection and disposal in Freetown has been deteriorating. In mid-1977, WHO assistance was requested, and the Health Ministry launched a crash programme.

The aim of the programme was to clean all public dustbins and start cleaning up, with the help of all available resources.

The report of the WHO project in July 1977 gave the following as prerequisites for the programme:

(a) Sanitary dumping in one or more locations;
(b) Employment of more labourers;
(c) Immediate acquisition of more garbage collection vehicles.

Data on wastes generation rates

Freetown has an estimated population of 350,000 (annex I). A study carried out in 1977 showed that the annual solid wastes production per capita was 170 kg, that is, approximately half a kilo a day. The annual garbage production is estimated at approximately 60,000 tons. However, the available facilities permit collection of only part of this amount.

Garbage collection

Organization

The Environmental Health Division of the Ministry of Health is responsible for the collection and disposal of refuse and wastes, including night soil collection, from the residential and commercial population of Freetown.

The Cleansing Staff of the Ministry of Health provides labour for sanitary landfilling at the King Tom (Bohme) dump, and other services such as street and market sweeping (with labour provided by the City Council).

Vehicles

Freetown had 25 garbage collection vehicles in 1968. In 1975, 9 garbage collection vehicles of 8 m^3 capacity were acquired. However, because of extensive wear and tear, caused by bad handling by drivers, poor maintenance and lack of spare parts, only 4 or 5 of these vehicles are reliable. It was recommended in the WHO report that garbage collection trucks of a similar type to the present ones but with a larger capacity, and a limited number of vehicles of a pulverizing type, also with a larger capacity, be purchased.

In 1978, the Ministry of Health received a soft loan of DM 2 million from the Federal Republic of Germany to purchase refuse collection trucks, dump trucks, one front loader, spare parts etc.

At present, and temporarily, the garbage collection system is based on a depot collection method that operates with single-axe trailer mounted containers at authorized collection points throughout the city. Household refuse is brought there and tipped inside. There are

32 yellow containers with 5.2 m^3 capacity

7 grey containers with 6.5 m^3 capacity

8 tractors for towing the containers

2 new tipper Bedfords

4 covered Fiats from the stock of 1975. These are used for collecting refuse as follows:

- 1 from door to door
- 1 from authorized dumping sites throughout the city
- 2 from the streets that is collected daily by street sweepers

The old grey containers are expensive and have to be emptied by hand; their use is to be discontinued. The yellow containers are each fitted with a cover and provided with a hydraulic emptying system. They are manufactured in the country.

Solid waste disposal

The King Tom dumping site, 2 miles from the city centre, is where liquid waste and night soils are tipped out. It is the cheapest dumping site readily available that, if properly prepared, could be used for six years (from 1977). Steps were taken in 1977 to change the uncontrolled dumping site into sanitary landfill. Unfortunately, a year ago, indiscriminate dumping at King Tom started again.

King Tom should be upgraded. During working hours, tipper lorries should set aside red earth from the mountains, three miles distant, to spread over the daily waste layers after the last lorry has been unloaded. A bulldozer is required for this work (CAT D6C or D6D type).

Maintenance

At the moment, the collection vehicles are run until they break down. Repairs are farmed out to private workshops. In such a way, availability of service is low and repair cost is high.

Freetown garbage collection and disposal or processing in the future

Prospects for 1985

The aim of the Ministry of Health is to provide to more than 70 per cent of the population of Freetown, by 1985, house-to-house garbage collection. This will necessitate that:

(a) The present collection system be replaced by tipping and/or compacting collection lorries of 10–12 m^3;

(b) Household dustbins be provided;

(c) A garage and maintenance workshop be established close to the King Tom disposal site, as recommended in the WHO report. Should a composting plant be implemented, it would be advisable to locate the garage and workshop closer to the plant site.

The proposed Environmental Health budget for 1979/80

An Environmental Health budget for 1979/80 has been submitted to the Ministry of Health in accordance with the recommendations of WHO. The share of the collection and disposal service is Le 852,000, of which Le 776,000 is a foreign soft loan or grant. These figures do not allow for a composting plant.

Further assistance has been requested from the Federal Republic of Germany and a soft loan of DM 5,000,000 is about to be settled.

Related problems

Waste containers manufacturing in the country

A total of from 50,000 to 60,000 20-gallon household dustbins are required for house-to-house solid waste collection from approximately 70 per cent of the population of Freetown by 1985.

The proposed Environmental Health budget for 1979/80 includes a provision for 10,000 such dustbins.

The mechanical capacity of the National Workshop at Cline Town has been reviewed and it appears that this workshop is suitable for manufacturing the required dustbins. However, due to the high cost of raw materials available domestically, imports of raw materials are recommended.

Treatment of night soil

The collection of night soil from 1,025 Freetown pail latrines that is discharged at the King Tom site has been reviewed.

The use of night soil, or any other liquid waste, together with household refuse in composting municipal garbage must not be contemplated. The procedure that consists of mixing or sprinkling night soil with fermenting wind-rows is condemned; hazardous liquid wastes could cause contamination or infestation and meets with serious objections, also workmen are reluctant to work on compost to which night soil has been added. The same objections do not apply to sludge from liquid waste should sewage treatment be implemented.

The proposed Environmental Health budget for 1979/80 includes a provision for an oxidation pond.

The site recommended for a composting plant is far away from the King Tom disposal site where night soil is currently discharged.

Hospital incinerators

The 1979/80 Environmental Health budget includes Le 70,000 for incinerators. Assistance from external sources has been requested to install an incinerator to burn such wastes as dead animals, condemned food and pathological and other wastes collected from three Freetown hospitals and dumped in the King Tom disposal site.

Transportation across the city of such wastes is difficult, and the rule in this matter is to annex an incinerator to the establishment - hospital, slaughter house etc. - where the wastes are generated. Small and relatively inexpensive incinerators are available from any industrialized country.

II. FREETOWN MUNICIPAL GARBAGE SURVEY

Production of solid urban garbage for composting

Amount of garbage

The amount of garbage generated annually in Freetown is obtained by multiplying the amount generated per capita per day times the number of days times the number of inhabitants, that is, 0.479 kg x 365 days x 350,000 = 61,192 tons rounded to 60,000 tons. Assuming a 5 per cent growing rate in the Western Area, garbage would reach, by 1991, 0.479 x 365 x 645,000 = 112,768 tons, i.e., 309 tons per day. This figure does not take into account the probable increase in refuse.

Amount of garbage collected

According to a rough estimate, the garbage collected at present is about 35 per cent of that generated, i.e., 21,000 tons. If the goal of the WHO project is reached, by 1985 the garbage collected will be 70 per cent. Thus, the following figures have been used as a base for calculations: 21,290 tons in 1981 and 47,652 tons in 1985.

Amount of garbage processed

Usually, a composting plant operates 310 days per year. However, in West African countries, due to water saturation of refuse of 70 per cent or more during the rainy season, the composting process becomes very difficult and unpredictable during the peak months of the rainy season. So, it is estimated that the plant is able to operate only 270 days per year.

In such conditions, amounts to be processed would decrease to 15,750 tons in the first year and 35,250 tons in the fifth year. Thus, the running costs of the composting plant should be estimated based upon these figures.

Characteristics of Freetown household refuse

Method of determining the composition of garbage

Due to the heterogeneous type of household refuse, sampling for an accurate analysis is rather delicate. In order to determine the physical composition of the garbage, a simplified procedure was recommended (annex II). Directions were given on how to perform refuse analyses, spread over one week, and the necessary equipment ordered through the Ministry of Health, mainly two sieves with diameters of 50 mm and 10 mm. However, this equipment, although totally unsophisticated, was ready only two days before the expert's departure. It was therefore necessary to transport sorted components of garbage in plastic bags to the opposite side of the town in order to use the only available scale that could be found, so that one sole sorting operation could be carried out. Tested garbage was not representative of typical Freetown municipal garbage. Should it be decided to implement the project, accurate physical and chemical analyses will have to be carried out (annex II).

However, the sampling and sorting operation carried out at the King Tom dumping site was a valuable demonstration of the procedure to be observed later for more accurate determinations.

Average composition of Freetown garbage

Based on the way it looks, as observed many times in different areas during the two-week mission, the average composition of Freetown refuse is assessed as follows:

Physical composition	Weight (%)
Organic matter (animal or vegetal wastes)	65-75
Plastics (rubber or leather)	5-6
Rags (paper or cardboard)	15-20
Metals	2-3
Glass (bottles), china, earthenware	3-4
Stones and other inert material	2-4

Humidity tests could not be carried out. Based on the average physical composition it is estimated at 58-64 per cent. Therefore, it is considered that so long as the moisture content is not over 65 per cent, Freetown municipal garbage is good for composting outside the peak months of the rainy season. This is similar to results for most West African garbage.

III. JUSTIFICATION OF A COMPOSTING PLANT PROJECT

Public health and agricultural aspects

Public health

The tremendous disadvantages of simple refuse disposal are generally recognized in Freetown. Recommendations have been made to change the King Tom disposal site into a controlled sanitary dumping ground, and WHO recommendations have resulted in an improvement in the situation. Nevertheless, care must be taken to maintain the slightly improved dumping at King Tom.

