THE SOLID WASTE DISPOSAL PROBLEM IN SOUTHERN ITALY: THE LECCE, COSENZA AND LAMEZIA TERME PLANTS

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ABSTRACT

The authors describe the three main installations financed by the Cassa per il Mezzogiorno (Development Board for the South of Italy) designed for the disposal of urban solid wastes (USW).

The installations under consideration are remarkable both from an organizational point of view (plants serving extensive areas comprising various municipalities) and a technical point of view (plants designed for the co-disposal of USW and sludges by means of advanced systems such as recycling, RDF production-composting).

INTRODUCTION

At present, in Italy there is not a single operative Authority entrusted with the control of the solid waste pollution problem and the rational territorial distribution of the interventions required for the solid waste treatment.

Most actions are directly provided for by the Municipalities, especially when large cities are concerned, or by groups of Municipalities that join together into consortia.

Furthermore, there is no up-dated national law governing the whole subject matter in compliance with the general directives laid down by the European Economic Community (EEC). There are, however, some regional laws with very uneven characteristics and, owing to this fact, the technical regulations formulated by applied research organizations and scientific institutions (C.N.R., Universities, specialized firms) may not be organically implemented in the operative field.

The “Cassa per il Mezzogiorno” (Development Board for the South of Italy)* is a State Agency set up in 1952 to the purpose of realizing special public works, financing industrial plants and the agricultural and livestock promotion in the South of Italy to attain the social and economic balance of this area with respect to the rest of the Country.

Many significant works entrusted to this Agency by the National Planning Authority (CIPE) concerned large hydraulic works (for the rational water exploitation), liquid waste treatment plants (for the reutilization of purified water) and the treatment of urban solid waste together with the organic slimes produced by the treatment plants.

Insofar as the industrial and urban solid waste problem is concerned, lacking any unitary national directive, the “Cassa” must limit its commitment to just the works included in the programs set up by the National Authority.

The general map of Southern Italy shown on Fig. 1., shows the territorial jurisdiction of the “Cassa” and the areas that are at present being studied to the purpose of attaining a rational solution of the solid waste problem, even in connection with the water purification problem. The map, however, does not show the initiatives of other Authorities.

Since it is just a few years that the solid waste problem has been entrusted to the “Cassa,” few *“Cassa per Opere Straordinarie di Pubblico Interesse nell’Italia meridionale”; shortly called the “Cassa”.
works have been implemented up to now, while regarding the rest, the intervention situation is still in the study and engineering design phase.

It should be pointed out that in countries such as Italy, characterized by scarce primary resources and a high population density (and, therefore, significant amounts of produced waste), the pollution treatment techniques must necessarily aim at and take into account those processes warranting the maximum possible recovery of recyclable materials in the forms that are most suitable for the characteristics of the various zones of the country (compost, iron, paper, plastic and energy). Since these techniques are presently being developed to a great extent, the Public Administration meets significant difficulties in the selection of plants featuring the two required characteristics: a modern engineering design and a reliability ascertained on an industrial scale.

In this report, therefore, we shall deal with three plants promoted and financed by the “Cassa,” that are deemed to be significant both as regards their dimension and the technical and organizational solutions.
THE LECCE PLANT

The objective was to have a solid waste treatment plant, designed to meet the requirements of an area of 2,760 sq km, making up the Lecce province, located in Southern Italy, in the Puglia region. This prevailing flat territory is served by a good road network and has a population of 790,000 inhabitants living in 96 different Municipalities.

The project chosen provides for an integrated solid waste transportation and treatment system and it was deemed the best, among all the possible solutions, from the following points of view:

1. Minimum transportation and treatment costs per ton of waste to be treated.
2. Most suitable treatment system in respect of the nature and the average chemical and physical characteristics of the waste generated in the area.
3. Most preferable system, as it provides for the recovery of the waste fractions having greater value for the social and economic environment of the area.
4. Minimum residual pollution resulting from the treatment processes and being, in any case, in compliance with the law in force.

In order to attain these main objects, the “Cassa” called an international competitive bidding for a design-tender. Bidders were requested to perform all the required studies on the physical, demographic, agricultural, social and economic as well as urban environment and to prove the functional and economic soundness of their tenders.

It was deemed advisable to have the general design phase and the technical and economic tender phase joined in a single center of responsibility to avoid a separate and nonconcomitant performance of these phases that might hinder the attainment of first-rate results on account of the continuous technical development of treatment processes and changes in the market for the recovered products.

Taking into account the complexity of the problem faced by the bidding firms, the range of proposed solutions has been very wide, with really different results in respect of:

1. Number and site of the treatment plant.
2. Number and site of the transfer stations.
3. Technologies employed for the waste treatment.

The Committee choose the project solution based on the construction of a single centralized plant, at the center of the region, with four transfer stations duly located (Fig. 2). Capacity of the treatment plant was fixed in 80 t/hr of waste.

PROJECT DATA

The demographic situation of the Province (1976), and its expansion forecasts for the years 1981, 1991, and 2001 were taken as “basis” for dimensioning the system.

The following situation resulted.

<table>
<thead>
<tr>
<th>Table 1 Demographic Situation and Forecasts</th>
</tr>
</thead>
<tbody>
<tr>
<td>-----</td>
</tr>
<tr>
<td>Resident inhabitants</td>
</tr>
<tr>
<td>Occasional inhabitants (yearly)</td>
</tr>
<tr>
<td>Occasional inhabitants (presence of peak month)</td>
</tr>
</tbody>
</table>

The above inhabitants are distributed in 96 small Municipalities plus the main town (Lecce). The considerably high number of occasional inhabitants is due to the large crowd of tourists during the summer season.

As a basis for the project, the daily waste production per capita was taken and is shown in Table 2. Average coefficients of waste collection are also shown.

<table>
<thead>
<tr>
<th>Table 2 Waste Production and Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>-----</td>
</tr>
<tr>
<td>Average waste production of resident inhabitants (kg/inh./day)</td>
</tr>
<tr>
<td>Average waste production of occasional inhabitants (kg/inh./day)</td>
</tr>
<tr>
<td>Average coefficient of waste collection from resident inhabitants</td>
</tr>
<tr>
<td>Average coefficient of waste collection from occasional inhabitants</td>
</tr>
</tbody>
</table>
By combining the data shown in Tables 1 and 2, Table 3 was derived, which was used as a basis for dimensioning the system.

