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SOLID WASTE AND SEWAGE SLUDGE MANAGEMENT

FOR THE CITY OF SEOUL, KOREA

A DISSERTATION

SUBMITTED TO THE GRADUATE SCHOOL

in partial fulfillment of the requirements for the

degree of

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BY

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Norman, Oklahoma

1975

SOLID WASTE AND SEWAGE SLUDGE MANAGEMENT

FOR THE CITY OF SEOUL, KOREA

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ABSTRACT

The solid waste and sewage sludge management for the city of Seoul, Korea, should be solved by multiple approaches through examining the methods being used in the city and reviewing the methods used presently in other parts of the world. To develop a best choice of management of solid waste, the choice should be based on economical, sanitary, and beneficial practices, not only for the city of Seoul but also for the country of Korea.

The multiple approaches used in this work are (1) basic planning of the solid waste -- how to approach the aim of the subject; (2) development of waste generation -- how much and what kind of waste generates in the area, both now and in the future; (3) conceptual design of alternatives -- comparison of each alternative based on a conceptual design; (4) alternative selection -- selection of the best alternative through an unbiased and rational evaluation; (5) Korean coal-ash studies -- how the major portion of solid waste in the city could be used beneficially; (6) evaluation and requirements of compost in Korean land -- since the best alternative is the composting practice, composting could be beneficial for the Korean land; and, (7) policy decisions (in Addendum) -- authorization of an advisory committee to act on environmental policy decisions and management methods.

Based on the combined information in this work, the composting method along with sanitary landfill practices could be the most beneficial approach to management of waste, and the final product from the composting plant is highly beneficial for permanent Korean agricultural use.

The solid waste model ($Y_1 = 0.5276 + 8.40 \times 10^{-6} X_1 + 0.2019 X_2$) could predict approximate amounts of solid waste generation in the future. Korean coal ash could be used for the construction and agricultural purposes of the city and country.

Finally, the development of an advisory committee at the present time is highly recommended for better management and protection of environmental problems in the city of Seoul and the country of Korea.

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FOR THE CITY OF SEOUL, KOREA

Chapter I

INTRODUCTION

General

The problem of solid waste and sewage sludge management in the city of Seoul, Korea, which has become serious in recent years, can only be solved by applying integrated management system concepts. Consequently, the various city and national governmental units with operational or administrative authority in this area must develop a unified approach to ensure safe and efficient handling, collecting, transporting, treatment or disposal, and recycling of these wastes while satisfying local and national needs and management objectives. This study is an attempt to answer significant and fundamental problems of waste management which should be solved now and in the future for the city of Seoul. The major problem involves the management of municipal solid wastes, which constitute the largest portion of the wastes in the city of Seoul. Minor problems which are also included in this study are related to sewage sludge and night soil sludge management.

Figure 1 shows the location of existing and proposed sewage and night soil treatment plants.[1-3] The sewage treatment plants are designated as channel treatment plants because raw sewage is discharged into stream channels and subsequently diverted into sewage plants on the streams for treatment.

The general methodological approach to these problems requires the development of data on the sources of the wastes and on economical considerations, agricultural usages, and environmental benefits to both the city of Seoul and to the nation. From this information, evaluations could be made and comparisons with alternative systems undertaken, with the final objective being the development of a model for the management of solid waste.

An important phase of this study is to develop a method of recovering and recycling the valuable organic and inorganic materials that the city now "throws away" directly onto badly needed land.

The amount of solid waste and sewage generated by the people living in the city of Seoul is as high as that of other densely populated areas of the world (Municipal Refuse Disposal (APWA), 1970, and Bond and Straub, 1973). Primary problems associated with this waste generation are: how should the wastes be disposed of without endangering public health and welfare; how can the valuable organic and inorganic substances in the refuse be recovered and reused; and how can the quality of the

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[1,2,3] Reports of the Seoul Metropolitan Government, 1970, 1972, and 1967.

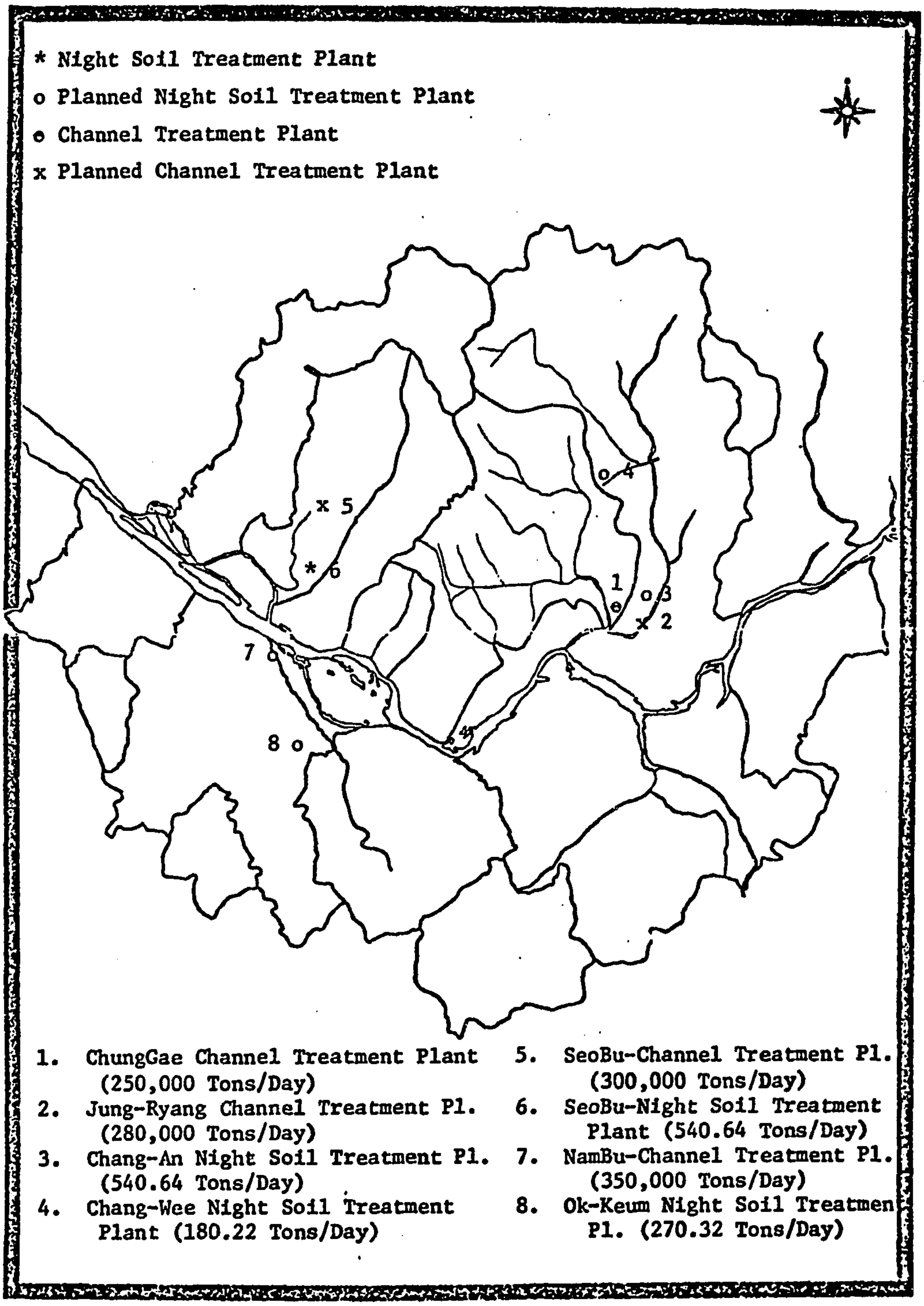


Figure 1
MAP OF LOCATION OF NIGHT SOIL AND CHANNEL TREATMENT PLANTS AND THEIR CAPACITIES

environment be restored to again be worthy of the term "CLEAN WATER, GREEN MOUNTAIN WITH BLUE SKY" that has been the pride of Korea? As in other countries, these problems are among the most challenging, perplexing, and serious of current national concerns.

But an additional Korean problem--the lack of organic residues in crop lands--makes the efficient management and recycling of wastes doubly urgent and essential for Korea's welfare. In Korea, agriculture is by far the largest industry at present. Also, people in Korea recognize that "AGRICULTURE IS THE LARGEST CAPITAL OF ALL." Thus, the recycling of these wastes into compost for soil building or conditioning could play a major role in Korean Government Projects to reclaim and rebuild agricultural land. Further, the manufacture of composting products from a mixture of dewatered or wet sewage sludge and compostable waste has been proven to be a sanitary, nuisance-free, and economically feasible method of waste treatment in the United States, Isreal, and various European countries (Hart, 1968).

This project is therefore designed to help elected Korean officials and public works directors evaluate the current waste problems and to provide workable solutions in terms of the evaluation, management, and value, not only for the city of Seoul, but also for the nation.

Problems

Around thirty years ago, disposal of solid waste and sewage from the municipality of Seoul was a relatively simple procedure because the vastness of the environment was able to absorb the waste without extensive deterioration. Since that time, population increases and rises in the standard of living have resulted in not only an increase in waste generation but in the complexity of the waste. As with other areas of the world, the effect has been the emergence of environmental problems not significant in the 1940's. Solid waste and sewage sludge have become more and more serious, and dangerous, and will continue to be so in the future. These wastes are current and/or potential sources of noxious odors, gas explosions, water pollution, disease, epidemics, air pollution, and other threats to the physical well-being of the city's inhabitants, not to mention the esthetic environmental damage. Specific illustrations of these problems are given below.

A. Solid Waste Disposal Practices in the city of Seoul

The current solid waste disposal practices of Seoul result in the following undesirable conditions:

1. Economic loss due to useless disposal of compostable organic solid waste.
2. High transportation costs to move the waste long distances to disposal sites.
3. Dust, odor, and unsightliness generated by the present collection system.
4. Inefficient operation of the collection system, although employing a large number of people working long hours.

5. Traffic disorders created by the present system.
6. Reduction in the beauty of Seoul by use of the present sorting system.
7. The deterioration of surface and ground water caused by improper disposal of wastes.
8. Breeding sites for mosquitoes, flies, and rats.

B. Dewatered Night Soil Cake and Wet Sewage Sludge

The dewatered night soil cake and wet sewage sludge will cause the following problems without proper management:

1. Without any proper removal or usage of the sludges, the efficiency of the sewage and night soil treatment plants may be reduced due to loss of water quality through contamination from high and enriched nutrient sludge.
2. Odor generation may occur during decomposition.
3. Unsightly appearances may result in the city of Seoul.
4. Besides these problems, some of the problems of solid waste disposal listed above may be aggravated.