Subject to the strict observation of a sanitary dumping rule, controlled disposal could be a good way for refuse removal, and it meets with health regulation requirements.

Controlled disposal does not require heavy investment or a great number of workmen. It is the least expensive way for municipal garbage removal and elimination (annex III).

According to WHO findings, the King Tom site could be used for landfilling until 1983 or 1984. However, because of the nearness of the Congo River, the pond and Whiteman's Bay remain exposed to pollution hazards, especially as long as night-soil continues to be discharged into the pond. A new landfill site has to be chosen, preferably in a south-east direction. The possibility of water pollution must be borne in mind when choosing the new site.

Agricultural

Further investment in compost production can be justified in order to produce organic fertilizers for agriculture. Such investment would go beyond the target for healthy garbage elimination and become an agricultural project which the Ministry of Agriculture might support.

Compost definition and characteristics

Compost definition

Compost is a product of solid waste obtained by fermenting organic matter, which is contained in household refuse and other similar wastes. Good compost is a bulky black product, free of pathogenic agents and smelling of wet soil. The composting process is aerobic.

Compost composition and value

The composition of compost depends on the composition of the refuse, and is, therefore, subject to considerable variation. The average composition of compost produced in tropical countries is as follows:

	Raw compost (%)	Dry compost (%)
Water	30	
Organic matter	24.5	35
Minerals	44.8	64
Carbon (C)	13.4	19.1
Nitrogen (N)	0.91	1.30
Phosphorus (P)	0.21	0.30
Phosphorus pentoxide (P_2O_5)	0.48	0.68
Potassium (K)	0.56	0.80
Potassium oxide (K_2O)	1.12	1.92
Magnesium (Mg)	0.47	0.70
Calcium (Ca)	3.67	5.40

C/N ratio = 14.7

pH = 8

Compost is valuable for three properties:

(a) Nutrient value. The major mineral elements, N,P,K, as well as Mg and Ca are present in compost, though not in sufficient quantities for the product to merit the name of fertilizer. Nevertheless, since relatively high amounts are involved it could be estimated that 1 ton of compost having the above composition should provide soils with:

9.1 kg nitrogen equivalent to the amount provided by 20.22 kg urea with 45 per cent N content

4.8 kg P_2O_5 equivalent to the amount provided by 26.67 kg single superphosphate having 50 per cent P_2O_5 content

6.7 kg K_2O equivalent to the amount provided by 13.40 kg SO_4K_2.

In this way, the application of compost would save appreciable amounts of chemical fertilizers. Ca and Mg content is also noticeable since such elements are essential for the growing of crops;

(b) The organic matter of compost as soil conditioner. The use of compost increases the yields of almost all types of plants, for which the nutrient content is only partly responsible. The active part of the organic matter of the soil is "humus", which is the final stage of organic matter transformation. Fertility is therefore dependent on humus content, and the "argilo-humic complex" controls the reactions of the soil at the same time as it stimulates all biological activities inside it.

Humus capability may be compared with that of a sponge: during watering, it sucks up water to full capacity and stores it for the plants. The capacity of the ground increases. Thanks to the large surface area of the humus particles, the plants' nutrients are absorbed and then prevented from being carried away by leaching into the deepest ground layers. Thus, compost serves to hold back the nutrients and water in the root zone of the crops and this results in the better use of chemical fertilizer which saves money and foreign currency.

It is vital for sandy soils in a dry climate to retain a certain degree of moisture for as long as possible.

Prevailing climatic conditions in the tropics are severe soils. The process of degradation always starts with a rapid decrease of the organic matter content of soils, which sometimes disappears completely. Once deprived of a sufficient quantity of organic matter, the soil loses its coherence: wind and rain erode fine soil. Within a few years, tropical soil deprived of organic matter becomes a sterile mineral environment unsuitable for cultivation. Thus, the restitution of organic matter to tropical soils is imperative. Neither manure nor agricultural offal is able to provide a sufficient supply and, in spite of its inadequacy to satisfy all requirements, compost produced locally from household refuse should be the only regular supply of organic matter for limited agricultural purposes;

(c) Compost minerals and oligo-elements. Besides Ca and Mg, the major mineral elements, such as sodium, sulphur, iron ,copper, manganese and boron, are present in compost. Compost also includes a great number of mineral elements of which minute quantities are indispensable to the growth of plants. Among these the most important are zinc, molybdene and cobalt. The absence of these oligo-elements induces so-called deficiency diseases in vegetables.

Such "heavy" elements as mercury, cobalt, lead, chromium and cadium are beneficial in the lowest minute traces but poisonous in slightly increased quantities, and repeated application to the same plot of land for a number of years running could induce organic troubles. However, the hazards of heavy elements in compost generated from Freetown household refuse should not be over-estimated.

Joint application of compost and chemical fertilizers

The use of compost cannot replace chemical fertilizers. Unfortunately, under no circumstances could compost meet national agricultural requirements.

Compost is mainly a soil conditioner but is best used with chemical fertilizers as, by preventing leaching losses, it results in relevant chemical fertilizer savings.

Nutrient value, which is low in compost, could be improved by chemical fertilizer blending, either at the composting plant or on the field by the farmer himself.

Compost blending with sewage water sludge

An excellent compost could be obtained by mixing household refuse with the sludge from a sewage treatment plant, which has a high content of nitrogen.

Freetown has no sewage treatment plant yet, but it is not too early to stress that when one is built it should be located close to a composting plant, if any.

Restrictions on the use of compost

If all Freetown garbage were processed, the yearly amount available for agricultural uses would be about 20,000 tons, for application to 600-700 hectares.

Since compost is a bulky product, long distance transport is very expensive (Le 0.25 per km per ton).

Without taking the value of compost as soil conditioner into account, and considering its fertilizer value solely, the cost of transport is about 13 to 15 times more for bulky compost than for concentrated chemical fertilizers. Therefore, compost should be applied to special intensive crops, such as market garden crops, and should generally be used within a limited radius of the composting plant.

Agricultural tests performed in Sierra Leone

For a long time farmers in Sierra Leone have been aware of the lack of organic matter in the soil and have found that the way to compensate for this is to add to it organic material to act as soil conditioner to improve its physical properties.

Rice farmers use the archaic method of burning large stretches of forests to fertilize the soil with ashes. Market gardeners buy cattle, pig or poultry manure according to its availability. Also, raw household refuse is used in market gardening, sometimes after the sorting of the biggest inert components on the field. All kinds of wastes, refuse or rubbish that contain organic matter are good for agricultural use, preferably after fermentation on the field.

Composting tests at Njala University

The Faculty of Agriculture, Njala University, usually prepares a small amount of compost, about 1 ton per year, for its own crop experiments. Raw material is mainly thatch grass mixed with top soil. The process is anaerobic. Compost is used at any time during the dry season generally by itself but it can be mixed with small quantities of chemical fertilizer. (See annex IV for data collected from Njala University College, Faculty of Agriculture.)

Composting tests at the Horticulture Station of the Ministry of Agriculture, New England

Western Area market gardeners prepare compost - which has been tested at the Horticulture Station using all sorts of refuse such as grass, sweepings, their own household refuse and mould collected from the King Tom disposal site, which is not bad in spite of being mineralized and rather poor in organic matter.

Private tests on composting

Composting of household and other refuse is practiced by some private market gardeners. Comparative tests have been carried out and the results are excellent: crops yield and quality are increased.

Comments and recommendations on tests

Composting tests. Suitable compost must meet the following requirements:

(a) It must be free of pests or vegetable parasites. It must not transfer any human, animal or plant disease;

(b) It must have a particular granular structure in accordance with the contemplated use;

(c) It must be free of plastic, rags etc. and not contain broken bottles. Glass must be reduced to harmless, scarcely visible, particles;

(d) It should be of a composition that will not cause any biological imbalance in the crops;

(e) It should be of a composition that will slowly transform the organic matter into humus.

The compost obtained by aerobic fermentation of household refuse meets the above requirements if mechanically processed. Fermentation also has to be complete. The incorporation of green fertilizer into a soil could result in an imbalance of nitrogen. Incompletely fermented compost may resume fermentation in the soil; beside the possible presence of pathogenic germs of the most resistant kind, the release of considerable carbonic gas could be harmful to young roots.

One of the most important results of aerobic fermentation is to decrease the carbon content of raw garbage. Since the greatest part of the carbon is eliminated as CO_2, the C/N ratio becomes smaller as fermentation proceeds. The most favourable C/N ratio of fresh refuse lies between 25 and 35. A decrease in the ratio allows the fermentation process to be controlled. Thus, for fresh refuse with a C/N ratio of 27 or 28, a compost C/N ratio 15 or even less could be otained. Final C/N ratio can be considered as a final test of quality.

In short, aerobically well-processed compost only contains stable organic substances that bacteria of the soil can only decompose progressively.

Code of practice for semi-industrial composting trials. There is absolutely no doubt that Freetown household refuse could be processed without any serious problem since the moisture is less than 65 per cent and adequate composting facilities are provided. Composting tests are not required.

Semi-industrial composting tests would be justified eventually to assess the agricultural value by agricultural tests. Thus, compost should be made only as it is required for such test purposes.