### TABLE 3 DESIGN DATA

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yearly waste produced by resident inhabitants</td>
<td>t 192,757</td>
<td>201,591</td>
<td>250,268</td>
<td>304,018</td>
</tr>
<tr>
<td>Average monthly waste produced by resident inhabitants</td>
<td>t 16,063</td>
<td>16,799</td>
<td>20,856</td>
<td>25,335</td>
</tr>
<tr>
<td>Yearly waste from resident inhabitant to be treated</td>
<td>t 183,120</td>
<td>193,527</td>
<td>242,760</td>
<td>297,938</td>
</tr>
<tr>
<td>Average monthly waste from resident inhabitants to be treated</td>
<td>t 15,260</td>
<td>16,127</td>
<td>20,230</td>
<td>24,828</td>
</tr>
<tr>
<td>Yearly waste produced by occasional inhabitants</td>
<td>t 731</td>
<td>1,040</td>
<td>1,884</td>
<td>2,940</td>
</tr>
<tr>
<td>Yearly waste from occasional inhabitants to be treated</td>
<td>t 731</td>
<td>1,040</td>
<td>1,884</td>
<td>2,940</td>
</tr>
<tr>
<td>Monthly waste produced by occasional inhabitants (peak month)</td>
<td>t 235</td>
<td>420</td>
<td>852</td>
<td>1,400</td>
</tr>
<tr>
<td>Monthly waste from occasional inhabitants to be treated (peak month)</td>
<td>t 235</td>
<td>420</td>
<td>852</td>
<td>1,400</td>
</tr>
<tr>
<td>Total waste produced yearly</td>
<td>t 193,488</td>
<td>202,631</td>
<td>252,152</td>
<td>306,958</td>
</tr>
<tr>
<td>Total waste to be treated yearly</td>
<td>t 183,851</td>
<td>194,567</td>
<td>244,644</td>
<td>300,878</td>
</tr>
<tr>
<td>Total monthly produced waste (peak month)</td>
<td>t 16,298</td>
<td>17,219</td>
<td>21,708</td>
<td>26,735</td>
</tr>
<tr>
<td>Total monthly waste to be treated (peak month)</td>
<td>t 15,495</td>
<td>16,547</td>
<td>21,082</td>
<td>26,228</td>
</tr>
<tr>
<td>Industrial waste t/day</td>
<td>19,715</td>
<td>21,424</td>
<td>23,140</td>
<td></td>
</tr>
<tr>
<td>Sewage sludge t/day</td>
<td>25,623</td>
<td>41,537</td>
<td>45,369</td>
<td></td>
</tr>
</tbody>
</table>

To establish the average waste composition, the 96 Municipalities were grouped into seven categories according to their dimensions, as per the following table.

### TABLE 4 MUNICIPALITIES CLASSIFICATION

<table>
<thead>
<tr>
<th>Categ. No.</th>
<th>Municipalities No.</th>
<th>Total inhabitants No.</th>
<th>Percent of the total Muni- cipality</th>
<th>Representative Municipality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 deg. 26</td>
<td>0- 3,800</td>
<td>64,293</td>
<td>8.15</td>
<td>S. Cesarea</td>
</tr>
<tr>
<td>2 deg. 23</td>
<td>3,800- 6,000</td>
<td>111,618</td>
<td>14.15</td>
<td>Otranto</td>
</tr>
<tr>
<td>3 deg. 27</td>
<td>6,001-10,300</td>
<td>213,964</td>
<td>27.12</td>
<td>Martano</td>
</tr>
<tr>
<td>4 deg. 9</td>
<td>10,301-13,700</td>
<td>110,579</td>
<td>14.01</td>
<td>Maglie</td>
</tr>
<tr>
<td>5 deg. 6</td>
<td>13,701-21,000</td>
<td>90,584</td>
<td>11.48</td>
<td>Gallipoli</td>
</tr>
<tr>
<td>6 deg. 4</td>
<td>21,001-32,000</td>
<td>105,569</td>
<td>13.38</td>
<td>Nardò/ Galatina</td>
</tr>
<tr>
<td>7 deg. 1</td>
<td>32,000-</td>
<td>42,403</td>
<td>5.37</td>
<td>Lecce (city)</td>
</tr>
<tr>
<td>96 789,007</td>
<td>100.00</td>
<td></td>
<td></td>
<td>Lecce (suburbs)</td>
</tr>
</tbody>
</table>

A Municipality was chosen out of each one of above categories as typical, and waste analyses were carried on through three campaigns, on samples collected during different seasons.

The average arithmetical values, the average ponderal values and the corrected average ponderal values were calculated.

To calculate the above corrected average values, it was assumed that the LHV of the waste be a function for the inhabitants resident in the various Municipalities. Starting from this hypothesis, it has been defined an average waste for the province (corrected ponderal average) which shows, in 1981, the following characteristics:

- Paper/textiles, wood, screened under 20 mm: 14.9 percent by weight
- Plastics: 6.4 percent by weight
- Metals: 2.6 percent by weight
- Inerts: 4.8 percent by weight
- Organic matter: 46.9 percent by weight

Total moisture: 51.0 percent by weight

Low heating value: 860 kcal/kg

Taking into account the changes which are foreseen to take place in the province during the next years, it was estimated that the composition
of the average provincial municipal solid waste indicated above will change as follows.

**TABLE 5 WASTE COMPOSITION AND FORECASTS**

<table>
<thead>
<tr>
<th>Material</th>
<th>1981 Percent</th>
<th>1991 Percent</th>
<th>2001 Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper/textiles, wood</td>
<td>14.9</td>
<td>22.5</td>
<td>27.6</td>
</tr>
<tr>
<td>Screen under 20 mm</td>
<td>24.4</td>
<td>18.0</td>
<td>12.1</td>
</tr>
<tr>
<td>Plastics</td>
<td>6.4</td>
<td>6.6</td>
<td>6.7</td>
</tr>
<tr>
<td>Metals</td>
<td>2.6</td>
<td>4.0</td>
<td>5.2</td>
</tr>
<tr>
<td>Inerts</td>
<td>4.8</td>
<td>4.6</td>
<td>4.4</td>
</tr>
<tr>
<td>Organic matter</td>
<td>46.9</td>
<td>44.3</td>
<td>44.0</td>
</tr>
<tr>
<td>Total moisture</td>
<td>51.0</td>
<td>49.0</td>
<td>48.0</td>
</tr>
</tbody>
</table>

**DIMENSIONING OF THE SYSTEM**

To establish dimensions of the system and to locate the equipment and transfer stations, it has been hypothesized that the number of treatment plants might range between 1 and 4.

In fact it has been judged that a plant would not be economically justified when designed to serve less than 200,000 inhabitants and transfer stations when designed to serve less than 20,000 or more than 150,000 inhabitants. The objective was therefore to find out, throughout the usual calculation procedures used for the mathematical research, the system giving as lowest, for the above mentioned cases, the function expressing the sum of the following costs:

1. Cost of transportation of waste from transfer stations to the treatment plants.
2. Cost of waste treatment at the plants.
3. Cost of transportation of final products to the utilization facilities.

The best solution of the problem was the one showing a single treatment plant and four transfer stations located as described on the enclosed map (Fig. 2). This map also indicates the site of the cement mill and the site of the controlled landfilling area for rejects and emergency situations.