Objectives

The ultimate objective of this study is to improve and to provide an alternative method for solid waste and dewatered night soil cake and wet sludge disposal systems in the city of Seoul, Korea. This is to be done in a manner that will protect public health and welfare, preventing the spread of disease, maintain the beauty of the city, and conserve natural resources through composting of the wet sludge and solid waste mixture.

The composting product will be valuable as a soil conditioner or builder for farming land and forestry of Korea. Although such land contains some nutrients and trace elements, the compost product can be fortified with additional chemical nutrients to form an organic-base fertilizer. Additional objectives of the project may be specified as follows:

1. Elimination of the problem of landfill shortage for burying the wastes.
2. Investigation and improvement of methods of disposal most suited to the area and type of wastes generated.
3. Development of a mathematical model for solid waste generation.
4. Development of a long-range solution to ensure continuing, effective waste disposal for the city of Seoul and the nation.
5. Enhancement of the sanitary, agricultural, economical, and ecological aspects of the city and country.
    a) Sanitary:
        i. Proper management of solid waste and wet sludge will provide for public health safety and diminish the potential for transmission of epidemic diseases.

ii. The composting method is recognized as a sanitary disposal system by the U.S. Public Health Service, as well as similar agencies in other countries of the world.

iii. The project will reduce the amount of dust generated by the existing system.

b) Agriculture:

The art of agriculture consists of correlating crop growth requirements with natural environmental conditions by various measures to supply the best plant growth and yield. The application of compost in the Korean agricultural land will bring the following advantages:

i. As a short-term effect, the compost products of the sludge and refuse mixture will increase soil fertility. The effect is similar to those of mineral fertilizers and is due to decomposition of unstable organic matter and the release of inorganic matter soon after application.

ii. As a long-term effect, the composting products provide suitable soil conditioning for crop production over several years. The effect is based on an increase in the humus content of the soil that helps to adjust the environmental conditions of the soil.

iii. The composting product will save the farmer's labor and time used in preparing soil conditioners.

iv. The compost product will increase the efficiency of the "GREEN MOUNTAIN" aspect of the Korean government project of forestation and conservation.

v. The use of compost will increase the rate of food production, one of the major projects of the Korean government, and diminish erosion by accelerating the growth of terrestrial plants, through the physical-chemical properties of compost.

vi. Permeability of soils amply supplied with organic matter is a potent weapon against drought damage (Rodale, 1973).

vii. Soil of organically treated land is less compact and more easily handled in plowing and cultivating.

c) Economic:

Economic benefits to be derived from the project include:

i. Conservation of energy as all the compostable organic wastes are recycled naturally, thus replacing inorganic fertilizers.

ii. Increase in salvage opportunity for recyclable materials.

iii. Reduction of disposal costs.

iv. Suitability of the disposal model for use by the levels of Korean government, both locally and nationally.

v. Enhancement of the tourism potential (indirect effect) due to better sanitation and cleanliness of the city.

vi. Addition of sewage sludge into the composting of solid wastes.

vii. Reduction in the problem of water pollution control costs.

viii. Increase in the amount of organic soil conditioning and its higher quality.

d) Ecological:

Ecological benefits of the project include:

i. Reduction of water and air pollution caused by municipal solid waste and sewage sludge disposal.

ii. Protection and/or recovery of a clean aquatic ecosystem in or around the city of Seoul.

iii. Enhancement of beneficial soil micro- and macrofungal activities in terrestrial ecosystems.

7. Land development and reclamation of waste land for permanent agriculture within short periods of time.

8. Ensuring the continuing production of compost by the sludge and solid waste mixture.

9. The possibility of a complete fertilizer by mechanical addition of nitrogen and phosphorus depending on the contents of the compost, and by physical-chemical treatment of the compost.

10. Securing a proper recycling of organic and inorganic material through the bio-geochemical cycles.
11. Securing the development of a permanent agricultural Korea.
12. Preventing toxicity from an excess of certain elements in the soil (Rodale, 1973).

Need for Study

The Korean Nation applied manure or organic matter to improve crop production early in its well-recorded history, and this practice continues into the present. Man depends mainly on food sources from agricultural products. The principal concern of agriculture today is the maintenance of a good soil condition which, despite abundant application of commercial fertilizers, is losing its fertility. If we continue to use commercial fertilizers to produce viable plants, it is necessary to supply trace elements in addition to the major nutrients (present in commercial fertilizers) and physical conditioners. Since compost contains most of the required elements, it supplies the elements lacking in commercial fertilizers as well as the functions of physical conditioners.

Carleton (1971) states that "humus (final product of compost) is a vital element which can accurately be called the life blood of true soil." We have available in Korea a tremendous amount of compostable matter from municipal solid waste and wet sewage sludge.

The return to nature by means of composting organic materials constitutes not only a constructive answer to one of the major problems in environmental management, but also supplies a source of valuable elements essential to soil productivity for permanent Korean agriculture.

Because Thomas Malthus's theory that the power of population is infinitely greater than the power of the earth to produce subsistence for man seems to be coming true, each country should be prepared to find a solution to avoid forthcoming massive famine, based on the reality of expanding population, depletion of natural resources, and increased food demand. As a general rule, one acre of fertile land per capita is required for a nation to be self-sufficient in food production. Most European countries achieve this self-sufficiency (except England with 0.4 acres per capita), while others show food surpluses (the United States with 2.9, Australia with 4.0, and Canada with 6.5 acres per capita), enabling them to export a surplus (Wagner, 1971). Conversely, most Asian countries, including Korea and China, require significant imports.

Self-sufficiency, to some extent, is affected by the rate of production in a given cultivated land. In Korea, the demand for food is outstripping the supply in both acreage and rate of food production. Therefore, the Korean government has focused on enlarging the amount of cultivated land available by extending the shoreline, reclaiming the waste lands, and increasing the rate of production in various ways. Despite the highly developed techniques of food production, at least one-fourth of the world (Wagner, 1971) suffers from undernourishment or malnutrition. The traditional peaceful sharing of agricultural products between countries with deficits and surpluses is also limited; for example, a journalist described the recent agricultural inflation, which began in the fall of 1973 in the U.S., in Time Magazine (July, 1974), "The comfortable agricultural surplus that in the past has kept American food prices relatively low compared to prices in the rest of the world may be gone forever." At the World Food Conference in 1974 in Rome, Italy, sponsored by the United Nations Food and Agricultural Organization, the common concerns of the delegates from over 140 nations were on increasing world crop production and on purchasing the surplus food of other countries (The Hankook Ilbo, 1974). This information indicates the necessity for non-sufficient food producing countries to provide better management of food exports from the United States, while concurrently increasing their food production to the self-sufficient level. An increase in the rate of food production may be achieved in several ways:

1. Development of better agricultural technology suitable to each country.
2. Better management of soil fertility to increase productivity in cultivated land.
3. Protection of limited crop land from erosion. (Erosion not only reduces the space of the crop land but also removes light soil particles, either organic or inorganic substances, or both, from the land.)
4. Protection of limited aquatic areas from eutrophication and sedimentation from agricultural sources to enable them to continually provide supplemental food requirements.
5. Proper recycling of the valuable organic and inorganic sub-

stances through natural systems. In 1971, a symposium sponsored by the Institute of Ecology (Kucera) stated: "The use of phosphorus will continue to increase at rates that will deplete all known reserves of rock phosphate in about sixty years."

6. Public awakening to the shortage of food supply and public concern to establish better attitudes on recycling or preserving the limited food sources.

Plants may grow in almost any type of soil, but their growth rate is dependent on the soil fertility. This, in turn, is closely related to the amount of organic matter, including living plant roots, bacteria, fungi, earthworms, insects, etc., and inorganic substances including trace elements. The benefits from the addition of organic compost to the soil are numerous:

1. It markedly improves the physical properties of soil, makes it easier to till, more porous, aerated, and helps the soil absorb precipitation through sponge action to reduce runoff and soil erosion.
2. It reduces the amount of commercial fertilizers required by as much as forty percent (Municipal Refuse Disposal (APWA), 1970) due to the prevention of leaching.
3. It increases healthy biological activity in the soil, which stimulates plant growth and enables roots to grow eight times (Municipal Refuse Disposal (APWA), 1970) as fast in soil with organic matter than in soil with inorganic matter.

4. It encourages biological activity important in the break-down of insoluble mineral compounds that are required as an essential element for plant growth.
5. The soil micro-organisms can convert soluble nitrogen into organic nitrogen which becomes a source of plant growth as the micro-organisms decay.
6. Soluble organic phosphorus reacts in the same manner as nitrogen substances.

The addition of compost to the soil increases the productive capacity of soil. The collection and safe disposal of sewage sludge and solid wastes, which are compostable, are among the most important problems of public health to the city of Seoul. Solid waste and sludge problems are also public health problems; for example, indiscriminate disposal of these wastes can result in epidemics originating from an associated toxicosis or zoonosis. Solid waste provides an excellent harbor, food and breeding media for flies, mosquitoes, and rodents.

Mosquitoes and flies are the most important group of arthropods that transmit diseases to man (Ball, 1971).

1. Mosquito borne diseases
    a. Malaria (plasmodium spp.)
    b. Encephalitis (virus)
    c. Dangue fever (virus)
    d. Yellow fever (virus)
    e. Hemorrhagic fever (protozoa)
    f. Filariasis (Wuchereria bancrofti)

2. Fly borne diseases

   a. Typhoid fever (*Salmonella typhosa*)

   b. Paratyphoid fever (*Salmonella paratyphic* A and B)

   c. Cholera (*Vibrio comma*, and *V. cholerae*)

   d. Bacillary dysentary (*Shigella dysenteriae*)

   e. Bacillary amebic (*Entoamoeba* spp.)

   f. Salmonellosis (*Salmonella* spp.)

   g. Parasitic worm infections (hook, round, and tape worms)

The arthropod population is closely related to the availability of food sources and breeding sites, which are directly related to the occurrence of solid waste and organic debris produced by human activity. Mosquitoes, especially, require moisture for egg deposition and for favorable growth for the larval and pupae stages of their life cycle.

Rats and mice, the most important group of rodents, are responsible for the spread of a number of diseases, either directly, as by contamination of human food with their urine or feces, or indirectly by way of their fleas and mites. The most important rodent-borne diseases are:

a. Rat bite fever (*Streptobacillus moniliformis* or *Spirillum* spp.)

b. Leptospirosis (*Leptospira* spp.)

c. Salmonellosis (*Salmonella* spp.)

d. Murine typhus fever (*Rickettsia* spp.)

e. Plague (*Pasteurella pestis*)

f. Rickettsial pox (*Rickettsia* spp.)