With a lot of goodwill and working staff equipped with shovels and forks, it is possible to carry out tests manually with raw garbage. It would be enough to operate on a coated level area, to form heaps of discharged garbage, and to check temperatures by means of a set of plunging bi-metal thermometers, then to turn over the heaps manually and to use manual sieves for the screening and grading of the compost, which is an arduous and time consuming operation.

However, besides the fact that such a practice would inevitably degenerate into an awfully dirty job, yield and quality of compost obtained in this way do not meet the above-described requirements. In order to provide acceptable compost for eventual agricultural tests, refer to annex V.

Experiments planning and execution. To provide as much reliable information as possible, crop growing experiments have to be carried out on a scientific basis. However, such experiments have to be performed according to local farming methods. Irrigation has to be performed by the same way and in the same amount as is locally carried out. Experiments involving specific crops could be set up jointly with Njala University, Newton or New England as well as with any skilled farmer who would agree to co-operate.

Compost demand and surveyed potential market in Sierra Leone

Main crops

Rice (330,000 ha or 815,100 acres) is the most important crop in Sierra Leone, and it is the basic food for the people. Total production is 320,000 tons of upland rice and 125,000 tons of swampland rice. Growing areas are generally distant from urban centres and the archaic method of cultivation that destroys the forest is not suitable for the use of compost. A high-priority rice programme is carried out through a package-programme involving extension, credit, fertilizers etc., but which does not plan to use any organic fertilizers.

Maize (10,500 ha or 25,935 acres) could be grown better on an adequately drained productive soil, as could coffee (20,000 ha or 49,400 acres) and other plantation crops, such as palm-oil, cocoa and rubber, which are not produced competitively for the world market.

Citrus fruit trees have relatively better yields because they are grown in soil improved with moderate amounts of organic fertilizers.

Unfortunately, farming in Sierra Leone is not yet adequately structured. Large-scale plantations do not exist and co-operatives are scarce so that the potential users of compost are not easily identified. Moreover, centres of cultivation are generally distant from urban centres, and in any case, the amount of compost that could be produced from Freetown household refuse is insufficient for such extensive crops.

<u>Market gardening crops</u>

<u>Market garden areas.</u> The largest use that could be made of compost without requiring long distance transport is for market garden crops. The main cultivation centres are the Bo area (approximately 140 miles from Freetown) in the Southern province; Makeni (114 miles) and Kabala (192 miles) in the Northern province; and Kenema (190 miles) in the Eastern province.

Eventually, it could be possible to organize the storage of compost in these areas. A good motor road links Bo and Kenema to Freetown, and there is a fair road that links Kabala and Makeni to Freetown. Motor roads are passable at any season, but hammock roads and tracks are not always passable during the rainy season.

<u>The Western Area.</u> This area is the most suitable to provide a regular and consistent outlet for Freetown composting plant products. The main market garden plots inside the Western area are as follows: on the north-west side: Regent, Leicester, Wellington, Allen Town, Hastings, Rokel and Waterloo; on the north and south-west sides: Aberdeen, Lumley, Adoukia, Ogue Farm and York. The most important crops developed by private market gardeners are: lettuces, cabbages, beans, peppers, radishes, onions, garlic, aubergines (garinex), spinach, okra (gombos), tomatoes, manioc (cassava) and potatoes. Orchards, flowers and ornamental plants are also grown in this area. Home-made compost from leaves, refuse, sweepings etc. is applied to these crops.

In Ogue Farm, Chinese farmers grow vegetables in over 50 acres (20.2 ha) in the dry season and swamp rice in the wet season. The soil is clay, and since it would not be easy to obtain manure or any other available organic material, there is a big loss of chemical fertilizers that are carried away by leaching or washing processes. Well-water is available in sufficient quantities.

Since market garden crops are grown in a lot of small plots of land that are beyond any statistical control, acreages under these crops are not easy to assess. Probably 620 to 750 acres (250 or 300 ha) are currently being cultivated inside the Western area.

Market gardening could be developed but it is not sure that sufficient outlet could be found. It seems that extension beyond the Western area is inevitable to ensure an adequate outlet for Freetown composting plant production.

According to information collected by the UNDP resident representative in Sierra Leone, there is a new agricultural development project for exploiting a 500 ha farm that has been bequeathed to the Methodist church. The land is about 18 miles from Kissy and located in Wellington, in the Western area, in the middle of the market gardening area. Because of its vicinity to Freetown that should be a good outlet for Freetown compost.

<u>Recommendations for compost application to market gardening crops</u>

<u>Amounts to be applied.</u> The amounts of compost used in the experiments carried out at Njala or in New England (annex IV) are very high. The compost used at Njala, and, also, probably, that used in New England, is anaerobically fermented. If household refuse compost is supplied by a composting plant operating in aerobic conditions, as explained above, amounts should be lower. The amounts recommended vary considerably but lie between 8.1 to 16.2 tons per acre (20 and 40 tons per ha) depending on the properties of the soils that can be assessed by chemical analyses.

Since the compost is to be regarded primarily as a soil conditioner that sucks up water to full capacity and stores it for the plants, amounts to be applied to pure sandy soils should be significantly higher. In clay-bearing sandy soils, the clay content increases the absorbing capacity of the soil, which means greater quantities of water and plant nutrient substances are retained, while in pure sandy soils high amounts of up to 7 or 8 kg per m^2 are recommended. The joint effect of nutrient and water is optimal with compost amounts as low as 4 or 5 kg per m^2. Compost applied in such conditions results in tremendous increases in yield and quality, especially with such crops as carrots (30%), spinach and onions (50%).

It is recommended that compost be applied every 18 months, otherwise, the use of high amounts of compost in one year need not necessarily be repeated the following year, or at any rate, not on the same scale. It must be ascertained under local conditions that the organic matter from the compost has not disappeared completely into the soil by the following year.

Compost application. The surface of the soil must be protected in tropical countries. The best way to use compost is to spread it over the surface, mixed with some earth (to prevent it being blown away) to form an earth-compost superficial covering some centimeters thick. This way, excessive dessication of compost is prevented.

The earth-compost covering protects the surface of the soil without preventing the penetration of soluble organic and mineral substances to the level of the roots during the rainy season.

Prospects on a subsidiary outlet in the ornamental potted plant market

A subsidiary outlet for compost might be the ornamental potted plant market. Compost for sale to horticulturists has to meet the requirements set forth above. Another possibility would be to grow ornamental potted plants at the composting plant for direct sale to private customers, as is the practice of the composting plant in Abidjan, Ivory Coast. Mould mixed with 30-40 per cent compost is used for this purpose. Such business makes a 100 per cent or 150 per cent profit.

IV. EVALUATION OF COMPOSTING FACILITIES

General information

Aerobic fermenting process

Compost processing is based upon the natural aerobic fermentation of coarse-crushed garbage, according to procedures suited to tropical countries. Coarse-crushed refuse is put to controlled fermentation in the open air and under cover. This previous fermentation has a dual purpose: first, aerobic micro-organisms that consume carbon, which abounds in fresh refuse, release carbonic gas increasing the temperature and resulting in the release of a large amount of steam. Carbon consumption leads to a decrease in the C/N ratio; secondly, the increase in temperature speeds up the hatching of eggs and larvae and causes the grubs to die sooner. In other words, the temperature increase acts as a pasteurization process that destroys pathogenic agents.

Fermentation should be carefully monitored by placing thermometers inside the compost heaps. In order to facilitate fermentation, the following steps should be taken:

(a) Ample ventilation must be provided to facilitate exhaust of the foul air and introduce fresh air into the fermenting mass in order to maintain aerobic conditions;

(b) Fermenting crushed garbage should be mechanically homogenized to make microbial sowing easier by increasing contact between micro-organisms and crushed refuse particles

It is necessary to run fermentation in such a way that all bacteria spread out as freely as possible within their respective optimal development ranges: this is important to ensure the successive predominancy of specific families of micro-organisms at the right time. In such conditions, the processing should be scheduled as follows:

First stage: attack and destruction of proteins and nitrogenic substance (average temperature 40-50°C).

Second stage: destruction of hydrocarbons, mainly cellulose and fatty substances. This stage is characterized by the intensive development of heat with release of gases and water.

Third stage: the composting process should be completed by the maturing stage, during which specific bacteria progressively leave space free for more common bacteria; at the same time, the temperature decreases, then stabilizes at the level of the ambient temperature. Thus, the maturing process takes place during the storage stage.

In practice, the composting process should be run as follows: Coarse-crushed garbage is set up in windrows of from 3.50 to 4.00 m width. During the 9 or 10 days of prefermentation under cover, four phases can be observed in the changes of temperature:

(a) A mesophilic stage, with the temperature rising to 55°C in the centre of the compost heaps during approximately 36 or 48 hours;

(b) A lower thermophilic stage, with the temperature rising to 65°C during the next two or three days;

(c) A second thermophilic stage of a three-day duration, from 65°C to 75°C;

(d) After 9 or 10 days, a third thermophilic stage when the temperature is slowly decreasing.

The greatest enzymatic activity takes place during the first two stages, which last for from four to five days. This process is required to destroy all pathogenic agents and bacteria.