This solution is justified also by the fact that the lower cost of the waste treatment at a single plant widely compensate the higher transportation costs, and this is due to the employment of suitable compacting vehicles. Shortly, the system was dimensioned as follows: A treatment plant designed to treat yearly up to 366,080 tons of waste and 50,336 tons of sludge in the year 2001, and having a nominal capacity of 80 t/hr.

The foreseen operation data are as follows:

**TABLE 6 PLANT OPERATING TIME**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekly operation hours</td>
<td>60</td>
<td>80</td>
<td>88</td>
</tr>
<tr>
<td>Weekly working days</td>
<td>5</td>
<td>5</td>
<td>5.5</td>
</tr>
<tr>
<td>No. of shift/hours each</td>
<td>2/6</td>
<td>2/8</td>
<td>2/8+</td>
</tr>
<tr>
<td>Coefficient of average</td>
<td>0.86</td>
<td>0.86</td>
<td>0.88</td>
</tr>
<tr>
<td>yearly plant utilization</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No. 4 transfer stations having the following characteristics (1981).

**TABLE 7 TRANSFER STATIONS CHARACTERISTICS**

<table>
<thead>
<tr>
<th></th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from plant (km)</td>
<td>17</td>
<td>21</td>
<td>31</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>incoming waste (tons/day)</td>
<td>94</td>
<td>53</td>
<td>79</td>
<td>115</td>
<td>341</td>
</tr>
<tr>
<td>No. of waste vehicles trips to the plant per day</td>
<td>8</td>
<td>11</td>
<td>10</td>
<td>14</td>
<td>43</td>
</tr>
<tr>
<td>Hoppers capacity (m³)</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>208</td>
</tr>
<tr>
<td>km run by the vehicles</td>
<td>272</td>
<td>462</td>
<td>620</td>
<td>532</td>
<td>1,886</td>
</tr>
</tbody>
</table>

The project foresees that 27 Municipalities transport their solid waste directly to the plant, for a quantity of 282 tons/day in the year 1981.

No. 24 compacting vehicles have been chosen, each having 8 tons capacity. Ten of them will transport waste from the transfer stations to the plant. They will have a commercial speed of 38.6 km/hr, proportioned with the roads situation.

Two vehicles will be destined to transport rejects to the landfilling area and ten to transport RDF to the cement mill. Two vehicles are foreseen as standby, to cover requirements during maintenance operations period.

**THE TREATMENT PLANT**

**RECYCLED PRODUCTS**

The plant is a waste treatment plant operating materials recovery and recycling by a dry process.

The plant allows the recovery of the following products:

1. Digested and stabilized compost obtained with the addition of sewage sludge.
2. Detinned scrap iron pressed in bales.
3. RDF to be used at the cement mill.
4. Glass and other inerts, which, during the first phase, will be sent to landfilling.

From the analysis of the waste and on the basis of the efficiency of the separation/selection system, the following main products will be yearly obtained (t/year):

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Detinned scrap iron t/year</td>
<td>5,120</td>
<td>9,820</td>
<td>15,646</td>
</tr>
<tr>
<td>Digested and stabilized compost t/year</td>
<td>104,790</td>
<td>123,843</td>
<td>136,854</td>
</tr>
<tr>
<td>Glass cullets t/year</td>
<td>10,326</td>
<td>12,325</td>
<td>14,396</td>
</tr>
<tr>
<td>RDF t/year</td>
<td>67,439</td>
<td>96,674</td>
<td>131,735</td>
</tr>
<tr>
<td>Rejects to landfilling t/year</td>
<td>12,231</td>
<td>15,943</td>
<td>18,756</td>
</tr>
</tbody>
</table>
THE MARKETS FOR RECYCLED PRODUCTS

The Compost

The decision to privilege the production of compost arose from the analysis of the local agricultural market, which led to the following conclusions.

There are, in the area, numerous agricultural farms constituted as Companies on the basis of the "cooperative" juridical principle and all of them are involved in growing a type of valuable culture, based on vegetables, olives, grapes, tobacco and fruits. This type of culture is effected over a land area highly favoured by the climate conditions, but still on a land formed by a rocky plateau with very limited cover layer of organic matter.

After having examined the samples of compost obtained from similar waste treatment plants, it was easy to sign an agreement with the Board representing those farms for the sale and delivery of the whole production to them. The referenced technical specification of produced compost is shown in Table 9 below. Reference price of digested and matured compost, delivered free on trucks at the waste treatment plant, was established, in 1979, at $24/t, for a product having 40 percent of water and inert material, as per the above mentioned specification.

<table>
<thead>
<tr>
<th>TABLE 9 MAIN CHARACTERISTICS OF COMPOST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Contents of organic matter on the dry fraction, higher than 60 percent by weight.</td>
</tr>
<tr>
<td>2. Contents of azote (as N) on the dry fraction, higher than 0.8 percent by weight.</td>
</tr>
<tr>
<td>3. Contents of phosphorus (as P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt;) on the dry fraction, higher than 0.5 percent by weight.</td>
</tr>
<tr>
<td>4. Contents of potassium (as K&lt;sub&gt;2&lt;/sub&gt;O) on the dry fraction, higher than 0.4 percent by weight.</td>
</tr>
<tr>
<td>5. Ratio carbon-nitrogen ranging from 10 to 25.</td>
</tr>
<tr>
<td>6. pH higher than 6.5.</td>
</tr>
<tr>
<td>7. Humidity ranging from 30 to 55 percent.</td>
</tr>
<tr>
<td>8. Plastics contained within the dry fraction, lower than 2 percent by weight.</td>
</tr>
<tr>
<td>9. Contents of glass, after screening on 10 mm holes, lower than 3 percent by weight in the quantity not screened out (on the dry fraction).</td>
</tr>
<tr>
<td>10. Size allowing the 90 percent of compost to pass through a screen with 20 mm holes.</td>
</tr>
</tbody>
</table>

There is an allowance of ±5 percent on the above mentioned values, due to the imprecision of scales.

The fact is that the surface destined to agriculture in this province was 630,000 acres, out of which 1.8,000 destined to olive growing and 94,000 acres to grape growing, gave and gives assurance as to the capacity of the market for this product.

The Fuel

The decision to produce RDF, instead of recovering and recycling paper and plastics, was taken thanks to the presence of a cement mill in the area, at Galatina.

This cement mill is equipped with two production lines, one having a capacity of about 900 t/day, and the other having a capacity of about 300 t/day. Both lines operate by a dry process. The first line has a rotary kiln BREDA-KRUPP, and vertical heat exchanger, direct, with chambers one over the other.

The second line is equipped with a rotary kiln Hambolt, and heat exchanger, with cyclons placed one over the other.

The fuel oil so far used is of the "thick" type (d = 0.89 kg/l; 9600 kcal/kg LHV).