A number of other diseases of less frequent occurrence are associated with rodents such as toxoplasmosis and lymphocytic choriomeningitis.

Improper solid waste handling provides a vast network of resting places for rats and mice. This problem will probably intensify in Seoul as the food content in the solid wastes increases and improper management of solid waste continues. Unmolested, the rodent population could rapidly reach the maximum number that available food and harborage will support. When this point is reached or exceeded, some will be forced to seek food by entering accessible homes and business establishments through the plumbing, yards, streets, and sidewalks. As a result, it will be impossible to control rodents and arthropods without proper management of wastes.

1. Direct economic loss by arthropods and rodents:

   The loss of food and property is a function of their population and rate of exposure to food sources through:

   a. Direct contamination of food.

   b. Damage to private and public property.

   c. Direct loss of food by consumption, which has been one of the major problems in Korea.

   d. Crop damage by rodents and arthropods.

2. Indirect economic loss by arthropods and rodents:

   The following economic losses are due to the direct effect that the rodents and arthropods have on human society and the indirect effects of exterminating these pests.

   a. Disease-produced loss of available manpower.

   b. Cost of biocide to control rodents and arthropods.

c. Reluctance of people to enter an area where destructive pests breed.

d. Unexpected expenses to control diseases.

A. Reasons for Modern Composting Practice

1. Sewage sludge is much safer for agricultural use in the form of compost than untreated sewage sludge.

2. Compost containing animal or human waste can be regarded as safe if the method of production of compost ensures that a temperature of 60° C (140° F) throughout the entire mass has been maintained for a minimum period of five days.

3. The modern composting practice could be shortened to handle the tremendous amounts of wastes and to supply the compost demand.

4. Combined treatment of refuse and raw sewage sludge by composting will improve the economy of the process, enhance the decomposition, and augment both structure and nutrient content of compost.

5. The added expense of incorporating sludge with refuse in an existing composting plant is small compared to the cost of sludge treatment in a conventional waste water treatment plant.

6. Since moisture must usually be added to mix solid waste for optimum composting, sludge can be added to provide moisture along with some nutrients.
7. Agricultural use of compost can be the cheapest and most simple method to fortify a cultivating soil.
8. Refuse and sludge compost give better results than fresh wastes or sludge alone.
9. The modern composting process will provide less hazard to public health.

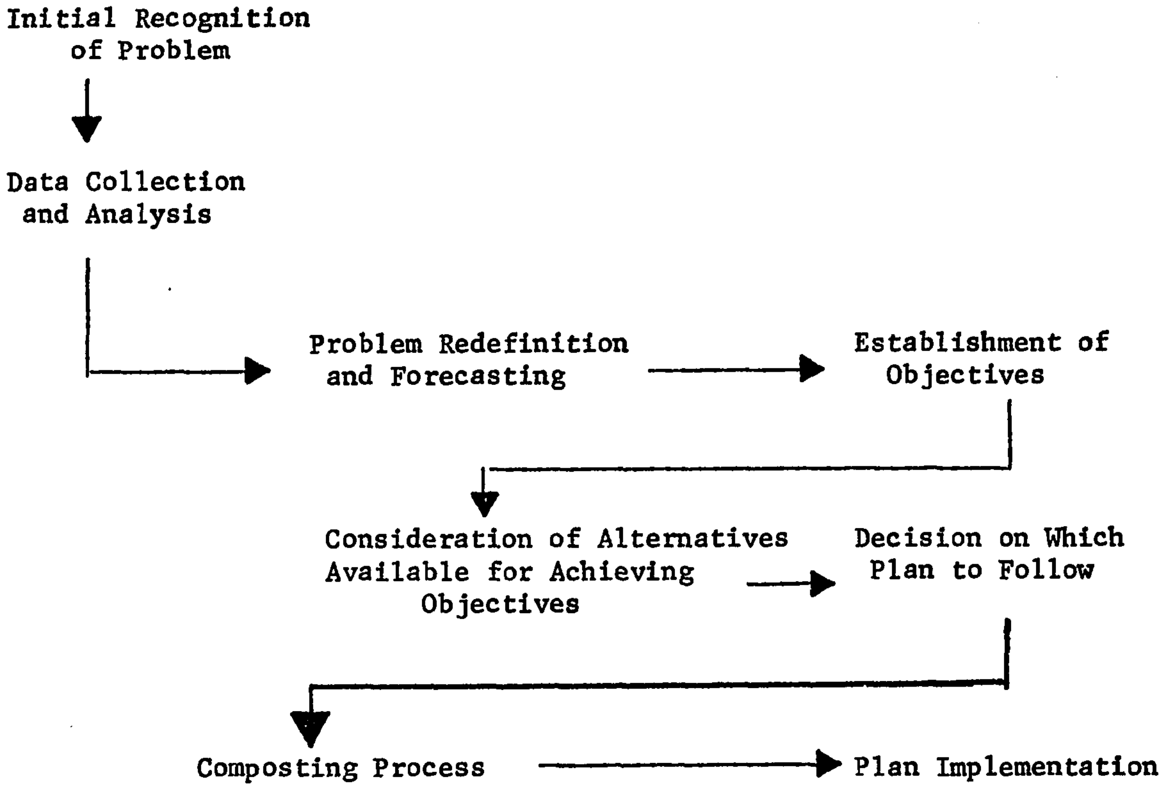
B. Goals in Planning

Major goals for this work will be: (1) to protect the public from pollution, disease, and nuisance; (2) to provide more efficient and economic management of wastes for the city and the nation; (3) to increase soil fertility; (4) to develop a model for disposing solid waste and sewage sludge; and (5) to provide partial service from separation or collection to its ultimate disposal or distribution.

Scope of Planning Model

The basic planning model of this work follows the method recommended by the U.S. Department of Health, Education, and Welfare, Bureau of Solid Waste Management (Toftner, 1970). Management planning should be the conscious process for achieving future objectives and for obtaining long-term benefits with rational and full considerations of any alternatives for the city of Seoul, Korea.

A. Basic Planning Model



To clarify this model a concise explanation for each step is made.

B. Initial Planning

Awareness or recognition of an environmental condition existing in the area of the ChungGae Channel, Seoul, and in Korea overall, is the first step in the planning process.

1. Background of Seoul, Korea

Historical: Seoul dates back to 1394, when King Tae-Jo, the first ruler of the Yi dynesty, selected the site for the capital of his kingdom. "Seoul" derives from the word "Sol-Ul" meaning "Snow

Fence." Since then, Seoul has become the center of government for the country. Seoul has risen from the ashes of destruction twice during the War of 1950-52, and has been re-established from the devastation to a new city and is one of the eight largest cities in the world today.

Location: Seoul is located in the middle of the Korean Peninsula (Figure 2).

Population: 6.54 million (March 7, 1975)[1]

Area: 613 aq. km.

2. Background of Study Area

Since the characteristics of solid waste and sewage sludge generated in the metropolitan areas are highly homogeneous, except for the industrial district of Yong Dong-Po, the model of the solid waste and sewage management of this study on the ChungGae-Chun will be an example for other districts existing under the jurisdiction of the city of Seoul.

General Statement of Study Area: The ChungGae drainage area is a natural drainage basin for storm water runoff and ground water from Buk Ark Mountain to the Han-River. This area is one of high density in the city of Seoul.

Population: 1,300,000 people[2]

Drainage basin: 5600 ha (Figure 3)

Seoul metropolitan government: The executive officials above the third Governmental Executive Grade (GR-GP) level are appointed through legal procedures by the President of Korea. The Mayor of Seoul

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[1]The Hankook Ilbo, March 7, 1975.

[2]Report of the Seoul metropolitan government, 1970.