Since there is enough oxygen inside the compost heaps to allow a satisfactory aerobic process during the first few days, it is best not to disturb the process until an inside temperature of 65°C is reached, that is, after completion of the mesophilic stage. A thorough turning of the windrows is then sufficient to allow CO_2 to exhaust and fresh air to penetrate in order to support the following aerobic fermentation. The heaps should be turned beyond the fifth day until a temperature of 70° or 72°C is reached, and beyond the ninth day until the temperature stabilizes at about 75°C. A third turning corresponds to the removal of the prefermented heaps and transfer to the maturing area.

Description of the process

To determine quantities and fix prices, all containers or trucks delivering the garbage and all vehicles delivering the processed compost are weighed on a weighbridge. The containers or trucks discharge the garbage onto a platform adjoining the feed hopper or directly into it. The receiving section is so designed that a number of trucks can manoeuvre at the same time. From the platform, the garbage is moved to the feed-hopper by means of a bulldozer or shovel-loader. From the feed-hopper, a slat conveyor delivers the garbage continuously to the crusher for preliminary crushing. Generally, the crushing machine is a hammer-mill.

The crushed refuse is taken by either a conveyor below the crusher's outlet or a wheeled shovel-loader for transfer to the prefermentation area under cover, and windrows of 3.50 or 4.00 m width are set up.

The separation of metals, sifting or other refining operations take place after prefermentation. There are two reasons to proceed in such a way: first, most of the water inside the compost is released during the prefermentation process, partly vaporized and partly in seeping liquid form; secondly, after 10 days of micro-organism attack, the cellulosic fibre and structure frame is destroyed, which makes the sifting process easier. The crushed tins and metals inside the mass are not a hindrance at the prefermentation stage and can be separated later.

The compost refining line consists of a hopper conveyor feed device and a rotating or vibrating sieve fitted with screen sheets of an appropriate diameter perforation. Compost obtained with screens of a diameter of 0-15 granulation size corresponds to the type used in market gardening. An overband magnetic separator removes any metal. The separated metal is transferred to sieving rejects. Should an outlet exist for scraps in Freetown, a scrap press could be installed. Glass has to be reduced to harmless, scarcely visible particles by strokes of the crusher. If the hammer-mill cannot produce such small particles, a fine crushing mill will be required.

Refined compost is removed and stored in heaps of about from 3.5 to 4 m high on an open site. The transfer can be done either by the wheeled shovel-loader or by a conveyor belt of the so-called "grasshopper" type.

The compost should be used within two or three months because the mineralization process takes place and weight losses occur after that.

Equipment required for Freetown composting plant

Some composting plant fitters advocate no mechanical shredding of refuse prior to the composting operation. The expert does not agree with this opinion; no scheme to treat a substantial quantity of refuse would be satisfactory without shredding. All modern composting schemes start the operation with the shredding of refuse.

All shredding equipment that is designed for a specific capacity has to be fed in such a way that the shredding operation is performed steadily, without clogging or blocking. A slat conveyor is recommended for a regular feeding of the crusher, and the unit has to be adjusted in such a way that the slat conveyor's speed is synchronized with the crusher's rotation speed.

Thus, the shredding unit, which includes both slat conveyor and crusher, is the basic element for any composting plant. It is also the most expensive part of it since all the remaining equipment - conveyors, sifting equipment etc. - is standard.

The Freetown composting plant should not be sophisticated. A heavy duty shredder and other equipment have to be easily run, maintained and repaired. Parts must be easy to replace and available from a stock of spare parts designed for a three-year operation. The stock must be regularly renewed and it should be the responsibility of the plant manager to order spare parts, restocking in due time in order to avoid a shortage that would stop the plant and lead to its closing.

Since the Freetown composting plant has to be implemented and operated at the lowest cost possible, the garbage and bulky compost handling and loading should be performed by means of a wheeled diesel engine that could be fitted with appropriate attachments.

Special mobile windrow-turning machines are available from different makers. When the composting plant is fully operating, such specialized equipment could be provided.

Material discarded after sieving, and also separated metal, if there is no outlet for it, should be put in containers or lorries for transfer to a sanitary dumping site.

Recommendations concerning civil works

The size of buildings should be determined by the use to which they are to be put and the characteristics of the ground.

Supporting elements should be designed to withstand operational stress: all other sections of the plant could be made of light material such as metal sheets or asbestos-cement plates fastened to concrete or an iron frame. Complete crushing units with hopper, slat conveyor and supporting iron frame are sometimes supplied by specialized manufacturers. Otherwise, anti-vibration concrete platforms should be built by a local contractor.

Lining material used for compost aerobic fermentation and storage areas must be able to resist temperatures of up to 70°C. Asphaltic revetment should be able to withstand severe treatment by the shovel-loader bucket, and other materials must offer high abrasion and shock resistance. Suitable slopes and drainage should be provide allowing satisfactory surface water drainage.

The fermentation area should be under a cover consisting of asbestos-cement or similar roofing supported on a modular iron frame with posts spaced to allow a wheeled shovel-loader to manoeuvre.

Oil transformers and electrical control buildings should meet with standard safety requirements.

Site for composting plant

Since the composting process is to be carried out in the open air, special environmental considerations must apply in selection of the site.

The main factors to be considered are:

(a) It should be isolated from other development such as dwellings and schools. The composting plant could be located in an industrial area. However well the plant is operated, no composting plant can avoid emission of odour and dust, and plastic and paper will be scattered by the wind. The material is heavily infested with flies and insects and attracts scavenging birds in search of food;

(b) Its location should be chosen in such a way that garbage collection trucks can reach the plant without encountering traffic difficulties;

(c) It should be within economic distance of the potential users;

(d) It should be generally level and have an adequate area;

(e) It must have an adequate electricity supply;

(f) It must have an adequate water supply;

(g) It must have readily accessible and adequate facilities for the disposal of non-compostable materials.

A rapid survey was made in order to select potential suitable sites. The King Tom dumping site was not considered suitable; garbage dumping on this site has to stop within four or five years, and this site should be reserved for other purposes after decontamination and clean-up.

The only site that satisfies most of the above requirements is the land that runs along the main national road between Kissy and Wellington, probably nearer to Kissy. Between the national road and the Sierra Leone River, the land is generally level and the soil is very strong. Most of the land belongs to the Government and expropriation would not therefore be required.

There is a good bituminous surfaced road to the site and it could easily be reached by garbage collection lorries or containers. The main marketing area for the compost produced is easily accessible. Water and electricity are readily available.

Composting plant investment cost evaluation

The equipment planned for this unit is minimal, so that investment is the lowest that could be contemplated for reliable operation. The plant has a capacity of 10 tons per hour and could be operated for one or two eight-hour shifts per day.

A grading fine crusher is not provided. The extra cost for providing it would be about Le 43,000 or Le 45,000 for equipment ready for operation.

Buildings and civil works

Buildings and civil works are to be supplied by the Government. Some of the following items should be increased as the garbage being processed increases.

Buildings and civil works

	Phase one (Le)	Phase two (Le)
Site preparation: over 6,000 m^2 first phase and 6,000 m^2 extension second phase at Le 3.60 per m^2	21,600	21,600
Excavation works and earth banking up 600 m^3 at Le 19.60	11,760	
Concrete weighbridge pit 3 x 3 x 1 m	1,000	
Reception and shredding block; industrial type building, reinforced concrete or iron frame filled with hollow bricks or asbestos-cement sheets. Asbestos-cement roofing. 32 m^2 at Le 320	33,280	
Office and weighbridge building 32 m^2 at Le 320 per m^2	10,240	
Refining open building, iron framework and shed 120 m^2 at Le 90 per m^2	10,800	
Prefermentation section, open framework and shed with modular structure, at Le 90 per m^2 Phase one: 1,000 m^2 Phase two: over 1,560 m^2	90,000	140,000
Reception area of 225 m^2, coated area at Le 15 per m^2	3,375	
Windrowing area (under cover), or reinforced concrete at Le 60 per m^2 Phase one: 1,000 m^2 Phase two: over 1,560 m^2	60,000	93,600
Maturing and stockpiling coated area at Le 15 per m^2 Phase one: 1,500 m^2 Phase two: over 1,350 m^2	22,500	20,250
Servicing roads, coated area at Le 15 per m^2 Phase one: 3,000 m^2 Phase two: over 2,000 m^2	45,000	30,000

	Phase one (Le)	Phase two (Le)
Main water supply, according to site utilities (cannot be assessed at present time)		
High voltage power supply and connection according to site utilities (cannot be assessed at present time)		
Total	309,555	305,850

<u>Mechanical and electrical equipment</u>

Mechanical and electrical equipment foreign supply includes:	($)	($)
1 vehicle weighbridge, weighing range 30 tons, platform 8 x 3 m, for weighing the incoming garbage collection lorries or outgoing compost delivery trucks	32,000	
1 slat conveyor for raw garbage continuous delivery to the hammer-mill, length 9 m, width 1 m, with variable speed gear drive motor, speed range 1.7 to 7.5 rpm chain transmission	86,000	
1 hammer-mill, capacity 10 tons per hour with drive motor 150 hp 1,500 rpm with set of V-belt drive components and set of ancillaries and special parts	94,000	
1 elevating belt conveyor length 6 m, width 0.80 m, with feed hopper and feed worm, drive motor 2 hp, 1,500 rpm and V-belt transmission	8,500	
1 sifting unit rotating trommel type, exterior diameter 2.10 m, length 5 m, with inlet hopper and discharge worm diameter 0.90, drive motor 5.5 hp, 1,500 rpm and V-belt drive complete	37,000	
1 elevating belt conveyor, length 6 m, width 0.80 m, drive motor 2 hp, 1,500 rpm and V-belt transmission	8,500	
1 overband magnetic metal extractor fixed to the head of the belt conveyor with suspension magnet, discharge equipment, 2 hp geared motor and selenium rectifier	7,600	