The total consumption of fuel oil, during normal operation, thus amounts to about $3.8 + 1.6 = 5.4 \text{ t/hr}$, equal to $5400 \times 9600 = 51,840,000 \text{ kcal/hr}$.

Now, in order to substitute 50 percent of the fuel oil so far used and supposing that the RDF has an average LHV of 3,000 kcal/kg, it would be necessary:

$$\frac{51,840,000}{2 \times 3,000} = 8,640 \text{ kg/hr of RDF}$$

i.e. $8,640 \times 24 \times 7 = 1,450 \text{ tons/week}$, against an estimated availability of about 1,300 tons/week during 1981.

To use correctly the RDF up to a capacity of 1,450 tons/week, the cement mill will be, of course, equipped with suitable systems for collecting, stockpiling, reclaiming, proportioning, transport and combustion. It has been pointed out that, thanks to the special technologies used for the realization of these systems, it has entirely avoided any physical contact by the cement mill personnel with the RDF.

Reclaiming and proportioning of the RDF from the pit is carried out automatically by an extractor-proportioner-feeder system, with adjustable speed, controlled from a long distance. Transportation and proportioning to the burners of the kilns is effected pneumatically.

The air needed for the above pneumatic transportation is taken inside the building which includes the RDF pit, with the aim also to keep the pit itself in negative pressure and thus avoid the escape of dust and smell.

The air above is consequently conveyed through the openings of the burners to the kilns, together with the transported RDF, and acts as primary combustion air.
It is foreseen for both lines a medium flame temperature of about 1,800°C and a temperature of fumes leaving the rotary kilns of about 1,000°C; consequently, the retention time and the turbulences related to the temperature spaces above considered, are the following:

<table>
<thead>
<tr>
<th>TABLE 10 ROTARY KILNS DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retention time (sec)</td>
</tr>
<tr>
<td>Line 1 Turbulence (RE)</td>
</tr>
<tr>
<td>Line 2 Turbulence (RE)</td>
</tr>
</tbody>
</table>

As fumes of both lines stay totally for more than 6 sec at a temperature ranging between 1,800 and 1,000°C, with turbulences always higher than 50,000 Re, and so discharge of micro-polluting organic materials of PCDD and PCDF type are to be excluded.

The results declared and considered achieved by the winning Company, on firing similar RDF at other cement mills both by injection and by adding to the crude oil, granted the Company the signature of a draft of agreement for the sale to the local cement mill of an RDF having the characteristics shown in Table 11.

The price established in the above draft of agreement is the following:

\[ \text{Price per ton RDF} = \frac{\text{CNV}_1}{\text{CNV}_2} \times C \]

with

- \( K \) = index between 0.3 and 0.7
- \( \text{CNV}_1 \) = heat net value of RDF
- \( \text{CNV}_2 \) = heat net value of oil (5-20 degrees Engler)
- \( C \) = price per ton of oil

Index “K” represents a penalty factor related to the content of water, inerts and chlore in respect of the technical specification under reference.

At the best possible conditions, with \( K = 0.7 \), the RDF price will be equal to the 17.5 percent of the fuel oil price.

### Other Products

**Scrap Iron**

The market for this product does not require particular investigation thanks to the considerable need of scrap iron from steel mills and casting mills, and thanks also to the characteristics of the purified, detinned and packed product.

No investigation so far has been carried on with regard to the possible market for glass cullets, which will be sent to landfilling, as provided for in the present plans, but which still have alternative possibilities of utilization in the preparation of concrete, the construction of anti-slippering pavements, the production of emery paper, etc.

### THE TREATMENT PROCESS

A block diagram of the plant is shown in Fig. 3. As already stated, it is a completely dry treatment process. The plant was dimensioned to process the whole quantity of waste delivered to it during the day.

The Committee granted the preference to this specific process-system for the following main reasons:

1. Dry process.
2. Simplicity of the flow sheet.
3. Absence of pulverizing mills.
4. Low energy consumption.
5. Production of compost duly purified from inerts and plastics, and digested by means of a controlled aerobic digester, which provides for a retention time adequate to guarantee the operating personnel under the sanitary aspect, as well as to start the fermentative reactions which will take place at the stockpiling yard.
6. RDF duly purified from inerts and heavy materials.
7. Scrap iron thermally purified and de-tinned.
8. Reduced quantity of rejects to be sent to landfilling.
9. Possibilities offered by the highly flexible process-system to add, at a market suitable date, a section for the recovery of waste paper and light film plastics.

The treatment system consists of four lines, 20 t/hr capacity each line (Figs. 4 and 5).

The Committee was further confirmed in its evaluations following a deep analysis of the operating performance of an experimental working line by 10 t/hr capacity (50 percent of the proposed single line) carrying out the whole treatment process, and following the examination of the products resulting from this line.
A problem in common to all the Municipalities by this time is the treatment of solid waste and sewage of the towns, so as to be able to put in the environment substances which can respect the chemical-physical characteristics imposed by the laws in force.

The plants for solid waste treatment, due to logistical, technical and historical reasons, are generally located in different places regarding the plants treating sewage.

The unification in a single place, one plant and one operation of the plants for solid waste and sewage, is desirable from many points of view.

It is to be remarked that, while it is easy to confer in the same place solid waste (which are transported on trucks), we cannot make the same assertion for waters which normally move by gravity and are influenced by the orography of the ground.

The unification of solid waste and sewage treatment plants is advantageous for the following reasons:

1. As to the location, we have the advantage of installing the plants, which are generally unwelcome by the population owing to psychological reasons, in only one place.

2. The plants, by the unification, take mutual advantages such as:

   (a) Water treatment plants need electric energy; waste treatment plants can be manufactured to generate electric energy for internal use and for selling the exceeding part to the water treatment plant.

   (b) The water treatment plant can supply water for waste treatment, i.e. to wash combustion flue gases and to cool turbine condensers for generation of electric energy.

   (c) The waste treatment plant may receive, without any difficulty, sludges coming from the water treatment units (mixing them to the compost or, for instance, burning them). Otherwise, these sludges may create a considerable disposal problem.
(d) The waste treatment plant, in case it is an incineration unit, may easily utilize the biological gas produced into the eventual digesters of the water treatment units.

The plant is centralized also as far as the services, maintenance, control management, personnel, etc.

This involves considerable advantages in respect of the economic point of view.

PROJECT DATA

In the area of the Crati valley, surrounding the Cosenza city, the studies carried out have emphasized the possibility to collect in a single area all waters coming from 10 Municipalities (Fig. 6).

It might be possible to deliver to this area the waste coming from 30 Municipalities.