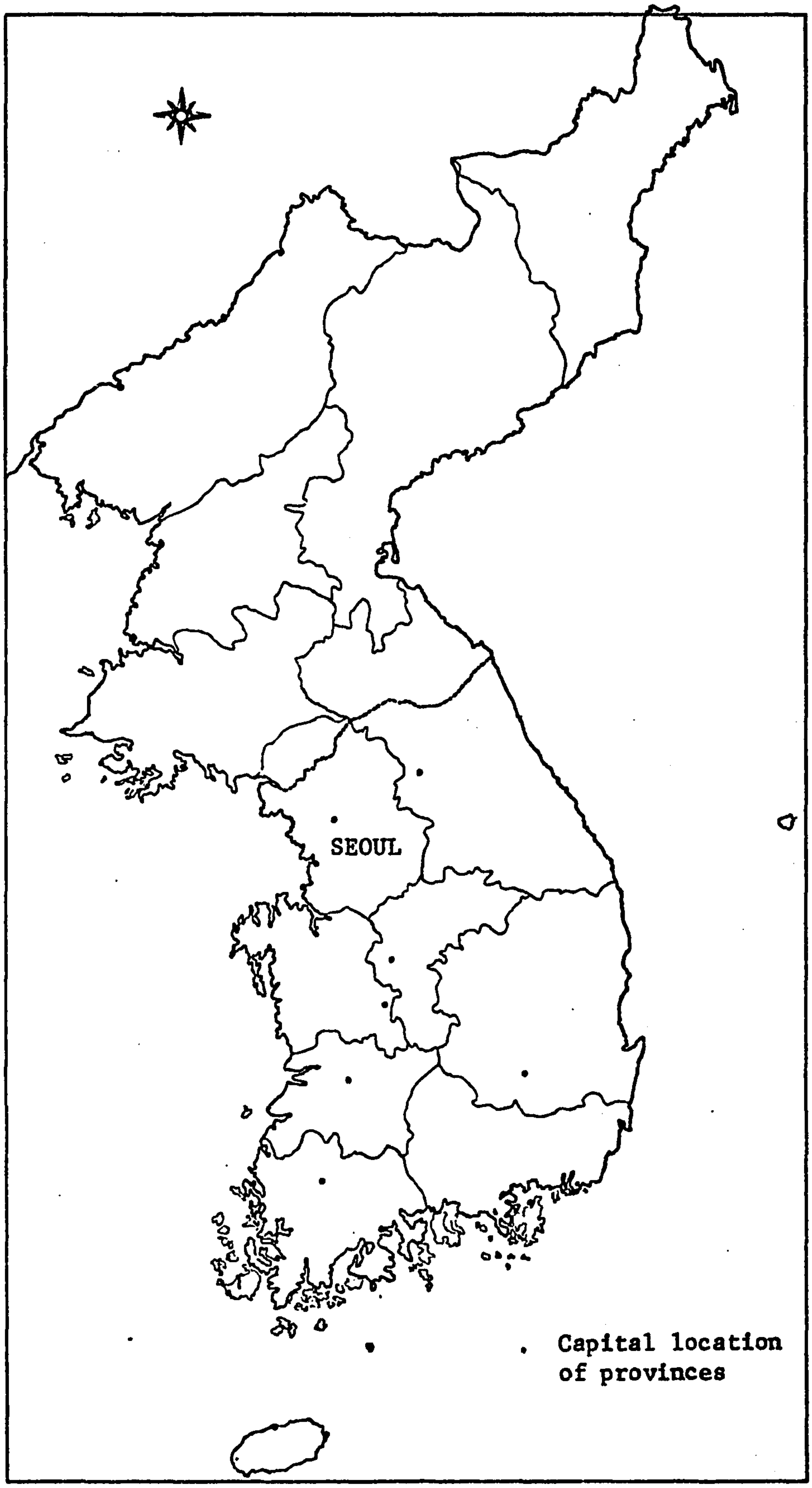


Figure 2
MAP OF KOREA

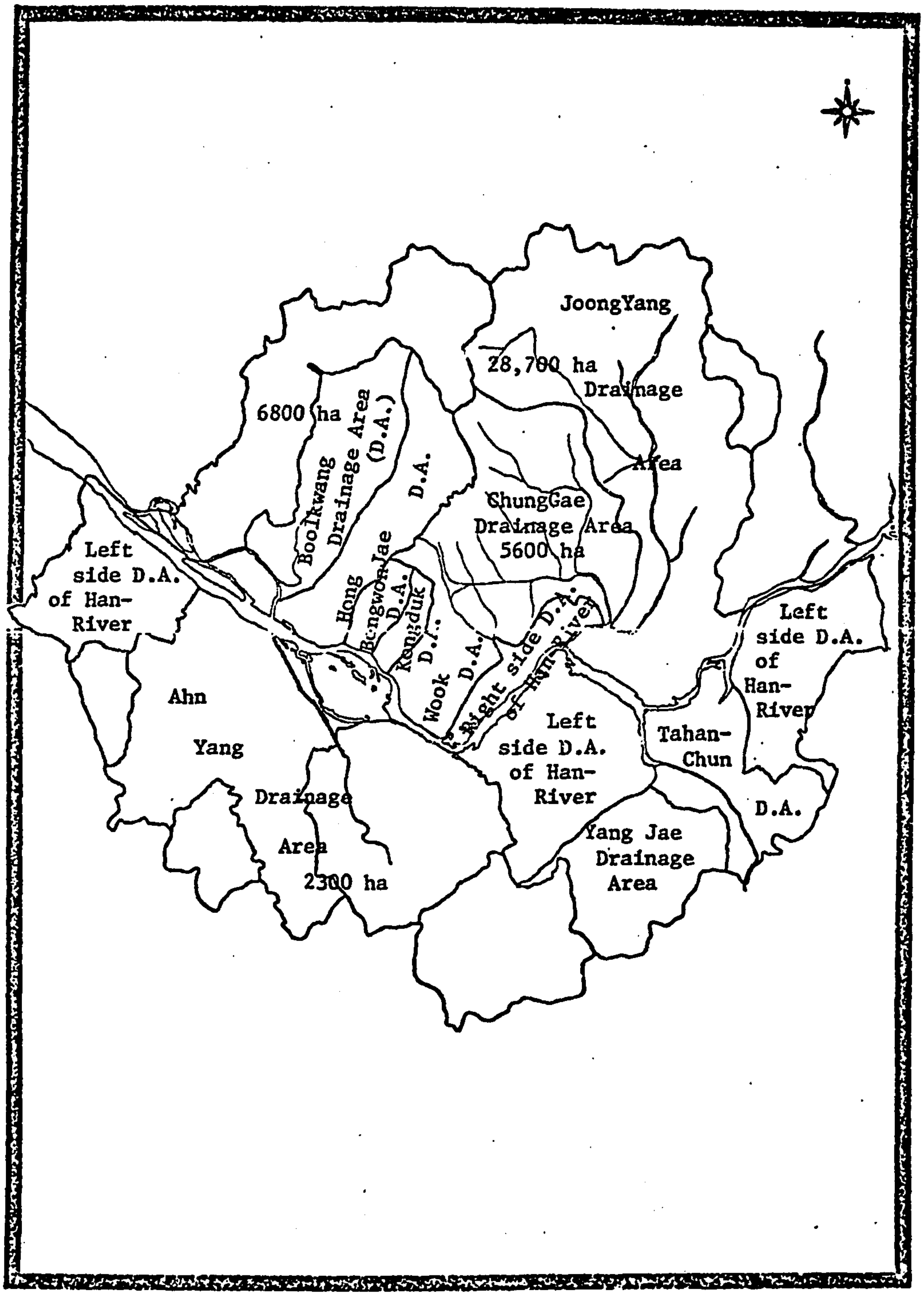


Figure 3

MAP OF THE DRAINAGE AREA OF THE CITY OF SEOUL, KOREA has responsibility for final decision, within proper procedures, on any planning for the city of Seoul.

Plant location: The actual site of the compost plant shall be selected in the study area through full discussion with the executive officials of the Seoul Metropolitan Government related to this work.

Chapter II

BASIC PLANNING OF SOLID WASTE MANAGEMENT

Data Collection and Analysis

In order to develop a realistic approach to current and future disposal requirements such as processing and procedures of solid waste and sewage sludge, it is necessary to determine the quantities, composition, and types of solid wastes now being generated and to estimate the amount expected in the future. The amount and composition are required for a basic study and can be decisive in the planning of the entire installations and dimensions of the waste disposal or reclamation plans. However, quantities of municipal solid waste and sewage sludge from the city of Seoul continue to increase because of two factors: (1) population, and (2) per capita increase in their generation.

A. Total Quantity of Solid Waste in a Section of ChungGae Drainage Area

The information on total quantities and compositions of solid wastes generated by a given community is indispensable for decisions on collection policy as well as for determining the final disposal method.

B. Density of Solid Waste

1. Seasonal Variation of Waste:

   The consideration of seasonal variation of solid waste in the ChunGae Channel is very important for refuse collection, transportation, and designing maximum capacity to handle peak loads.

2. Physical and Chemical Composition of Solid Waste:

   The physical and chemical composition of the waste will determine which disposal method may bring maximum benefits.

C. Studies of Existing Conditions of Solid Waste and Sewage Sludge

The studies of present solid waste programs may provide a basic information on how to increase the efficiency of the current program and to develop better alternatives to solving problems, such as

(a) Storage, collection, transportation, and disposal systems.

(b) Volume reduction system.

(c) General management practices (e.g., utilization of manpower and equipment).

(d) Expenditures for solid waste management.

Problem Redefinition and Forecasting

Without better management of the solid waste and sewage sludge generated by the Seoul municipality, destruction of the air and water quality, damage to landscape of the city, prevalence of epidemic disease, and reduction of aquatic productivity will continue. Solutions to the problems of environmental quality of the city, the requirements of fertilizers and soil conditioners for farming, and the need to increase the rate of production of limited cultivated areas are urgently needed today.

A. Future Problems

1. Type:

a. No land on which to dispose the solid waste in the area of the city of Seoul.

b. Increasing production of sewage sludge.

c. Solid waste disposal by landfill type practiced by the Seoul Metropolitan Government will also contaminate the Han-River and estuaries by leachate.

d. Transportation, traffic complexity, and difficulty of finding disposal sites will increase disposal cost of the landfill practice.

e. Landfilling is a destructive process which does not effectively provide organic residues that are urgently needed for Korean soil.

f. Air pollution will be increased through improper practices of landfill and methods.

g. Landscaping plans of the Seoul Metropolitan Government will not be advanced without proper management of both solid and sludge waste.

2. Control Difficulty in the Future:

a. Delayed control requires high cost and makes the problem more difficult to control.

b. Prevalence of epidemic diseases.

B. Establishment of Objectives

The short range objectives of this work are to reverse the environmental deterioration; advance general public health; improve the well-being of urban, suburban, and rural areas simultaneously; and provide efficient collection of secondary materials while ensuring that remaining residues will be disposed of in ways that will not abuse the environment.

The long range objectives of this work are to conserve valuable organic and inorganic substances to increase the productivity of terrestrial and aquatic land and to conserve the landscape of the city of Seoul.

Some of the immediate aims to these objectives are to:

a) Solve immediate needs of land shortage for disposing of solid wastes.

b) Improve the current disposal management of solid waste and sewage sludge. Even though existing management can solve the solid waste problem, the composting process will improve the efficiency of handling, sorting, storage, and transportation of solid waste.

c) The management of this work could help achieve more cooperation among the governmental agencies through mutual benefits.

d) Improve public support. Because of better management, public attitudes are undergoing change to protect their property.

e) The relationship between urban and rural society will be improved for mutual benefits (Figure 4).

f) Improve the control of epidemic diseases through better management of the disease source.

g) The overall mechanisms of compost will help to provide a complete balance between nature's cycles and man's activities as follows:

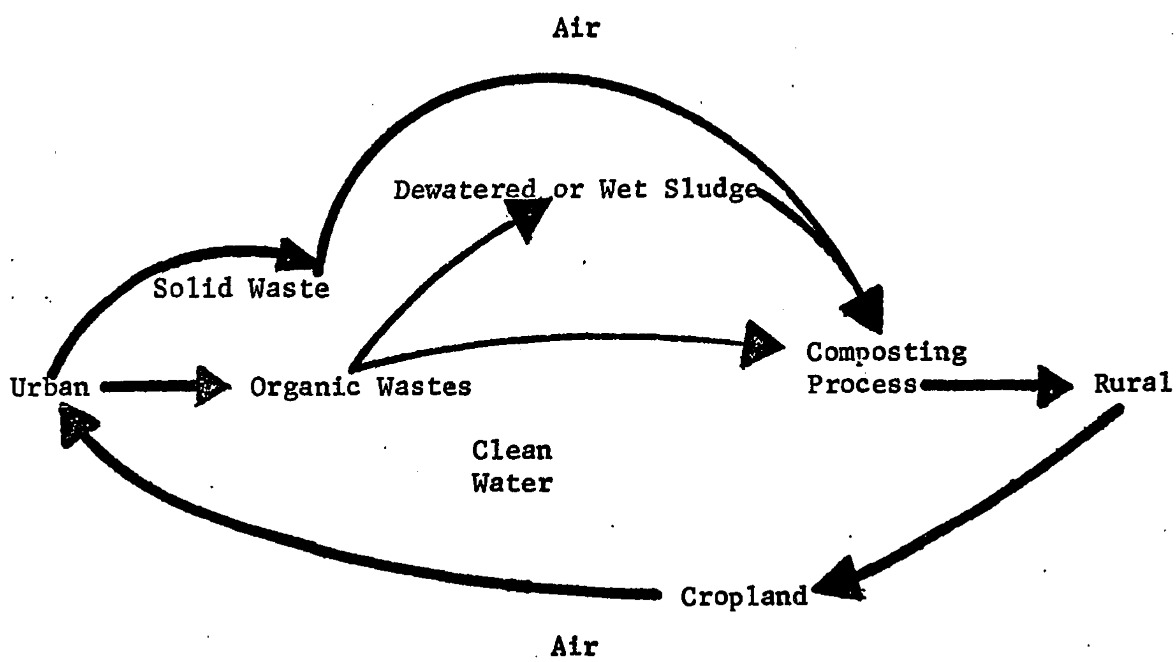


Figure 4
PROPER CYCLE OF SOLID WASTE

C. Consideration of Alternatives Available for Achieving Objectives

As the aim of this work is to eliminate the problem of solid waste and sewage sludge, there are several alternatives available to consider. Among the methods which are practiced in large scale in the United States, as well as other countries in the world, there are two methods besides composting that will be examined for sanitary refuse disposal: sanitary landfill and incineration.