	Phase one ($)	Phase two ($)
1 elevating belt conveyor for stock-piling with feed hopper and worm, length 10 m, width 1 m, drive motor 6 hp, 1,500 rpm and V-belt transmission	10,500	
6 bi-metal plunging thermometers, temperature range 0/85°C, 100 mm dial, stainless steel stem (1 m x 12 mm o. Ø) - stirrup handle	800	
Electrical equipment comprising 1 three phase oil transformer KWA 250, 1 electrical control panel, the main cabling and earthing equipment	52,000	
f.o.b. subtotal	336,900	
Contingency fund (5%)	16,850	
f.o.b. total	353,750	
Plus transportation from overseas 12% on f.o.b. cost price	42,450	
Plus assembly on the site 18% on f.o.b. cost price	63,680	
Total cost price for assembled and operational equipment 2/	459,880	

Rolling equipment

Imported wheeled loaders and lorries include:

	Phase one ($)	Phase two ($)
1 wheeled shovel-loader with diesel engine 140 hp, 4-wheel drive, hi-tip bucket, quick release, 3 m^3 bucket with refuse clamp, refuse dozer blade. Phase one: 1 loader Phase two: 1 loader	77,000	77,000

2/ As this project will be in the public interest, it is assumed there will be no customs duties.

		Phase one ($)	Phase two ($)
1 diesel engine lorry payload 10 tons for rejects transportation and other uses		25,000	
<u>Alternatively</u>			
1 standard agricultural tractor 40 or 50 hp with towing hook for trailers	18,000		
1 set of 2 hydraulic tipping trailers, 10 m^3 for rejects removal and transfer to dumping site	7,000		
Total	25,000		
Another, but more expensive, solution would be 1 multi-dump-truck lorry with diesel engine, payload 15 tons with the appropriate lifting device and 1 set of two dumping trucks			
Total f.o.b.		102,000	77,000
Plus transportation from overseas 8%		8,160	6,160
Total rolling equipment		110,160	83,160

<u>Spare parts</u>

	Phase one ($)
This imported equipment includes all normal wear parts to be periodically replaced (hammers, grate segments, protecting rings, slats etc.) as well as spare parts for more usual replacement (motor-rotors, pulleys, V-belts, rollers, transmission chains etc.) for processing about 35,000 or 40,000 tons of garbage (2 or 3 years operation), lump c.i.f. value	48,000
Total	48,000

Summing up of total investment

	($)		(Le)
Phase one			
Buildings and civil works (supplied by the Government)			309,555
Mechanical and electrical equipment (imported)	459,880	or	482,374
Rolling equipment (imported)	110,160	or	115,668
Spare parts (imported)	48,000	or	50,400
Total	618,040		958,497
Phase two			
Buildings and civil works (supplied by the Government)			305,850
Rolling equipment (imported)	83,160	or	87,318
Total	83,160		393,168

Amortization of the composting plant 3/

Buildings and civil works

Phase one: Le 309,555 to be amortized within 20 years at 5% interest rate

Gross annuity: Le 15,478

Yearly interest: Le 774

Actual annuity: $\frac{309{,}555 + 774 \times \Sigma(1 - 20)}{20}$ = Le 23,605

Phase two: Le 305,850 to be amortized within 20 years at 5% interest rate

Gross annuity: Le 15,292

Yearly interest: Le 765

Actual annuity: $\frac{305{,}850 + 765 \times \Sigma(1 - 20)}{20}$ = Le 23,325

Mechanical and electrical equipment

Phase one (single): Le 482,874 to be amortized within 10 years at 7.5% interest rate

Gross annuity: Le 48,287

Yearly interest: Le 3,621

Actual annuity: $\frac{48\ 874 + 3{,}621 \times \Sigma(1 - 10)}{10}$ = Le 68,203

3/ Since spare parts are taken into account for the projected operation cost appraisal, they are not considered as amortizable supply.

Rolling equipment

Phase one: Le 115,668 to be amortized within 5 years at 7.5% interest rate

Gross annuity: Le 23,134

Yearly interest: Le 1,735

Actual annuity: $\frac{115,668 + 1,735 \times \Sigma(1 - 5)}{5}$ = Le 28,339

Phase two: Le 87,318 to be amortized within 5 years at 7.5% interest rate

Gross annuity: Le 17,464

Yearly interest: Le 1,310

Actual annuity: $\frac{87,318 + 1,310 \times (1 - 5)}{5}$ = Le 21,394

Total annuities

Phase one:

23,566 + 68,203 + 28,339 = Le 120,108

Phase two:

120,108 + (23,325 + 20,373) = Le 164,827

This evaluation is purely theoretical. The life of the equipment could be much longer. Strict maintenance will keep the plant as good as new.

Recommended procedure for the implementation of the composting plant

If a decision is taken by the Government of Sierra Leone to proceed with the Freetown composting plant, the procedure should be as follows:

(a) An international invitation to tender should be launched on the basis of an adequate specification book and tender documents;

(b) The contract for general engineering and supplying plant equipment should be awarded as a package deal to a foreign manufacturer;

(c) Buildings and civil works should be done by a suitable local subcontractor according to the design and engineering data provided by the successful tenderer.

V. THE COMPOSTING PLANT OPERATION AND RUNNING COSTS

Operation

Personnel

Staff required

	Annual wages	
	Per man (Le)	Total (Le)
1 plant manager	4,000	4,000
1 senior mechanic and foreman electrician	2,000	2,000
*1 assistant mechanic	880	880
*1 assistant electrician	880	880
*2 engine drivers	750	1,500
*4 unskilled labourers	504	2,020
*1 weighbridge operator	750	750
1 lorry driver	750	750
1 security guard	750	750
1 clerk typist	1,000	1,000
Staff total annual cost		14,530

*Operative staff section.

Note: These figures are for one 8-hour shift per day, six days per week, that corresponds approximately to the working time required for processing 80 tons of garbage per day. For processing a large amount up to two 8-hour shifts would be required involving Le 20,560.

Qualifications of staff members

The plant manager requires a lively practical turn of mind rather than extensive or theoretical scientific knowledge. He looks after the general operation of the plant, provides spare parts and takes all the precautions necessary to avoid any shortages or breakdowns. He maintains contact with the Ministry of Health and the Freetown City Council as well as the world of agriculture, especially market gardening, with the goal of developing the use of compost and improving quality by strictly checking fermentation and grading operations.

It is recommended that the plant manager collaborate closely with Njala, Newton and New England agronomists and take part in agricultural tests on chemical fertilizers and use of compost suitable to specific crop cultivation.

accounting and invoicing activities should be taken care of by the appointed clerk typist.

The senior foreman has responsibility for the operation, maintenance and repair of all mechanical or electrical machinery, as well as rolling equipment, aided by the assistant mechanic and assistant electrician.

The turning of windrows and handling of compost in fermentation and stock-piling areas are the tasks of the wheeled shovel-loader drivers. It is stressed that the turning-over is to be carried out very conscientiously and carefully.

Other staff members are unskilled labourers.

Technical assistance and training

Key personnel, that is, the plant manager and the mechanical electrician foreman, require specialized training in composting plant operation and compost production. United Nations fellowships should be sought for six man-months to be spent in external specialized training at an appropriate composting plant where, if possible, climatic conditions and the nature of the refuse are similar to those of Freetown.

Training periods should be organized jointly by UNIDO and the plant's manufacturer. It is advisable that key personnel be present on site while the plant's equipment is assembled.

Other local staff members should be trained at the composting plant.

During the first year of the operation of the factory, the contractor should provide adequate operation and management staff comprising of one garbage processing plant manager and one plant maintenance specialist.

Utilities

Electricity

An oil transformer of 250 kVA output should be sufficient to allow a fine crusher or additional equipment to be installed.

Total installed power is: P_{IHP} = 174 hp equivalent to P_{IKW} = 128 kWh

Total consumed power is about 65% of total installed power, or about P_{CKW} = 83 kWh, which processes 10 tons garbage.

The Sierra Leone Electricity Corporation charges:

(a) Basic tax according to kWh demanded per month: Le 5;

(b) Consumption rate tax per unit (non domestic high voltage tariff) : 8.5 cents.