TABLE 12

<table>
<thead>
<tr>
<th>Season average and yearly average of total composition of solid waste</th>
<th>Spring and fall</th>
<th>summer</th>
<th>winter</th>
<th>Yearly average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical, chemical and physical analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screen under 20 mm</td>
<td>percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cellulosic material</td>
<td>percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(out of which: paper textiles, wood)</td>
<td>percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastics</td>
<td>percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metals</td>
<td>percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inerts</td>
<td>percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic matter and miscellaneous</td>
<td>percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel materials</td>
<td>percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noncombustible materials</td>
<td>percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flying matters</td>
<td>percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ashes</td>
<td>percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LHV</td>
<td>kcal/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical and physical analysis of screened matter under 20 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LHV kcal/kg

| Water | percent | 54.55 | 42.64 | 44.30 | 49.47 |
| Fuel matters | percent | 21.13 | 25.81 | 22.61 | 22.56 |
| Noncombustible materials | percent | 24.31 | 31.55 | 33.09 | 28.37 |
| Flying matters | percent | 46.82 | 46.82 | 37.41 | 44.02 |
| Ashes | percent | 45.13 | 46.65 | 55.35 | 48.36 |

These wastes have been analyzed and the results are shown in Table 12.

This table shows the considerable quantity of organic substances which is coupled with the low calorific value of waste.

There exists the difficulty of burning raw refuse; consequently, it was decided to base the solid waste treatment plant on compost production, and to incinerate the remaining part of the same waste.

Compost also eliminates a considerable quantity of humidity, and the resulting rejects have no difficulty in burning.

In fact, it is expected that the rejects calorific value exceeds 2,000 kcal/kg.

Table 13 reports the number of inhabitants served by the plant and the quantity of solid waste and water arriving at the same time.
Besides, there are the extrapolations of these quantities during the next years.

Table 13

<table>
<thead>
<tr>
<th>Years</th>
<th>1981</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of inhabitants being served by the plant</td>
<td>130,000</td>
<td>200,000</td>
</tr>
<tr>
<td>Average sewage delivery m³/hr</td>
<td>1,500</td>
<td>2,200</td>
</tr>
<tr>
<td>Solid waste and sludge quantity (70 percent water) ton/day</td>
<td>150</td>
<td>205</td>
</tr>
<tr>
<td>ton/year</td>
<td>55,000</td>
<td>75,000</td>
</tr>
</tbody>
</table>

Considerations on the energy balance.

The data reported here are considered as valid for Southern Italy.

Average consumptions of electric energy for water and solid waste treatment plants:
- Incineration plant with production of electric energy (capacity lower than 100 t/day) 80 kWh/ton
- Compost production plant 30 kWh/ton
- Water treatment plant 0.2 kWh/m³

From the waste analysis, the production of compost can be estimated as 60 percent.

Heat recovery being transformed into electric energy is of about 18 percent.

From the above data, we can say that the total consumption of electric energy for the plant sized at 1995 are about 8,500,000 kWh/year against a production of about 13,000,000 kWh/year.

From these considerations, one can derive that the possibility of complying with the energy demand of the whole plant seems to be confirmed.

The “Cassa del Mezzogiorno” has called for a tender concerning the manufacture of a plant which can reach, according to the above mentioned criteria, the following results:

1. To carry out the sewage treatment, in observance of the laws in force, by obtaining water for irrigation.
2. To carry out waste treatment by means of a compost production plant, to which it would be possible to mix biologic sludges resulting from the water treatment plant.
3. To utilize rejects coming from the compost production plant in order to generate electric energy used for inside consumptions and a possible sale to ENEL (State Power Authority).

THE LAMEZIA TERME PLANT

The Municipality of Lamezia Terme is located in Calabria (see Fig. 6) in the central area of the Tyrrhenian versant. It has a population of approximately 70,000 inhabitants and a territory that is quite suitable for the activation of an industrial development process.

To aid an attentive study performed in this territory, specific regulations have been laid down for the industrial settlements and the various infrastructural services, providing an area of 3 km² for the latter.

GENERAL POLLUTION TREATMENT SCHEME

Within the framework of services and infrastructures, special care has been devoted to the treatment of both liquid and solid wastes to the purpose of safeguarding against any risk of pollution all the nearby territory with its sea-side resorts and tourist-oriented activities.

The terms of this environment protection policy have been defined, starting from the year 1974, with a treatment scheme including the installations serving the industrial settlement as well as the following:

1. The Lamezia Terme Municipality, with its three main built-up areas and its eight smaller centers, with a present population of 70,000 inhabitants and, insofar as liquid waste is concerned, 80,000 inhabitants in the year 2001.
2. The territory of all Central Calabria, spanning from the Catanzaro Municipality to the Vibo Valentia Municipality (75 km) passing through Lamezia, with a resident population of 150,000 inhabitants insofar as the treatment of urban and industrial wastes is concerned.

The treatment platform is organized as follows (Fig. 7):

1. Treatment plant for the urban-type sewage within the built-up area and 1st flow industrial waste water in its entirety, with 2nd and 3rd flow industrial waste water treatment limited to the share that may be led back to the former after a preliminary treatment.
2. Treatment plant for the second and third flow industrial waste water involving organic and inorganic sewage that may not be treated in the first plant, as well as for the tank-ship ballast water.
3. Treatment plant for the urban sewage of the inhabitants of the Lamezia Terme Municipality as a whole, piped by means of a 10 km long sewer.
4. Treatment plant for the liquid and solid industrial wastes of the industrial settlement and for the solid urban waste of the district including the Catanzaro, Lamezia Terme, Vibo Valentia and some other smaller Municipalities.

TECHNICAL DESCRIPTION

The details of the technical-functional works are illustrated below.

FIG. 6 COSENZA & LAMEZIA TERME PLANTS
1 - SEWAGE TREATMENT CONTROL ROOM AND POWER STATION
2 - ACCUMULATION AND PRIMARY TREATMENT TANKS FOR INDUSTRIAL SEWAGES
3 - INDUSTRIAL SEWAGE NEUTRALIZATION
4 - OXIDATION TANKS
5 - FINAL SEDIMENTATION TANKS
6 - TERTIARY TREATMENTS
7 - INDUSTRIAL SLUDGE DEWATERING
8 - DENITRIFICATION TREATMENT OF HIGHLY CONCENTRATED SEWAGES
9 - TREATMENT OF BALLAST WATER
10 - INCINERATORS FOR INDUSTRIAL WASTES AND REJECTS
11 - FLUEGAS TREATMENT AND WASH WATER TREATMENT
12 - TANKS FOR INDUSTRIAL LIQUID WASTE TO BE INCINERATED
13 - ACCUMULATION PITS FOR INDUSTRIAL WASTE AND SURPLUSES OF SOLID URBAN WASTE
14 - COMPOSTING BUILDING
15 - URBAN SLUDGE DEWATERING
16 - URBAN SOLID WASTE AND SLUDGE COMPOSTING AREA
17 - COMPOST ACCUMULATION AND MATURATION
18 - PRETREATMENT OF URBAN SEWAGE
19 - PRIMARY SEDIMENTATION OF URBAN SEWAGE
20 - URBAN SEWAGE BIOLOGICAL OXIDATION
21 - FINAL SEDIMENTATION OF URBAN SEWAGE
22 - SEWAGE DISINFECTION
23 - THICKENING AND PUMPING OF URBAN SLUDGE
24 - ENTRANCE AND WEIGHTING STATION

FIG. 7 GENERAL LAYOUT LAMEZIA TERME PURIFYING SYSTEM
FIRST FLOW TREATMENT PLANT

The plant has been operating since 1979 and has an overall treatment capacity of 6,600 m³/day (Table 14).