1. Sanitary Landfill:

Definition: A sanitary landfill may be defined as "a method of disposing solid waste on land in such manner that no nuisances or health hazards are created. This involves reducing it to the smallest practical volume, covering it with a layer of earth following each day's operation, and covering the finished site with a final two feet of compacted earth."

The sanitary landfill began about 1934, for farming the rough area around Fresno, California, by filling land with the city's refuse and compacting it with tractors and covering it with 30 inches of soil, a process which was recommended later by U.S. Public Health Service. Since then, the method has been welcomed by the public in the United States. Recently, use of the sanitary landfill site around the United States has had to be curtailed in a number of large cities because of the difficulties of finding suitable sites within economic hauling distance. First of all, the municipal authorities must establish transfer depots with high capacities to reduce long distance hauls by many vehicles. Second, there is a prevailing consciousness of the necessity to reduce air pollution during dumping, compacting, and covering, especially during windy seasons. Third, when a landfill site is unsuitable there is a possible hazard of contamination of surface and ground water. Fourth, all landfills will produce some gases, primarily methane, which causes fires under certain conditions and which poisons organisms. Fifth, the decomposition of organic substances under landfill soil provides an unstable foundation for buildings. Furthermore, the public authorities may wonder what kind of treatment will be used in case there are no more available sites in the near future. The sanitary landfill does not allow for recovery of potentially valuable organic and inorganic substances which are essential for soil fertility and for recycling to save the limited amounts of natural resources.

2. Incineration:

Definition: Incineration is a process which destroys or reduces the volume of solid waste by relatively high temperature burning. Effective incineration eliminates the health hazards present in refuse by removing the combustible matter to inert ash.

Engineering design of incinerators began around 1900 in the United States. This entails reduction of combustible wastes into inert residues by high temperatures at 1400-2000^{o} F. Incineration has some advantages over landfills because of the small amount of residue left, which requires less land, the possibility of central location, and the fact that they are unaffected by climate. Generally, incineration methods are a destructive process of burning valuable organic and inorganic substances essential for soil fertility and reducing the potentials for recycling natural resources. Furthermore, if incineration is to achieve air pollution control standards, it requires large capital investments and high operating costs. Probably, it requires a large amount of heat energy to burn the refuse generated by the city of Seoul, which increases the fuel problem that Korea is facing.

3. Composting:

Definition: Rapid but partial decomposition of moist, solid, organic matter by the use of aerobic micro-organisms under controlled conditions to a sanitary, nuisance-free, and humus-like material.

Composting, as mentioned previously (pp. 7-8 and 18-19) is a solid waste disposal method which conserves our valuable natural resources. The following conditions have been found to be desirable for efficient aerobic and mechanical composting:

a. Temperatures of 160^{o} to 170^{o} to destroy disease producing organisms.

b. A carbon to nitrogen ratio of 40 to 1 or less. Care should be used to prevent deficiencies of essential food elements.

c. A pH range of 5.5 to 8 to prevent nitrogen loss.

d. Adjustment of moisture of 50 to 60 percent. Low moisture retards microbial action.

e. Addition of air throughout the composting material with an excess of oxygen remaining.

f. Seed compost should be recycled in the amount of about 1 to 10 percent by weight.

g. Particle size about one inch or less.

The objectives of composting are:

1. To stabilize putrescible organic matter.
2. To destroy all pathogens and weed seed.
3. To conserve the nitrogen, phosphorus, potash, and other valuable nutritional elements for plant growth.
4. To produce a uniform, relatively dry end product, free from objectionable and harmful objects.

D. Decision on Which Plan to Follow

This section deals with a solution to the solid waste and sludge management problems. As a result of consideration of the overall factors such as technical matters, soil condition of the agricultural land of Korea, salvage or recycling, sanitary conditions, and economics, the best method of waste disposal is a composting practice for the city of Seoul.

1. Technical Feasibility:

This work will provide some major information on design, operating and benefits of the composting system. Information on composting practices from European countries suggests the technical feasibility of establishing composting plants for the city of Seoul. Also, composting of sewage sludge is technically feasible, which was proved by the Gainsville Compost Plant in the United States, and other groups in European countries (Gainsville Compost, 1969; Hart, 1968; Rodale, 1973).

2. Soil Conditions of Agricultural Land of Korea:

The lack of organic residues in Korean agricultural and forest soil urgently requires organic residue such as humus that is a product of the composting process.

The development of new cultivated land and reclamation of waste land can be accomplished with humus-like soil conditioner. One of the biggest Korean governmental projects is to increase crop production in order to satisfy increasing food demands. The extent of damage to public and private properties by floods reached tremendous proportions and required unexpected governmental expenditures to cure the damage and to relieve the suffering. Furthermore, since loss of top soil by erosion decreases crop production, the problem of floods and erosion will be diminished or controlled by using soil conditioner through long-term practices.

3. Salvage or Reuse:

The composting process also provides a condition of resource recovery. Resource recovery is a beneficial activity for several reasons. If two production processes are compared, one using virgin materials and the other secondary materials, the system using wastes causes less air and water contamination, generates less solid wastes, costs less, and is more efficient in final disposal (Darnay, et. al., 1973). This is true if the environmental impacts of all activities in a system are measured -- mining, transportation, processing, fabrication, manufacturing. For waste material, collection may be equivalent to mining; for mining produtts, recovery of the waste is equivalent to disposal. If the costs of environmental impact and energy associated with use of virgin materials will be higher than the reproduction costs of secondary materials, there will be much more benefit in recycling. Fortunately, salvage or reuse of secondary waste is currently being carried on in Korea, but sorting of the materials is done improperly.

4. Sanitation:

The U.S. Public Health Service approved the composting process as a sanitary, acceptable method of waste disposal. Modern methodology for composting ensures that no pathogenic or other harmful materials are present to an extent that could be injurious to the health of users.

5. Economics:

Reports (Hart, 1968) from European countries indicated that the benefits from composting were higher than those of landfill and incineration, and that the market demand for compost is active. Western Europe is unable to produce enough compost to cover the enormous demand for this valuable product.

On the basis of Korean agricultural land and forest situations, compost will have a good opportunity in the market due to:

a. Lack of organic residue in Korean soil.

b. Lack of success of forestation projects due to the shortage of nutrients.

c. Desire for soil conditioners by farmers.

d. Governmental encouragement of the preparation of soil conditioners for farmers to increase the rate of crop production.

e. Active development of newly cultivated land by the Korean Crop Production Program.

f. No land for "throw away" of solid waste and water pollution due to contamination of surface and ground water from improper disposal of solid waste.

g. The cost of waste removal depends to a large extent on transportation expense. A composting plant can usually be located much nearer to residential areas than a dumping site for refuse, because the composting plant does not constitute a health hazard or require much space.

E. Future Potential Development From This Study

1. Heat recovery during composting.
2. Usage of briquette ash as a soil conditioner by composting it with sewage sludge and solid waste.

F. Implementation of Composting Plant

The implementation of the management of solid waste and sewage sludge for the city of Seoul, Korea, is the process of activating the design and operation of a composting plant.

Chapter III

DEVELOPMENT OF SOLID WASTE MODEL

Studies on Quantity, Composition, and Generation of Solid Waste in Seoul, Korea

It has been generalized that as the population increases and standard of living goes up in a given area, the amount of refuse produced also increases with a much greater variety of solid waste. This chapter attempts to verify the above statement and whether it could be applied to the city of Seoul, Korea.

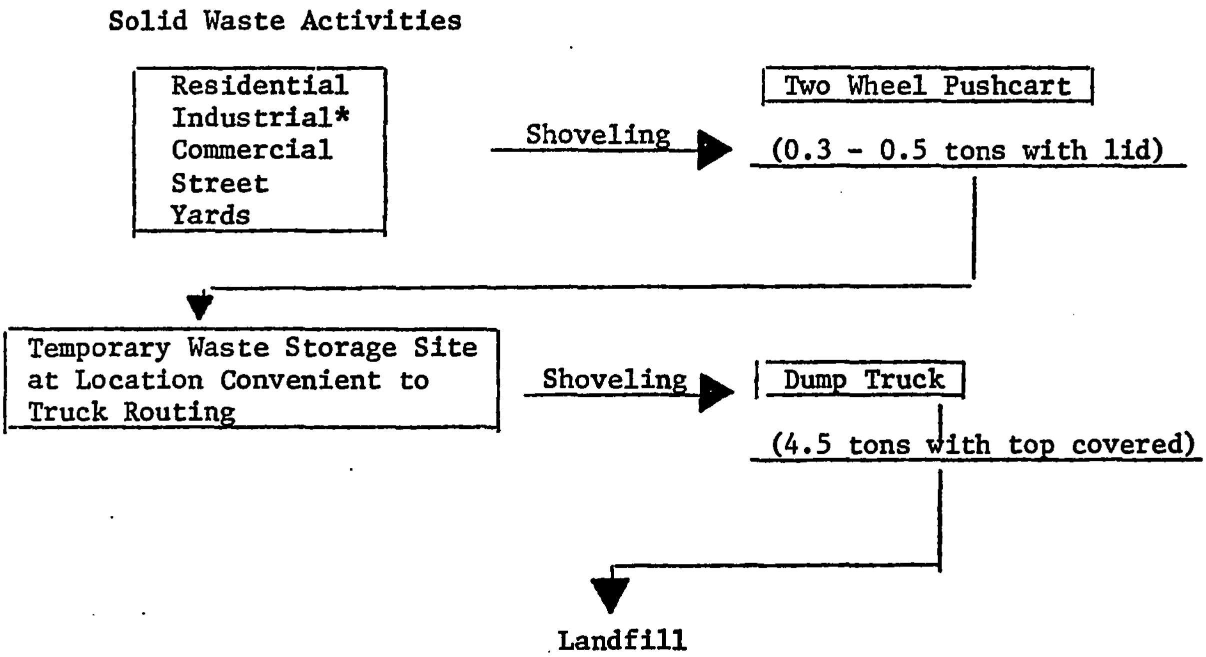
The term solid waste is defined (Bond, et. al., 1973) as "That normally solid material arising from animal or human life and activities and discarded permanently or temporarily as waste. It also includes deposited waste particulates temporarily suspended in water or air."