Thus, it is estimated that power expense will be as follows:

For 15,750 tons per year of processed garbage	Le
kWh total demand:	
P_{IKW} x 9 months x 5 Le	
(128 x 9 x 5)	5,760
Consumption rate tax:	
83 x 0.10 x 15, 750 x 0.085	11,112
Total	16,872
For 35,250 tons per year of processed garbage	
128 x 9 x 5	5,760
83 x 0.10 x 35,250 x 0.085	24,869
Total	30,629

Fuel

The diesel oil price in Sierra Leone on 1 March 1980 was Le 1.66 per gallon (or Le 0.365 per litre). The consumption of diesel oil by wheeled loaders is 12 litres per hour. It is assumed that when the composting plant is processing 15,750 tons per year, the loader operates 5 hours per day or 1,350 hours per 270 working days per year, and while processing 32,400 tons per year, the loader operates 10 hours per day or 2,700 hours per 270 working days. For the cost of the ingredients 5% is added. Thus, fuel consumption and price are as follows:

For 15,750 tons per year of processed garbage

Fuel consumption: 1,350 h x 12 l	=	16,200 litres
Fuel price: 16,200 l x 0.365	=	5,915 Le
+ 5% ingredients	=	300 Le
Total		6 215 Le

For 35,250 tons per year of processed garbage

Fuel consumption: 2,700 h x 12 l	=	32,400 litres
Fuel cost price: 32,400 l x 0.365	=	11,830 Le
+ 5% ingredients	=	600 Le
Total		12,430 Le

Water

Water consumption is assessed on an inclusive basis 100 l or 0.1 m^3 per ton of garbage processed.

The cost of water for industrial use is Le 1.80 per 1,000 gallons (or 4,548 l), that is Le 0.0396 for 1 ton, or:

For 15,570 tons per year of processed garbage about Le 625

For 35,250 tons per year of processed garbage about Le 1,395

<u>Spare parts</u>

The cost of spare parts is assessed at Le 1.35 per ton of processed garbage. Spare parts are imported and therefore expensive. It is possible that less expensive spare parts could be manufactured in the country at a later date.

Thus, cost of spare parts is as follows:

For 15,750 tons per year of processed garbage Le 21,260

For 35,250 tons per year of processed garbage Le 47,590

<u>Removal of rejects</u>

It is assumed that the removal of rejects and transfer to the dumping site will be done by the plant's own lorries, each of them making two round trips per hour and removing 5 tons of rejects.

Fuel consumption is 15 litres per hour and 5% ingredient price added. Fuel cost price is Le 0.365 per litre.

Thus, the costs of removing rejects are as follows:

For 15,750 tons per year of processed garbage

	Le
236 h x 15 l x 0.365	1,292
+ 5% ingredients added price	65
Total (rounded)	1,360

For 35,250 tons per year of processed garbage

528 h x 15 l x 0.365	2,890
+ 5% ingredients added price	145
Total	3,035

<u>Maintenance</u>

Rolling equipment

Costs of maintenance and repairs for rolling equipment spread over 10,000 working hours are 70% of the cost price, that is, for a wheeled loading engine: Le 6.11 per hour, and for a lorry: Le 1.98 per hour

Thus, rolling equipment maintenance expenses are as follows:

For 15,750 tons per year of processed garbage

	Le
1,350 h loader operation	8,249
236 h lorry operation	468
Total (rounded)	8,720

For 35,250 tons per year of processed garbage

2,700 h loader operation	16,497
528 h lorry operation	1,045
Total (rounded)	17,540

Civil works and fixed equipment maintenance

Buildings, civil works and fixed equipment general maintenance (excluding spare parts and repairs as per 5.1.3) expenses are assessed on the inclusive yearly basis 1.5% or respective investment, that is:

For 15,570 tons per year of processed garbage Le 11,886

For 35,250 tons per year of processed garbage Le 16,474

Insurances

All insurance costs are estimated on an inclusive basis

Civil works

1% of civil works investment or:

For 15,750 tons per year of processed garbage Le 3,095

For 35,250 tons per year of processed garbage Le 6,155

Insurance for equipment (including spare part)

2.5% of fixed equipment or:

For 15,750 and 35,250 both phases Le 13,330

Insurance for rolling equipment

3% of the investment or:

For 15,750 tons per year of processed garbage Le 3,470

For 35,250 tons per year of processed garbage Le 6,090

Management expenses

Management expenses are estimated on an inclusive basis of 7% of all expenses.

Projected operating costs for the Freetown composting plant (without amortization)

Processed garbage amount (tons/year)	15,750	35,250
Refined compost for sale (tons/year)	3,360	19,390

	Le	Le
Staff and labour	14,530	20,560
Electricity	16,372	30,629
Fuel	6,215	12,430
Water	625	1,395
Spare parts	21,260	47,590
Transfer of rejects to dump	1,360	3,035
Rolling equipment maintenance	8,720	17,540
Civil works and fixed equipment maintenance	11,886	16,474
Insurance civil works	3,095	6,155
Insurance fixed equipment	13,330	13,330
Insurance rolling equipment	3,470	6,090
Total	101,363	175,228
Management expenses 7%	7,095	12,266
One year operation cost	108,458	187,494
Incidence of amortization		
Amount of the annuity	120,108	164,827
One year operation cost with amortization	228,566	352,321
Cost price of processing 1 ton of garbage		
Without amortization	6.886	5.319
With amortization	14.512	9.995
Cost price of 1 ton of compost		
Without amortization	12.241	9.670
With amortization	25.797	18.170

A comparative cost analysis of the composting plant and sanitary dumping operations

Given below is a comparative cost analysis of the composting plant and sanitary landfill operations for 15,750 or 35,250 tons yearly. If garbage is compost processed, 15% of rejects have to be disposed of in a sanitary landfill. Transportation of rejects for disposal is included in the composting cost price, but the cost of the disposal operation itself is charged to the Ministry of Health. For reject disposal, the same basic cost price as for usual garbage disposal is assumed.

	Tons	
	15,750	35,250
Comparative cost prices without amortization		
Composting process 100%	108,453	187,494
Plus rejects 15% disposal	10,522	21,812
Total	118,980	209,306
Disposal 100%	70,145	145,416
Difference	48,835	63,890
Comparative cost price including amortization of respective facilities		
Composting process 100%	228,566	352,321
Plus rejects 15% disposal	20,165	36,968
Total	248,731	389,289
Disposal 100%	134,433	246,454
Difference	114,298	142,835

These figures can be interpreted in different ways but the most realistic one is the following: corresponding to fully operating plant without taking into account the amortization, composting will cost Le 63,890 more than sanitary dumping.

The question is whether this additional cost could be covered by compost sale or not.

Since 19,390 tons compost generated is available for sale, each ton of compost is to be sold at the minimum sale price of:

63,890 : 19,390 = Le 3.295

If compost could be sold at the above price, or more, Freetown household refuse composting would be economically sound.

If the amortization of facilities is taken into account, compost must be sold at the minimum price of Le 7.360 per ton.

VI. ESTIMATE FOR THE SALE PRICE OF COMPOST IN SIERRA LEONE

To estimate the sale price of compost, two aspects must be considered:

(a) Compost value as fertilizer. In terms of fertilizer value, 1 ton of compost contains:

	Le
Nitrogen (N)	4.044
P_2O_5	4.800
K_2O	2.680
NPK	11.524

The NPK content is higher than that of NPK 15/15/15, which is sold at Le 12.00 per bag of 50 kg;

(b) Compost value as soil conditioner. The value of compost as a soil conditioner should be added to its value as a fertilizer. Unfortunately, this value is difficult to assess because a market does not exist. However, the sale price of pig, cattle or poultry manure could be used as a basis.

Incidence of transportation cost

The usual transport tariff in Sierra Leone is Le 0.25 per ton per km (by road). If the sales price includes delivery at the plant, the cost of transport, in terms of nutrient, is about fifteen times higher than that of transporting NPK value in the form of chemical fertilizer. Because there is a shortage of manure, it is transported for long distances. From this point of view, the price depends greatly on the demand.

Actual compost value

In Sierra Leone, as in many developing countries, there is no established market for compost. By and large, each farmer uses his own farm waste on his farm. Although supplies of such waste are dwindling compared with demand, commercial availability of factory-made compost is unknown. The fact that there is neither an established market nor an acceptable market price is a serious obstacle in the marketing of compost.

Furthermore, and the same thing happens even in developed countries, a farmer is likely to equate a good quality factory-made compost with his farmyard manure and be reluctant to buy compost since he is not accustomed to paying for such a commodity.

Suggestions for the promotion of compost

A good deal of promotion by marketing and technical people will be required to sell compost. The authorities that could help the Sierra Leone Government to carry out this task are:

The Central Distribution Office, Ministry of Agriculture and Forestry, Freetown

The Principal Agriculture Officer (PAO) in each province concerned, possibly restricted to the Western Area, however, if demand is urgent from distant areas, transport subsidies should be granted

The Ministry of Agriculture Agronomic services, Njala, New England and Newton

The composting plant manager's co-operation should also be requested and every opportunity taken to upgrade and standardize the final product.

Suggestions for sharing costs and benefits of the composting plant

The Ministries of Health and Agriculture are both involved in composting plant investment and operation. The Ministry of Health could find less expensive ways of resolving the Freetown sanitation problem by the disposal of garbage by sanitary dumping. Since the composting plant, if implemented, would benefit farmers and market gardeners exclusively, the Ministry of Agriculture and Forestry should equally support the cost of the composting process, jointly with the Ministry of Health.