The functional scheme includes: rain water catchment basin; preliminary aeration and equalization tanks; clariflocculation; pH correction and active sludge biologic treatment.

The biological excess slimes and the filter backwashing water are recycled prior to the clariflocculation.

The sludges are extracted from the primary sedimentation and, after aiding their thickening and dehydration with centrifuges, they are delivered to the incinerator of the solid waste treatment section.

The complete cycle of the aforementioned plant is performed for rain water and the already mentioned industrial effluents, while sewer and second flow industrial wastes (Table 15) are introduced just prior to the oxidation tank process.

To further their specific preliminary treatment, it is also possible to introduce into the said oxidation tank (having a capacity of 10,000 m³) the ballast waters, should they still contain soluble organic substances as well as the third flow denitrified waters.

The process consists of the following:

1. Dilution with first and second flow waters to reduce the salinity, bringing it within limits acceptable to the development of the bacterial flora.
2. Addition of methanol as an organic substrate.
3. Acidification to neutralize the alkalinity that results during the anaerobic biological phase.
4. Anaerobic denitrification reaction.
5. Aerobic basin for nitrogen proportioning with final settling.
6. Sludge recirculation to the anaerobic basin.

The ballast water discharged by the vessels that dock in order to load finished liquid products are initially stored in a 500 m³ tank and are subsequently treated, at a rate of 20 m³/hr, in a continuous line. The process is as follows: Flocculation with pH correction; sedimentation and deoleation within a basin; flotation further to polyelectrolyte proportioning. Should the water contain, after this treatment, just insoluble products, it will be possible to discharge it into the sea; should instead the presence of soluble organic pollutants be ascertained, the water shall be delivered to the oxidation basin of the main installation.

| TABLE 14 CHARACTERISTICS OF THE TREATED SEWAGE (1ST FLOW) COMING FROM THE INDUSTRIAL AREA |
|---------------------------------|-----------------|-----------------|-----------------|
| Civil wastes: 440 m³/day | BOD 200 mg/l | COD 400 mg/l | S.S. 600 mg/l |
| Meteoric water: 1,060 m³/day | Sodium acetate 880 mg/l | Methanol 1,750 mg/l | Aniline 370 mg/l | Sodium formate 7.5 mg/l | Sulphates, chlorides 4,700 mg/l |

<p>| TABLE 15 CHARACTERISTICS OF THE TREATED SEWAGE (SECOND FLOW) COMING FROM THE INDUSTRIAL AREA |
|---------------------------------|-----------------|-----------------|-----------------|
| Working process wastes: 460 m³/day, including: | Nitrophenols 600 mg/l | Methylendianiline 1,400 mg/l | Aniline 370 mg/l | Methanol 35,500 mg/l |</p>
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>BOD</th>
<th>COD</th>
<th>S.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorides/sulphates 39,500 mg/l</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3rd flow and ballast water treatment plant

The 3rd flow wastes, amounting to 288 m³/day, consist of toluene, nitrobenzene and other undefinable organic compounds but with nitrates of up to 24,900 mg/l.

THE LAMEZIA TERME MUNICIPALITY URBAN SEWAGE TREATMENT PLANT

The basic data are as follows (see Table 16):

The plant utilizes the existing facilities and works side by side with the plant mentioned above. The plant is of the biological, active sludge type.

The sludge treatment provides for their thickening, conditioning with additives and mechanical dehydration to the purpose of using them in the production of compost from urban solid wastes.

Should controls under way point to the need to utilize the purified water for agricultural or industrial purposes, it will be necessary to provide for the installation of suitable filters prior to its utilizations.
TABLE 16 CHARACTERISTICS OF THE WASTE WATERS COMING FROM THE LAMEZIA TERME RESIDENTIAL AREA

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Present population</th>
<th>Population in 2001</th>
<th>Present water supply</th>
<th>Future water supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present population</td>
<td>75,000 inhabitants</td>
<td>80,000 inhabitants</td>
<td>400 l/inhab./day</td>
<td>500 l/inhab./day</td>
</tr>
<tr>
<td>Characteristics</td>
<td>BOD 4,800 kg/day</td>
<td>S.S. 7,200 kg/day</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SOLID WASTE TREATMENT PLANT

The solid waste treatment plant had originally been designed for the treatment of just the waste produced by the industries present in the area and a part of the urban wastes of the Lamezia Terme Municipality.

The failure of a few industrial complexes to start-up have made it necessary to provide for a thorough restructuring of the plant in order to allow it to treat (as mentioned above) all the urban solid wastes produced in Central Calabria. The treatment capacity of the plant results to be as follows:

- Urban solid wastes: 36,000 ton/year
- Sludges resulting from the urban sewage treatment plant: 8,300 ton/year
- Industrial solid wastes: 5,000 ton/year
- Liquid and oily industrial wastes: 2,500 ton/year
- Sludges resulting from the industrial waste water treatment plant: 3,000 ton/year

The characteristics of the urban solid wastes are listed in Table 17, while insofar as industrial wastes (solid, liquid and oily) are concerned we have a heating power of approximately 4,500-5,000 kcal/kg.

Taking into account the characteristics of the available wastes and the highly agricultural vocation of the area (production of wine, strawberries, green houses, etc.), for the purpose of making the most of the intrinsic possibilities of these wastes, it was deemed advisable to realize a mixed, compost-producing/incinerator plant.

Hence the assumption taken as a basis of the process: to recover the maximum possible amount of wastes, through economically sound and hygienically unexceptionable solutions, regarding both the installation and its functionality.

These may be summarized as follows:

1. To transform into compost the biodegradable organic fractions (together with sludge) after having purified them of any pollution substance so as to obtain a product suitable for agriculture.

2. To provide for the incineration of both the residual part of wastes discarded after the aforementioned selection operations, and the industrial wastes by means of a “two-phase” combustion process to be realized through the use of a new type of rotary furnace with equicurrent combustion.

3. To recover from the combustion residues the fine ashes, rich in carbon, that are added to the compost to which they contribute phosphorous and potassium salts as well as alkali and microelements that are very useful for agricultural purposes. Furthermore, to recover the ferrous metals that, after being cleaned and pressed into bales will be easily sold on the market.