The analysis of solid waste generation is an obscure and complex study because of the scarcity of accurate, reliable data and the variety of collection and disposal methods.

A typical problem in the solid waste generation in the city of Seoul is to measure or predict an actual quantity of solid waste at a pickup or disposal site because of routine salvaging of usable materials by individual salvagers. Therefore, primary solid waste becomes an unquantifiable term. Secondary refuse, then, means the solid waste actually disposed of at a landfill.

Information on composition and characteristics of the solid waste have not been documented. Therefore, a very general description on solid waste composition was compiled during August 1 to 14, 1974 (Table 1).

General scheme of solid waste disposal practice of the Seoul metropolitan government is shown below:



A. Quantity of Solid Waste:

Personal communications and data research at the city's library on the quantity of solid waste are shown in Table 2 . This data is accepted by experienced personnel in the Bureau of Public Work Service, Seoul metropolitan government.

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* The large waste generated by industries is disposed by owner with permission of the city government.

Table 1

APPROXIMATE ANALYSIS OF MUNICIPAL SOLID WASTE COMPOSITION, CITY OF SEOUL, KOREA

Category	Averaged Weight lb/yd^3	Weight %	Availability of Salvage %	Description & Public Health Considerations
Paper	20.30	2.36	30.0	Various types, some with fillers. 1) Phenols from printed paper causes taste in water. Harmful for public health.
Wood & Straw	20.80	2.42	1.0	Generally fragmented. Less than 20 in. in size from wood packaging, furniture & logs. 1) Wood provides food for objectionable fungi and insects. 2) Nuisance - insects may thrive in poor landfill.
Vegetable	130.60	15.19	--	Various waste from edible plants, rubbish, fruit waste and yard-plant material. 1) Odor is important environmental factor. 2) Provides habitat for harmful insects and rodents.
Rags	27.92	3.25	5.0	Various types of textile waste cloth, sweeping materials. 1) Odors from landfill may be nuisance in vicinity of site.
Rubber	2.48	.29	2.0	Shoes, pieces of tire. 1) See items in plastics.

Table 1

(Continued)

Category	Averaged Weight (lb)	Weight %	Availability of Salvage %	Description & Public Health Considerations
Glass	4.14	.48	3.0	Primarily broken bottles, containers, etc. 1) Broken glass may be hazardous in handling solid wastes. 2) May be aesthetically unacceptable in compost.
Metal & Cans	1.38	.16	4.0	Generally less than 5 inches in size. 1) All metal materials, especially lead, may cause chronic entoxication in air from solid wastes. 2) Particulate beryllium produces pulmonary edema. 3) Inhalation of cadmium oxide dust or fumes may cause pulmonary edema or hemorrage; can be fatal. 4) Inhalation of zinc fumes or dust causes "metal fume fever" and damage to epithecial cell in respiratory tract. (Percentage of alien toxic substances due to domestic wastes not significant but is noteworthy.
Synthetics (plastic)	14.70	1.71	6.0	Plastic & nylon materials mainly packing & containers. 1) Chlorinated hydrocarbons may damage central nervous system. 2) Some low molecular weight hydrocarbons, especially polynuclear & aromatic hydrocarbon, are carcinogenic.

Table 1

(Continued)

Category	Averaged Weight (lb)	Weight %	Availability of Salvage %	Description & Public Health Considerations
Dead Animals	1.00	0.1	--	Mainly rodents. 1) Sanitary and aesthetical problems. 2) Rodenticide should be carefully handled due to accute toxicity to man and animals.
Anthracite Briquette Ash	537.40	62.52	--	Detailed information described in later chapters.
Demolition	47.88	5.57	--	Waste material from razed buildings or other structures including construction waste. (Waste should be handled separately.)
Ceramics	3.40	.40	--	Generally containers. 1) Broken ceramics may be hazardous in handling solid waste. 2) Unacceptable in composting practices.
Garbage	5.00	.58	--	Animal waste resulting from handling, preparation, cooking, serving, & vegetable waste from cooking and serving. 1) Provides food source for rodents, flies, mosquitoes & other insects. 2) Insect & rodent carriers of disease harbored by poorly managed land disposal may constitute important health hazard. 3) Odor nuisance an important environmental factor.

Table 1

(Continued)

Category	Averaged Weight (lb)	Weight %	Availability of Salvage %	Description & Public Health Considerations
Others	42.60	5.00	--	Ashes from wood & other combustible waste other than briquette. Yard waste - mainly earth, stone, dust.
TOTAL	859.60	100.03		

Table 2

QUANTITY OF ANNUAL SOLID WASTE GENERATION IN THE CITY OF SEOUL, KOREA

Year	Total Solid Waste Generation (Ton)*
1972	2,963,070
1971	2,877,695
1970	2,731,208
1969	2,394,113

* The values from the Bureau of Public Works, Seoul Metropolitan Government. (1970, 1972, 1973)

B. Composition of Refuse

Three solid waste samples from the Sungbuk-District were collected in a one cubic yard wooden box (net weight 62.31 pounds), then weighed and analyzed at the Institute of Public Works of the Seoul metropolitan government and at several landfill sites. Personal communication with experienced salvagers also provided useful information for analyzing the composition of the wastes and for developing the model of solid waste generation.

C. Solid Waste Density

Some knowledge of unit weights is basic and necessary information in all phases of solid waste management since it is a factor needed to determine size requirements throughout the system.

An average density of 860 pounds per cubic yard here are only broad refuse density estimates using uncompacted refuse.

Mathematical Model of Residential Solid Waste Generation

(1) Objectives: To ascertain the quantities of solid waste being currently generated, to project future per capita generation rates, and to calculate the overall quantities of solid waste in a given area.

Residential waste quantities are identified as a function of the population density and income levels of a given community (Canter, 1973; Bond and Straub, 1973).

The following relationship between per capita waste production and population density is envisioned.

(2) Data Synthesis of Indirect Method:

This study attempts to establish a reasonable, not an absolute, method of developing a predictable model for solid waste generation in the city of Seoul, Korea.

Since there is no information available on the total solid waste generation after 1969, several assumptions are necessary in deriving data. Comparing points on "tons of solid waste" to "household unit" curve on Figure 5 indicated a fairly constant ratio of 2.5 $(\frac{\text{tons of waste/year}}{\text{household unit/year}})$ for the years 1969-72. Portions on the curve for years 1962-1968 were extrapolated using the factor 2.5. At this point, the tons of solids generated include domestic, industrial, institutional, and commercial wastes. To obtain only domestic quantities, a survey was accomplished to obtain a reasonable percentage of the combined wastes. The percentages subtracted and domestic adjusted values appear in columns 2 and 3 of Table 3.

The adjusted domestic value was analyzed for content and it was noted that a significant amount of soil was generated from unpaved roads and yards of individual properties at annually decreasing rates in the city of Seoul (column 4, Table 3). These percentages were also deducted to approximate more closely an actual domestic waste value. Recall now a previous statement concerning the mathematical model used and the fact that the model was not developed to include the unique nature of briquette ash waste as appears in the Korean culture.