It is therefore suggested that composting expenses should be divided between:

The Ministry of Health (or the Freetown City Council) up to an amount that does not exceed the cost price of equal quantity sanitary disposal

The Ministry of Agriculture and Forestry to cover the additional costs

Sales income should be shared between both authorities proportionally to their contribution.

VII. FINDINGS AND RECOMMENDATIONS

If the composting plant project is implemented, it is recommended that the Ministry of Health share the responsibility with the Ministry of Agriculture. The determining elements should be:

(a) That there is a sufficient outlet for compost;

(b) That farmers and especially market gardeners agree to pay the minimum price for compost that allows the composting plant's operation.

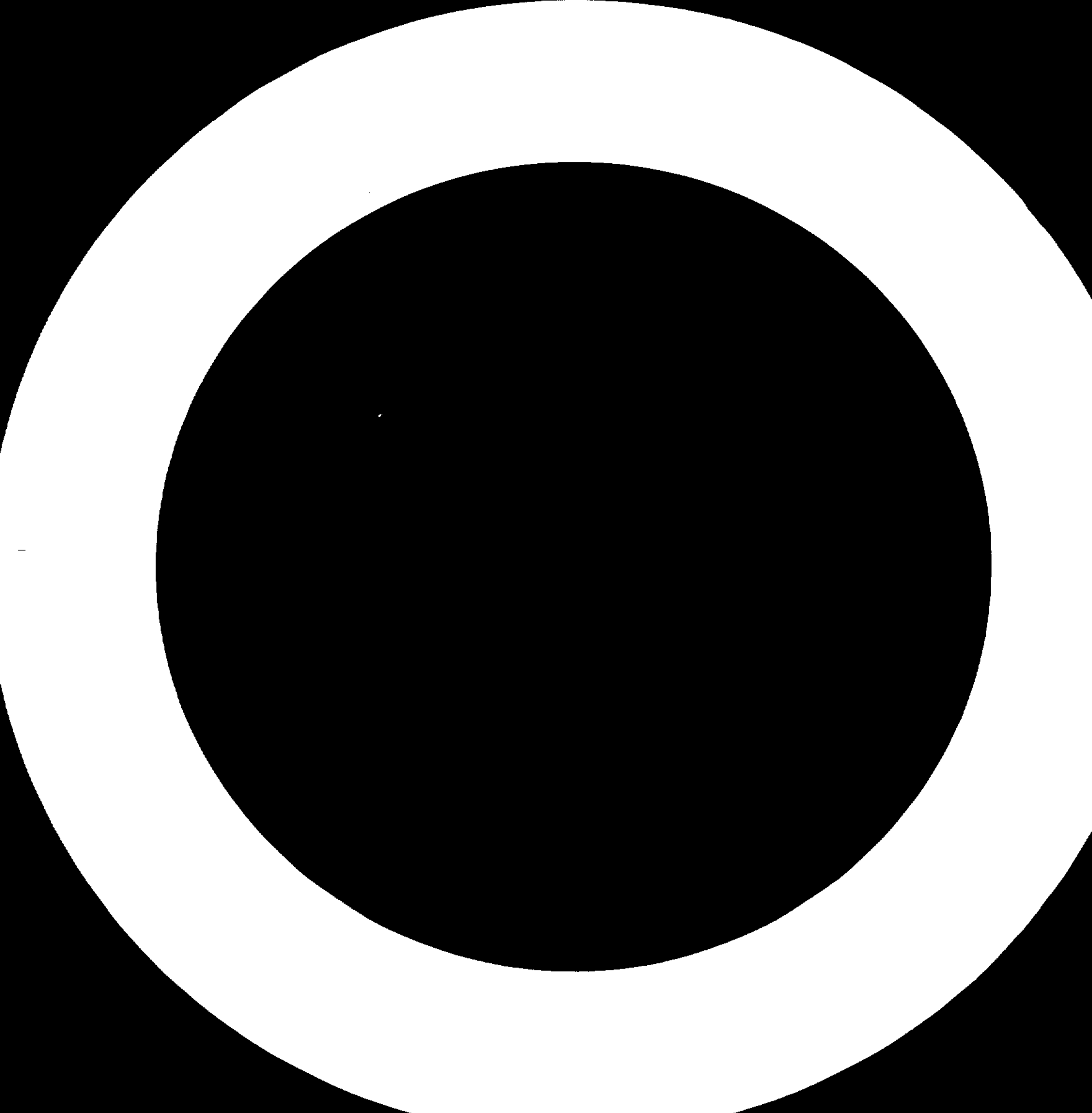
If both these conditions are fulfilled, the composting plant would be feasible. The timetable should be as follows:

(a) Garbage analysis campaign;

(b) Composting trails and agricultural tests in co-operation with Njala, Newton and New England authorities;

(c) Preparation of specification book and tender documents once the financial resources for implementation are obtained.

Where it is not possible to meet the required conditions related to the outlet and minimum price, the composting plant project should be abandoned and the Ministry of Health sanitation problem resolved by means of garbage disposal by sanitary dumping.



Annex I

POPULATION PROJECTION FOR SIERRA LEONE

(1) Census

Date	COUNT	ADJUSTED ESTIMATE
1 April 1963	2,180,355	2,289,373
31 December 1974	2,749,315	3,008,675

(2) Population projection to the nearest hundred

Year	Total population	Western Area urban incl. Freetown	Provincial urban	Total urban	Rural	Urban	Rural
1974	2 749 315	281 397	431 280	712 677	2 036 638	25.9	74.1
1975	2 813 924	295 467	448 531	743 998	2 069 926	26.4	73.6
1976	2 880 050	310 240	466 472	776 712	2 103 338	27.0	73.0
1977	2 947 730	325 752	485 131	810 883	2 136 847	27.5	72.5
1978	3 017 000	342 039	504 530	846 569	2 170 431	28.0	72.0
1979	3 087 900	359 140	524 700	883 840	2 204 060	28.6	71.4
1980	3 160 500	377 100	545 700	922 800	2 237 700	29.2	70.8
1981	3 234 700	396 000	567 500	963 500	2 271 200	29.8	70.2
1986	3 633 000	505 300	690 500	1 195 800	2 437 200	32.9	67.1
1991	4 080 000	645 000	840 000	1 485 000	2 595 000	36.4	63.6

Sources: (1) Central Statistical Office, Freetown

(2) Assignment report WHO sanitary engineer March 1979

Annex II

SIMPLIFIED PROCEDURE FOR ANALYSING MUNICIPAL GARBAGE IN WEST AFRICA

Equipment

Shovels, forks and hooks

1 sieve, mesh ø 40 - woodframe 2.5 x 2.0 x 0.1 m

1 sieve, mesh ø 10 - woodframe 2.0 x 1.5 x 0.1 m

1 scale capacity 150 kg

plastic bags 1003110 l

1 set of cases

Staff

10 labourers

Prescriptions for Freetown garbage physical analysis

Samples of garbage should be taken daily, seven days running at the King Tom dumping site where 300/400 kg of garbage are sorted daily. Since Freetown household refuse is fairly homogeneous, garbage for sampling should come from a representative popular district. Other sampling should be taken in three or four other central or suburban districts for checking.

Immediately after arrival the lorryload selected for sampling should be discharged. Each pile of garbage should be mixed manually and homogenized by means of shovels and forks until a cake-shaped pile is formed, which should then be divided into four quarters. The first quarter should be sorted manually and its components divided into 10 classes:

Paper and cardboard

Rags

Wood

Plastics

Leather and rubber

Non-ferrous metals

Ferrous metals

Glass and china

Inerts (stones, tiles etc.)

Putrescent matter: coarse above ø 50 mm, fine under ø 50 mm

Each one of the sorted classes of waste should be put into cases and weighed.

The second quarter should serve to measure the density of refuse; tarred cases or vessels of a known capacity should be filled with it. Refuse should be crushed and 1 or 2 kg of samples taken at random.

The two other quarters could be used for laboratory analysis. The moisture could be measured from each sorted component if the required equipment (heating chamber and appropriate laboratory scale) is available.

For reliable data, a seven-day sorting and analysis operation should take place four times a year at three-month intervals.

Annex III

RUNNING COSTS FOR SANITARY DUMPING

The following estimate has been made for comparative purposes of the operational cost for disposal by sanitary dumping of the garbage that the Ministry of Health or the Freetown City Council would have to dispose of if the composting plant is not implemented.

Freetown sanitary dumping running costs

Number of working days per year	270	270
Garbage amount put into landfill tons per year	15,750	35,250
Garbage produced per capita on 270 days (0.479 kg/day) in kg	129,000	270,000
Investment	Le	Le
Fencing	20,000	20,000
Service building (shelter 20 m^2)	6,400	6,400
Rolling (compacting and digging) wheeled equipment	250,000	400,000
Total	276,400	426,400
Running costs		
Fixed expenses		
Maintenance of fixed installations (2.5% of investment)	365	365
Insurance of fixed installations (2.5% of investment)	365	365
Insurance of rolling equipment	6,250	10,000
Subtotal	6,980	10,730
Personnel (social charges included) Subtotal	5,220	8,490
Proportional expenses		
Fuel, ingredients, maintenance and repairs	42,343	93,920
Water, electricity (0.05 per t)	787	1,762
Rodents destruction (0.05 per t)	787	1,762
Earth covering	9,439	19,230
Subtotal	53,356	116,683
Total	65,556	135,903

Administration cost: 7%	4,589	9,513
Total running costs (without amortization)	70,145	145,416
Annuities	64,288	101,038
Total	134,433	246,454
Cost price of 1 ton of garbage put into sanitary landfill	4.453	4.125
Cost price of 1 ton of garbage put into sanitary landfill (with amortization)	8.535	6.991

Notes 1. Equipment and facilities are reduced to their simplest terms: fencing, a shelter as a rudimentary office, and two earthwork diesel engines: one Caterpillar 920 and one Caterpillar 950.