4. To release in the environment the smallest possible amount of residues, in a no longer dangerous form:
   - (a) Transparent gaseous releases, free of unburnt matter, odorless and duly filtered and cleaned.
   - (b) Inert ashes, free of putrescible unburnt matter, in an amount weighing less than 7-8 percent of the treated wastes.

PROCESS ARRANGEMENT

Urban solid wastes and assimilated waste matter (Fig. 8) are unloaded by the truck into the main feeder pit (pos. 2) where they are fed to the processing line.

Should the feeder pit be full and/or in case of the simultaneous arrival of various trucks, the waste load may be discharged into the nearby pit (pos. 1) served by an overhead travelling crane equipped with a remote-controlled bucket.

From the control hut the driver will provide for the waste transfer from the pit into the main feeder — an operation carried out by means of the aforementioned overhead travelling crane.

The industrial wastes that are not suitable for compost or the wastes coming from infected areas shall instead be dumped into the pits of rejects to be incinerated (1a) together with the residues of the composting process.
The solid urban wastes shall pass from the main feeder (pos. 2) into a Zimothermic Mill (pos. 3), (Ferrero - Italian patent) suitably designed to carry out a selective grinding of wastes, their perfect homogenation and thorough oxidation.

This Mill is a large cylindrical body, rotating quite slowly, where the wastes that are introduced, torn to pieces and compressed by means of a screw conveyor, are almost subjected to a carding process due to the different relative speed of the ideal strata.
into which the material, continuously collapsing over, arranges itself.

Any possible fermentation process is blocked within the Zimothermic Mill by an in-depth oxidation.

Wastes are subjected to a selective grinding. Organic fractions are copped up and mashed.

On the contrary, glass, plastic materials, rubber, wood, etc., are preserved into fractions or shreds of significant size and may thus be separated by means of a subsequent rotary screening (pos. 4).

These pieces are delivered into the scrap pit (1a) and are subsequently incinerated in the furnace section (12). The tiny organic fractions that are recovered by the screen (4) shall be transformed into compost.

Prior to being subjected to the composting operations, the said fractions are subjected to a further pollutant selection treatment by means of two, recoil-type separators (5) in such a way that instead of being pulverized and lost in the mass to be turned into compost, they are separated and delivered to the incinerator (12).

The purified organic fractions are subsequently deferrated with the electromagnetic extractor (6) and delivered into the continuous blade-mixer (7).

Other materials are also delivered into the aforementioned mixer to form the mixture that must be turned into compost, namely:

1. Sewer sludges with 20-25 percent of solids, resulting from the urban sewage treatment plant; they are removed by the discharging conveyor belts of the dehydrating machines (1b) and are suitably proportioned.

2. Eventual mineral additives (phosphorite, magnesite, lime) or fertilizers (urea, complex chemical fertilizers) withdrawn from the silo (1d) and proportioned with (2d).

3. A portion of material being turned into compost, rich in bacterial colonies, recycled by the Bio-Tunnel with the batcher (2e).

4. A fraction of ashes resulting from the incinerating furnace (12) with the batcher (2f).

The amounts of the aforementioned contributions are accurately proportioned by means of the batching devices (b, d, e, f).

The mixture that must be turned into compost is prepared in the blade mixer (7) and is transferred by conveyors into the Bio-Tunnel (8).

The Bio-Tunnel (Figs. 9-10) is a closed building where, by means of suitable equipment and under ideal environmental conditions, it is possible to carry out a series of operations that lead to a rapid and total sanitization and composting of the mixture of organic material.

The fumes and gaseous products of the oxidation of the composting mass are exhausted at the very foot of the heap and delivered into a toroidal chamber located around the lower section of the filter-silo (10).

This filter-silo (Fig. 11) is filled from the upper part with stabilized compost, coming from the Bio-Tunnel, that constitutes the filtering material of the fumes mentioned above. After being purified, these
fumes are drawn in by a second exhauster (9) and delivered into the incinerating furnace (12). The stabilized compost coming from the Bio-Tunnel passes on to the filter silo keeping it continuously filled up.

A share of the said compost, withdrawn from the bottom by a batcher (2e) is recycled and enters once again into the Bio-Tunnel.

The remaining part is transferred to the compost stocking yard (11) and is ready to be put on the market.

We may now deal with the dimensioning of the plant by assuming as a calculation basis a population to be served of 150,000 inhabitants + 25,000 summer residents and considering also 80,000 inhabitants being served for the calculation of the treatment of the sludges resulting from the urban liquid waste treatment.

The plant is in operation 6 days per week and the per capita daily output of USW amounts to approximately 0.65 kg. Therefore, being $150,000 \times 0.65 \times \frac{7}{6} = 113,750$ kg/day, we may assume
that the amount of USW to be treated every working day ranges around 115 tons.

This means that a single Zimothermic Mill (Type MZT/15) shall be able to receive and process such amount.

Furthermore, the selected type of Zimothermic Mill is able, simply by speeding up or slowing down its rotation speed, to increase or decrease its treatment capacity. In such a way, it is fully able to cope with peak summer loads due to the presence of tourists.

Likewise, two of our SE 100/250 recoil-type separators are more than adequate to receive the organic fraction passed through the rotating screen, keeping into account the fact that it ranges around 60 percent of the arriving wastes and that one of our screens is able to treat 12.15 t/hr. of material.

We may now deal with the dimensioning of the Bio-Tunnel.

We may start with the calculation of the amount of sludges coming from the plant serving 80,000 inhabitants.
Considering that each inhabitant produces a daily amount of approximately 72 g of dry sludge, we obtain:

\[ 80,000 \times 0.072 = 7,700 \text{ kg/day of dry sludge} \]

that brought back to a 75 percent humidity — this being the percentage acceptable for mixing with the organic substance entering the Bio-Tunnel — gives:

\[ 5,700/0.25 = 22,800 \text{ kg/day of sludges with 75 percent H}_2\text{O} \]

which, taking into account the fact that the plant works just six days a week, gives a total of:

\[ 22.8 \times 7/6 = 26.6 \text{ t/working day} \]

Having ascertained that this is the amount of sludges entering the Bio Tunnel, we must now verify what is the share of rough solid wastes that goes together with these sludges.

Since wastes contain from 40 to 45 percent of organic rejects and a cellulose fraction ranging between 26-28 percent, considering that both fractions are lost to a certain extent in the unexploitable waste residues and in the limited evaporation and decarbonization within the cylinder, the fraction to be turned into compost reaching the Bio-Tunnel ranges around 60 percent of the arriving USW, with a humidity of approximately 55 percent.