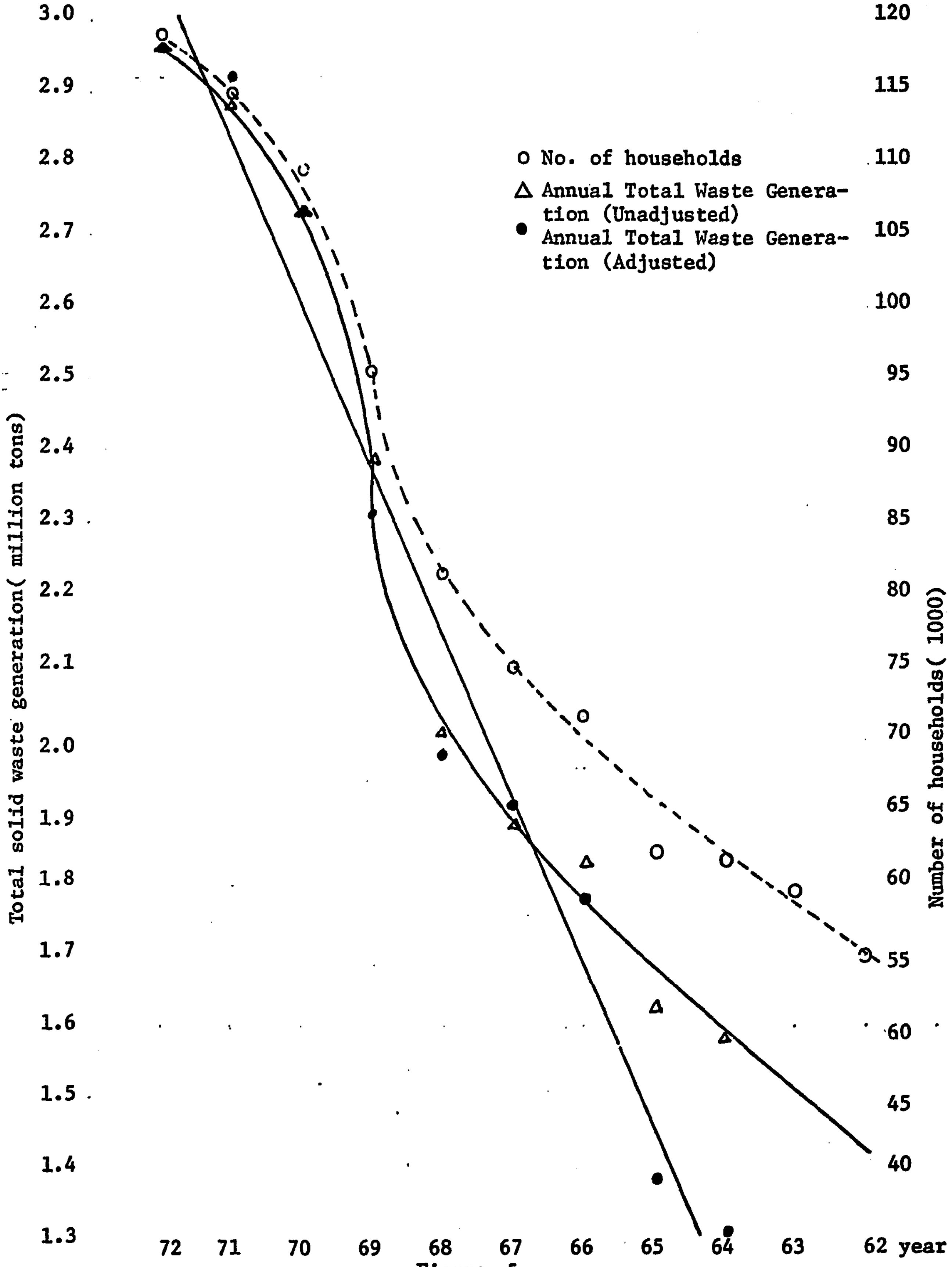

Figure 5

Annual solid waste generation and no.of households

Table 3

COMPUTATION OF DOMESTIC SOLID WASTE GENERATION, SEOUL, KOREA

Year	Total Solid Waste Generation (Ton). Value from the Fitted Curve. (COLUMN 1)	% Activities of Commercial, Industrial & Institutional. (COLUMN 2)	Adjusted Waste (Ton) Value from the Fitted Curve. (COLUMN 3)	% Solid Waste From Road & Yard. (COLUMN 4)	Adjusted Waste (Ton) Value from the Fitted Curve. (COLUMN 5)
1972	2,963,070[a] / 2,968,444[b] (0.2%)	14.0 / 14.0	2,548,240 / 2,555,862	1.0 / 1.0	2,522,758 / 2,527,333
1971	2,877,695 / 2,394,351 (2.0%)	13.5 / 13.5	2,489,206 / 2,538,214	1.5 / 1.5	2,451,868 / 2,500,141
1970	2,731,208 / 2,737,674 (0.2%)	13.0 / 13.0	2,376,151 / 2,381,776	2.0 / 2.0	2,328,628 / 2,334,141
1969	2,394,113 / 2,317,158 (3.2%)	12.5 / 12.5	2,094,849 / 2,027,513	2.5 / 2.5	2,042,478 / 1,976,825
1968	2,035,000 / 1,989,421	12.0 / 12.0	1,790,800 / 1,750,691	3.0 / 3.0	1,737,076 / 1,698,170
1967	1,880,000 / 1,916,356	11.5 / 11.5	1,663,800 / 1,695,975	3.5 / 3.5	1,605,567 / 1,636,616
1966	1,765,000 / 1,786,845	11.0 / 11.0	1,570,850 / 1,590,292	4.0 / 4.0	1,508,016 / 1,526,680
1965	1,670,000 / 1,369,644	10.5 / 10.5	1,494,650 / 1,225,831	4.5 / 4.5	1,427,391 / 1,170,669
1964	1,570,000 / 1,308,253	10.0 / 10.0	1,413,000 / 1,177,428	5.0 / 5.0	1,342,350 / 1,118,557

Where a = unadjusted value
b = adjusted value

Table 3

(Continued)

No. of Households	Yearly Waste Generation/Household (Ton)	Daily Waste Generation/Household (Pounds) (DWG/H)	Daily Briquetted Ash/Household (Pounds)	Waste Daily Without Ash/Household (SWG/H/BA)
(COLUMN 6)	(COLUMN 7)	(COLUMN 8)	(COLUMN 9)	(COLUMN 10)
1,182,655	2.133 2.137	11.688 11.712	6.930	4.758 4.782
1,151,078	2.130 2.172	11.671 11.900	7.194	4.481 4.706
1,096,871	2.123 2.128	11.633 11.664	7.074	4.563 4.590
961,491	2.124 2.056	11.638 11.268	6.795	4.838 4.473
837,362	2.074 2.028	11.364 11.117	6.558	4.804 4.559
754,201	2.129 2.170	11.666 11.891	7.230	4.436 4.661
734,334	2.054 2.079	11.225 11.391	6.966	4.285 4.425
649,290	2.198 1.803	12.044 9.881	5.691	6.354 4.190
633,026	2.121 1.767	11.623 9.680	5.574	6.053 4.106

Table 3

(Continued)

No. of Persons/ Household	Waste Generation With Ash/Person (lbs) (SWG/P)	Solid Waste Generation Without Ash/Person (SWG/P/BA)
(COLUMN 11)	(COLUMN 12)	(COLUMN 13)
5.17	2.261 / 2.265	.920 / .925
5.24	2.227 / 2.271	.855 / .898
5.27	2.207 / 2.213	.866 / .871
5.30	2.196 / 2.123	.913 / .844
5.58	2.037 / 1.992	.861 / .817
5.90	1.977 / 2.015	.752 / .790
5.80	1.941 / 1.964	.739 / .763
5.70	2.113 / 1.734	1.115 / .735
5.80	2.004 / 1.669	1.004 / .708

Total briquette ash waste was determined by looking at the total amount of anthracite coal (Table 4) for domestic purposes, coming into the Seoul municipal boundary. Approximately thirty percent of burned coal remains as ash waste, including a clay-like binder material used in making the briquette coal. Columns 12 and 13 in Table 3 show data, from mathematical manipulations, of solid waste generated per person per day with and without briquette ash.

The solid waste generation per capita did not show the expected linear increase with increased per capita income and population density. Particularly, the data from 1962 and 1963 were not correlated. Perhaps the original data is inaccurate and/or is insufficient data (four years) to develop a curve trend. Therefore, to obtain the best fitted linear progression, graphical adjustment was necessary, while ignoring those two values of 1962 and 1963. From the best fitted line ($Y = -1.014 + 0.0269\ X_1$ -- Figure 6), back calculation was studied to determine the percentage difference between the original and fitted curve values (column 13-b in Table 3). The value inversely calculated showed the given data for four years overestimated between 0.2 percent to 3.2 percent annually.

(3) Computational Method:

The coefficients of the Generalized Model (page 53) were estimated using the computerized program of Ordinary Least Squares (OLS) (Appendix A) estimation as stored in an IBM-360 of the Business Library, University of Oklahoma.

Table 4

DAILY COAL ASH GENERATION, SEOUL, KOREA

Year	No. of Households	Residential Usage of Coal (Ton)[1]	Daily Briquette Usage/Household (Pounds)	Daily Briquette Ash/Household (Pounds)
1972	1,182,655	4,980,301	23.10	6.930
1971	1,151,078	5,037,485	23.98	7.194
1970	1,096,871	4,719,950	23.58	7.074
1969	961,491	3,974,000	22.65	6.795
1968	837,362	3,341,069	21.86	6.558
1967	754,261	3,317,671	24.10	7.230
1966	734,334	3,112,062	23.22	6.966
1965	649,290	2,247,580	18.97	5.691
1964	633,026	2,146,788	18.58	5.574

[1] From an annual report of the city of Seoul (1973) and a supply and demand program of fuel of the city of Seoul (1971).

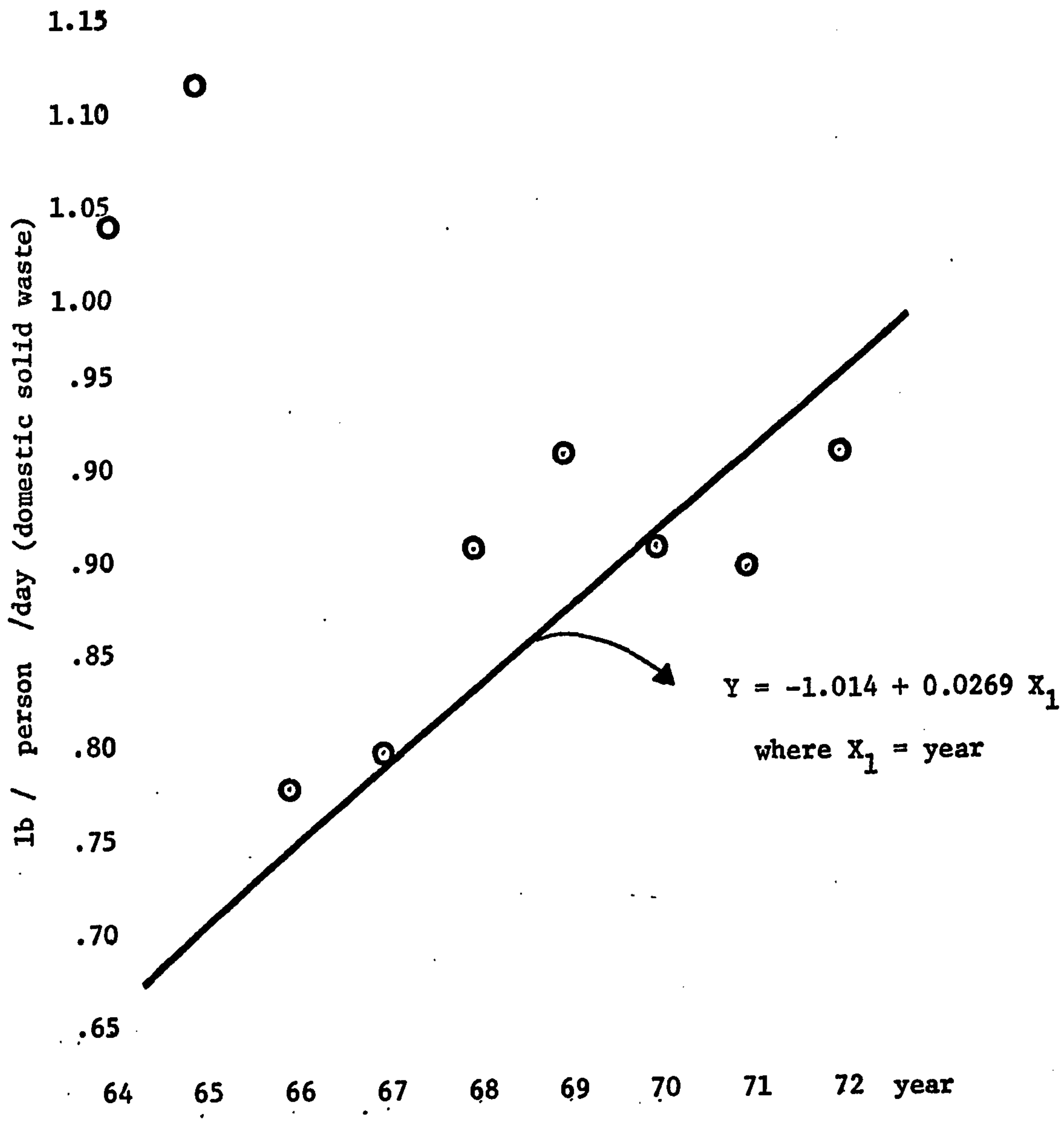

Figure 6

Solid Waste Generation Without Briquette Ash

A. Indirect Method

$$Y_1 = a + a_1X_1 + a_2X_2 \quad \text{———— Generalized Model}$$

where Y_1 = quantity of solid waste generation

X_1 = population density

X_2 = income level

Since this equation was not developed to consider the large amounts of briquetted ash in Korean waste, the mathematical model was tested in two ways. One includes the ash as a component, and the other does not.