2. Amortization conditions are: 10 years at 5% for fencing; 20 years at 5% for shelter; and 5 years at 7.5% for rolling equipment.

3. It is assumed that earth covering is used in the proportion of 25% of garbage weight, which is collected from a mountain 5 km away by means of tipping lorries that charge Le 0.25 per km/t.

4. Personnel for the first stage consists of: 1 foreman, 2 loader drivers and 4 unskilled labourers; and at the second stage: an additional loader driver and 5 additional unskilled labourers.

5. At the second stage, another Caterpillar 920 is provided.

Annex IV

AGRICULTURAL TRIALS WITH HOME-MADE COMPOST

Data collected from the Faculty of Agriculture of Njala University College

Trials carried out by the Soils Department

About 1 ton of compost for crop testings is prepared every year at the Faculty of Agriculture.

The composting process is anaerobic. At the rainy season, minced grass is arranged in grass layers 2 ft thick alternating with 1 foot of thick top soil, up to 4-5 ft.(taking progressive packing down into account).

Sometimes, but not always, solution $SO_4(NH_4)_2$ or $SO_4(NH_4)_2$ crystals are sprayed or spread over the layers.

Anaerobic fermentation starts off and continues during the whole year. The compost is turned over every two months.

Table. Recommended amounts of compost for market gardening crops.

	Anaerobic home made compost		NPK 20/20/20	
	lb/yd^2	kg/yd^2	oz/yd^2	kg/yd^2
Tomatoes	5	13.18	2	0.068
Lettuce/salad a/	4	10.55	2	0.068
Pepper	5	13.18	2	0.068
Maize	6	15.82	2	0.068
Okra	4	10.55	2	0.068
Beans	5	13.18	2	0.068
Local green vegetables	5	13.18	1	0.339
Sweet potatoes	4	10.55	-	-

a/ 1 oz $SO_4(NH_4)_2$ is added

Use

Anaerobic compost is used during the dry season, that is, from November to May, on soil that has been sterilized by burning. About 5 lb/yd^2 of compost is used, then the compost is turned. Chemical fertilizer, 2 oz NPK 20/20/20, is used six weeks later.

Without compost application, 4 oz NPK instead of 2 oz are applied. However, the best result is obtained by compost application: 30-40% yield increase is normally observed.

Oil palms and citrus trees

At any time in the dry season, a round hole about 30 in. wide and 24 in. deep is dug. The top soil is mixed with 10 lb. anaerobic compost and put inside, then the hole is filled. Trees are planted in the early rainy season. No chemical fertilizer is used until after the second season. Mulched grass is put on the top soil.

Data collected from the Horticulture Station, New England

Western area market gardeners prepare their own compost on the fields and use leaves, refuse, sweepings etc. The compost is used at the rate of 20 lb/yd^2 After applying compost, transplanting or seeding takes place, then a NPK mixture containing ammonium sulphate (or potassium chloride) with 15N/15P/15K blending rate is used. Such a mixture is imported from industrial countries and costs about Le 12.00 per bag of 50 kg. Three weeks after planting 2 oz/yd^2 is applied.

When the soil is naturally rich in organic matter, chemical fertilizer is not needed.

Home-made compost is successfully used on the following crops: lettuces, cabbages, beans, peppers, radishes, garinex (aubergines), spinach, tomatoes, okra (gombo). It is also used on flowers, ornamental plants and in orchards.

Data collected from the Ministry of Agriculture Experimental Station, Newton

The Newton - Western rea is 22 miles from Kissy. The Ministry of Agriculture Experimental Station is located on the right side of the main road, more or less equidistant from Wellington and Songo. This is a private market gardening area that contributes significantly to Freetown's supply of market gardening produce. The average area for the plots of land for trials is 0.5 ha.

Sandy soils in this area are intensely leached in the rainy season, so there is a general shortage of organic matter.

The Experimental Station grows the following market gardening crops for tests: lettuce, garinex, tomatoes, okra (gombo), cassava, maize, beans, groundnuts, peppers etc.

Chemical fertilizer, $SO_4(NH_4)_2$, urea or the usual blendings of NPIC, are used, but since land is exhausted, organic fertilizer of any sort is needed: poultry or pig manure, according to its availability, is used.

Compost produced in the composting plant could be sold in the Songo or Wellington areas. The distance is not too far, and lorries that bring market gardening products to Freetown could load compost from the plant for the return journey.

Data collected from the National Produce Co. Ltd. (NAPCO)

The General Manager of the National Produce Co. Ltd. is an agronomist engineer with extensive experience in tropical farming, having spent many years in various African countries. He grows his own vegetables and prepares home-made compost for his private use. According to his experience, the Sierra Leone soils in the Western Area need 70% organic matter by weight of top soil, or 168 tons per ha of organic matter for 15 cm depth of top soil.

Accurate tests, carried out mainly with tomatoes, have been performed by him in lateritic soils. One month after using compost, in the amount stated above, on sandy soils, the first tomato flowers appeared. After adding pig manure and compost blending, the first flowers appeared one month, and the first fruit 45 days, after planting. In both cases, superb fruit was obtained and the yield increased tremendously.

For application to Western Area soils, the General Manager recommends 100 tons of compost per ha (about 40 tons per acre) to be applied every 18 months.

It is good practice to blend compost and chemical fertilizers at a farm at the rate of 5-10 kg single superphosphate per cubic metre of compost.

Annex V

CODE OF PRACTICE FOR SEMI-INDUSTRIAL COMPOSTING TRIALS

The main goal of semi-industrial composting trials is to prepare small amounts of compost for agricultural tests. To obtain the same type of compost as that provided by any composting plant, semi-industrial facilities should include a small-scale reproduction of the projected plant, mainly a crusher and a riddle.

The following is a description of the procedure, adapted to local conditions, by a UNIDO expert for semi-industrial tests in Rabat, Morocco.

Preparation of refuse

Composting trials should be performed with 6 tons of compost.

The raw refuse is superficially sorted by hand in order to avoid damaging the crusher with hard materials. The eliminated material should not contain pieces of less than 10 mm length, except of course pieces of metal.

Large pieces of rags, cardboard and packing paper, should be removed and also tins, bottles and large stones.

Refuse shredding

Shredded material is required to accelerate the composting process and enable accurate control because the processed material has an optimum inter-particles spacing and a maximum amount of surface allowing uniform attack by aerobic micro-organisms. The process control and monitoring is easier and more accurate for homogeneous crushed product and it is more easily handled.

The process requires a small crusher, for instance, a hammer-mill of the type used in some food mills or a colour crusher mill. A hammer-mill is provided with a rotor of about 50 cm long carrying 12 to 25 articulated hard-duty iron hammers arranged in four or six opposite rows. Rotation speed is 900 to 1,200 rpm. The degree of crushing is virtually unaffected by variation in speed of rotation but by the speed of exhaust of the crushed product over the outlet grid. The selected grid should have rectangular passages of 20 x 25 cm.

Since the hammer-mill would serve for semi-industrial trials only, and should not be permanently installed, sizeable investment in such equipment is not advisable. It is suggested that a second-hand hand-fed hammer mill equipped with direct coupled 20 or 25 drive motor be obtained. An agricultural type power generating set with a V-belt transmission also could be used.

Trailer-mounted semi-industrial hammer-mills especially designed for semi-industrial tests are available from the manufacturer. Unfortunately, such equipment is expensive. If the investment is spread over various similar projects in different developing countries, the acquisition of such equipment could be considered.

Turning over

Compost heaps should be turned manually three times by forks or shovels. Fermenting material is spread over a platform, then the heap is rebuilt.

The temperature is checked by several plunging thermometers, and appropriate turning takes place once the inside temperature has reached $60^{\circ}C$, $70^{\circ}C$ and 72° or $73^{\circ}C$ (corresponding to the second or third day, fifth day and eighth or ninth day).

The third turning corresponds to the transfer of the heap to the maturing area where fermentation in the open air continues without other precautions. After about three weeks, the temperature drops below $50^{\circ}C$ and the compost can be used.

Compost cleaning and grading

Compost grading can take place either after the third turning over or just before delivery some weeks after maturing in the open air.

At this stage, sifting is carried out using a screen having a Ø of 40 mm mesh size, or better, two screens of Ø 40 mm and 20 mm. A wooden frame, 2 x 2.5 m, is hung from the roof and swung manually. Precautions should be taken to avoid underriddle dispersion by the wind.

The fermenting process should be carried out in a shed.

This way of processing allows the preparation of a marketable type product with a homogeneous granular structure good for agricultural testing.