Considering in the end that 26 percent of the out-going compost, with a 40 percent humidity, is recirculated, at the Bio-Tunnel entrance we obtain the following fractions:

<table>
<thead>
<tr>
<th>t/d compostable fraction (115 x 0.6)</th>
<th>H\textsubscript{2}O</th>
<th>Total H\textsubscript{2}O</th>
</tr>
</thead>
<tbody>
<tr>
<td>69.0</td>
<td>55.0</td>
<td>38.0</td>
</tr>
<tr>
<td>sludges with 75 percent H\textsubscript{2}O</td>
<td>26.6</td>
<td>75.0</td>
</tr>
<tr>
<td>recycle with 40 percent H\textsubscript{2}O</td>
<td>21.8</td>
<td>40.0</td>
</tr>
<tr>
<td>117.4</td>
<td>56.8 avg.</td>
<td>66.7 tot.</td>
</tr>
</tbody>
</table>

It is possible to note that the humidity of the in-coming mixture is lower than the upper acceptability threshold (60 percent).

One may consider that approximately 38 percent of fresh wastes turn into unexploitable waste residues, that is:

\[ 115 \times 0.38 = 44 \text{ tons} \]

With a production of ashes ranging around 25 percent, we obtain:

\[ 44 \times 0.25 = 11 \text{ tons,} \]

about half of which are less than 5 mm — 11 \times 0.5 = 5.5 tons, consisting of fine and dry ashes.

The addition of these fine and dry ashes to the mixture fed into the Bio-Tunnel, leads to a new mixture having the following humidity:

\[ \frac{56.7}{117.4} = 0.54 = 54 \text{ percent H}_2\text{O} \]

Considering a loss during the composting process of approximately 20 percent of dry substance, ashes excluded, we will have:

\[ 117.4 \times 0.45 = 52.83 \text{ initial dry substance} \]
\[ 52.83 \times 0.8 = 42.26 \text{ residual dry substance} \]

Taking this substance back to its final 40 percent humidity content, after having added the fine ashes that are supposed to be humidity-free, we get:

\[ 42.26 + 5.5 = 47.76 \]
\[ \frac{47.76}{0.6} = 79.6 \text{ tons of compost coming out of the Bio-Tunnel} \]

Therefore, the resulting loss is: 117.4 - 79.6 = 37.8 tons.

After having deducted the recirculation of approximately 22 tons, the final available compost results are:

\[ 79.6 - 22 = 58 \text{ tons} \]

The average total amount of material being turned into compost and present in the Bio-Tunnel will, therefore, be as follows:

<table>
<thead>
<tr>
<th>Days of introduction</th>
<th>In-going tons</th>
<th>Out-coming tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 days</td>
<td>117.4</td>
<td>79.6</td>
</tr>
</tbody>
</table>

\[ 197 \times \frac{1}{2} = 98.5 \times 14 = 1,379 \text{ tons} \]

With an average specific weight in the Bio-Tunnel = 0.62 we obtain:

\[ \frac{1,379}{0.62} = 2,224 \text{ m}^3 \]

The useful Bio-Tunnel sections is 12 \times 4 = 49 m\textsuperscript{3}. The respective length, taking into account that the length of a section (14 m) may not be used since it houses the turning over equipment, is

\[ \frac{2,224}{48} = 60 \text{ m (length of the Bio-Tunnel)} \]

Let's now consider the dimensioning of the
Fig. 12 Incineration Section

1 - Rejects and Industrial Solid Waste Pit
2 - Bridge Crane
3 - Charging Hopper
4 - Rotary Furnace
5 - Post-Combustion Chamber
6 - Ash Evacuation
7 - Emergency Stack
8 - Furnace Scrubber
9 - Furnace Fan
10 - Stack
stocking yard, designed for a two-month (60 day) storing capacity. The compost obtained every day (7 days a week), after deduction of the recirculation amount, (with a specific weight of 0.65) amounts to 58 tons as we have already specified.

Then: \[
\frac{58}{0.65} = 89 \text{ m}^3
\]

\[
89 \times 60 \times 6/7 = 5,340 \text{ m}^3
\]

Being the yard useful section equal to 120 m² with a 8 m loss due to encumbrances we obtain:

\[
\frac{5,340}{120} + 8 = 53 \text{ m of yard length}
\]

INCINERATION SECTION

The material is withdrawn from the pit of rejects (1) (Fig. 12) by a special grab (2) and entered into the hopper of the rotating furnace (4) that works in equicurrent in order to realize a two-phase combustion. In this furnace the wastes are subjected to a partial distillation; most of the organic substances, dissociating, cause the production of carbon ashes that act as reducing elements thus protecting from oxidation the metals being present. Therefore, metals are not oxidized and come out of the furnace together with the ashes practically un-astered and may be recovered.

Glass does not reach the melting point and, therefore, comes out of the furnace unaltered.

The combustion gases enter a post-combustion chamber (5) where duly preheated air is introduced to provide for the total combustion of the gases. These are cleaned by means of wet filters (8) and released in the atmosphere by means of a stack (10), in compliance with the laws in force.

The cooled ashes and slags are subsequently defferized by means of an electromagnetic extractor (6).

The recovered and packed iron is stored to be subsequently sold to steelworks.

The defferized slags are screened through a rotating screen.

The fine fractions of less than 3-4 mm are proportional and recycled to the mixer and used in the composting process since they contain alkali, K and P salts and a large quantity of carbon.

The larger fractions that are held back by the screen are sent to the dump since they consist of slags.

The remaining intermediate fraction contains for the most part glass, nonferrous metals and various types of inerts.

Should it be deemed advisable from an economic standpoint, this fraction may be subjected to further treatments for the recovery of glass and nonferrous metals.

The final residue to be sent to the dump ranges around very slow percentages (7-8 percent). It consists of inert and nonpolluting substances.

The incineration plant will have to work 7 days a week and will provide for the disposal of unexploitable rejects and industrial wastes.

Since the organic matter coming out of the Zimothermic Mills amounts to approximately 62 percent of the total, the unexploitable rejects to be delivered to the incinerator plant will amount to 44 t/day. The plant will, therefore, have a 50 t/day capacity.

The thermal load allowed for by an incinerator line is \(8 \times 10^6\) kcal/hr, with short-time peaks of up to \(92 \times 10^6\) kcal/hr; the thermal load ascribable to unexploitable rejects result to be (LHV = 3,000 kcal/kg) equal to:

\[
\frac{50,000}{24} \times 3,000 = 6,250,000 \text{ kcal/hr}
\]

Therefore, a single incineration line will suffice to absorb the whole capacity while the second one shall be utilized to incinerate the industrial wastes that, as we have previously mentioned, amount to approximately 30 ton/day with a maximum LHV of 5,000 kcal/kg and, therefore:

\[
\frac{14,000}{24} \times 5,000 = 2,950,000 \text{ kcal/hr}
\]

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Key Words
Co-disposal
Composting
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Refuse Derived Fuel

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