a. Information necessary for the model:

1. Population density and income level per person. (Table 5)
2. Household density and income level. (Table 6)
3. Briquette ash generation. (Table 4)

B. Direct Method

$$Y_1 = a_1 + a_2X_1 + a_3X_2 + a_4X_3 + \dots a_{n+1}X_n$$

$$= a \sum_{j=1}^{n} X_n + a_1$$

where Y_1 = unit of total solid waste generation

$X_1, X_2, \dots X_n$ = amount of each category of solid waste

a = constant

Table 5

POPULATION DENSITY AND INCOME PER CAPITA PER DAY, SEOUL, KOREA

Year	Population Den. (Persons/sq.mi.) (PDSM)	No. of Persons Per Household	Monthly Income Per Household[1] (Korean Won)	Consumer Price Index[1]	Actual Monthly Income/ Person[2]	U.S. Exchange Rate (Won/$)[1]	Daily Income/ Person ($)[1] (30 days/mo.) (DIPP)
1964	14,467.80	5.80	10,100	51.40	3,387.89	255	.36
1965	14,664.20	5.70	11,310	58.40	3,397.62	271	.36
1966	16,068.90	5.80	16,960	65.40	4,471.16	270	.48
1967	16,769.70	5.90	24,530	72.50	5,734.66	274	.61
1968	18,314.90	5.58	27,110	80.60	6,027.82	281	.64
1969	20,182.20	5.30	32,450	88.70	6,902.64	304	.74
1970	23,390.80	5.27	38,630	100.00	7,288.68	313	.78
1971	24,719.80	5.24	44,400	112.30	7,545.22	373	.80
1972	25,671.30	5.17	53,140	125.60	8,138.54	399	.87

1 Annual report of Urban Family Budget, 1973.

2 Based on 1970 figures.

Table 6

HOUSEHOLD DENSITY AND INCOME PER HOUSEHOLD, SEOUL, KOREA

Year	No. of Households/ Square Mile (NHPM)	Monthly Income/ Household Unit (Won)	Consumer Price Index	Actual Income/ Household (Based on 1970) (Won)	U.S. Exchange Rate (Won/ $)	Daily Income/ Household ($) (30 days/mo.) (DIPH)
1964	2,674.49	10,100	51.40	19,649.80	255	2.10
1965	2,743.21	11,310	58.40	19,366.44	271	2.06
1966	3,102.51	16,960	65.40	25,932.72	270	2.76
1967	3,186.70	24,530	72.50	33,834.48	274	3.60
1968	3,537.80	27,110	80.60	33,635.23	281	3.58
1969	4,062.24	32,450	88.70	36,584.00	304	3.90
1970	4,634.21	38,630	100.00	38,630.00	313	4.11
1971	4,863.23	44,400	112.30	39,536.95	373	4.21
1972	4,996.64	53,140	125.60	42,308.91	399	4.50

Title: OLS

Purpose: An attempt to estimate the coefficient of the suggested linear models to predict the amount of future solid waste generation per capita.

Date Completed: March 19, 1975.

Computer Used: IBM-360

Program Language Used: FORTRAN IV

Computation Time: Varies with size of problem.

3. Results of Computation:

$Y_1 = a_1 + a_2X_1 + a_3X_2$ ________ Model 1-1

where Y_1 = SWG/P/D = the amount of solid waste generation (pound/person/day) (Table 3)

X_1 = PDSM = population density (person/sq. mi.) (Table 5)

X_2 = DIPP = income level (\$/person/day) (Table 5)

$Y_1 = 1.2936 + 6.3289D\text{-}6^{*}X_1 + 0.9754\ X_2$ _____ Model 1-1'

$R_2 = .9458$

T statistics = 11.5330 (constant, 0.4263 (PDSM), and 2.8870 (DIPP)

Standard error of regression = 0.0585

Henry Theil U Coefficient = 0.6061

$Y_1 = a_1 + a_2X_1 + a_3X_2$ ________________ Model 1-2

where Y_1 = SWG/P/BA = solid waste generation without briquetted ash (pounds/person/day)

* 6.3289D-6 = 6.3289×10^{-6}

X_1 = PDSM

X_2 = DIPP

$Y_1 = 0.5276 + 8.4000D\text{-}6\ X_1 + 0.2019\ X_2$ ________ Model 1-2'

$R^2 = 0.9878$

Standard error of regression = 0.0095

T statistics = 29.1240 (constant), 3.5032 (PDSM), and 3.6997 (DIPP)

Henry Theil U Coefficient = 0.4606

$Y_1 = a_1 + a_2X_1 + a_3X_2$ ____________________ Model 1-3

where Y_1 = DWG/H = total solid waste generation (pound/household/day) (Table 3)

X_1 = NHPM = household density (households/sq.mi.) (Table 6)

X_2 = DIPH = household income level ($/household/day) (Table 6)

$Y_1 = 8.7377 - \underline{0.4994D\text{-}3\ X_1} + 1.2571\ X_2$ _______ Model 1-3'

$Y_1 = a_1 + a_2X_1 + a_3X_2$ ____________________ Model 1-4

where Y_1 = SWG/H/BA = solid waste generation without ash/household/day

X_1 = NHPM

X_2 = DIPP

$Y_1 = 3.7497 - \underline{0.8866D\text{-}3} + 0.3166\ X_2$ ____ Model 1-4'

__________ denotes irrational, and therefore unacceptable, signs of coefficients.

a. Evaluation of Sign Factor

With the assumption that the amount of solid waste generation is positively correlated with the income level, population or household density in normal circumstances, the coefficient of all independent variables used here should be positive. Since the underlined coefficients of NHPM in the Models 1-3' and 1-4' showed negative signs, these two models should not be used in further analyses.

The negative sign might be attributed to the doubtful data of solid waste generation per household or the deficient number of observations.

b. Statistical Evaluation

T-value computed for Models 1-1' and 1-2' compared with 2.447 of the tabulated value (for a = 0.05, with df = 6, and one tail) shows an acceptable model in 1-1', except PDSM.

c. Forecasting Evaluation

$$U = \sqrt{\frac{1}{n} \sum (Pi - Ai)^2 \;/\; (\frac{1}{n} \sum A^2 i)}$$

= 0.6166 ________ Model 1-1'

= 0.5161 ________ Model 1-2'

U = Henry Theil Inequality Coefficient

Pi = predicted change

Ai = actual change

If the forecasting model was perfect, the U coefficient should be equal to zero. If the U coefficient is equal to or greater than one, the predictive ability of the model will not be reliable (Liew, 1971).

4. Conclusions:

From the above model specifications, the best specification of the model for predicting the solid waste generation per capita can be chosen as Model 1-2'. However, Model 1-1' may also be used for predictive purposes if no other better alternative is available.

5. Comments:

To develop a better prediction model it is necessary to increase the degrees of freedom; namely, the number of observations. Although there was not enough information available to develop the model during this study, the analysis of the model that is included here may be useful in showing some examples of the suggested methodology of this research. Re-estimation of the coefficients of the provided models with increased information of the amount of actual waste generation should increase the efficiency of the model. Also, to help increase the accuracy of the composition analysis of solid wastes, field survey sheets are attached in Appendix B.

Chapter IV

CONCEPTUAL DESIGN OF THREE ALTERNATIVES FOR DISPOSAL OF SOLID WASTES

At the present time, there are three principal methods of solid waste disposal that inhibit wastes from becoming pollutants. These three major methods are: (1) disposing of the solid waste in a sanitary landfill, (2) incinerating the solid waste with final disposal in a sanitary landfill, and (3) composting the waste. However, each of the three major alternatives cannot completely solve the waste problem, with the possible exception of the sanitary landfill together with a pathological incinerator, due to the heterogeneous characteristics of the waste composition as shown in Table 1. To solve the waste problem, therefore, the combination of these three major alternatives should be employed as follows in Figure 7. The amounts and compositions of solid waste used in Figure 7 were based on hand separation values obtained in 1974 (Table 7).

(1) Alternative One: Sanitary landfill + pathological incinerator All the waste except dead animals could be handled by the sanitary landfill practice.

(2) Alternative Two: Sanitary landfill + pathological incinerator + coal ash

Since the city of Seoul is now facing the extreme shortage of available land for filling with solid waste, coal ash is assumed to be separated prior to land filling for the utilization of the ash in construction and agricultural purposes as studied in Chapter VI. Coal ash separation should be studied further.

(3) Alternative Three: Sanitary landfill + municipal incinerator + coal ash + pathological incinerator

Municipal incinerators are assumed to handle all the waste except glass, metal, demolition and ceramic wastes, which could be separated by relatively simple and inexpensive equipment (Drobny et. al., 1971) such as a inertial separator--ballistic, secator, and inclined conveyor. Those separators effect a separation based upon size (air resistance), density (gravity effects), and elastic properties of the solid wastes. Prior to the mechanical separation, this work is also designed to separate the large sized uncombustible waste from the waste-mixture by hand picking and sorting from the conveyor. Magnetic or eddy-current separator, and others (Drobny, et. al., 1971; Engdahl, 1969; An Interim Report of the Gainsville Compost Plant, 1969) were not studied in this work because of high costs and unknown efficiency when applied to Korean solid waste materials.

Since the separation of vegetable material from the mixture of waste is uneconomical and technically infeasible at the present time, vegetable waste is assigned into the municipal incinerator, but even the addition of the waste into the incinerator is unrealistic economically due to high moisture content in it. Also, the basic reason for installing a pathological incinerator in addition to the municipal incinerator is because most dead animals that are killed with pesticides should be treated safely due to the toxic effects of pesticide residues.

(4) Alternative Four: Sanitary landfill + composting plant + coal ash + pathological incinerator

The same assumptions are used here as in Alternative Three. Uncompostable materials are assumed to be separated.

(5) Alternative Five: Sanitary landfill + municipal incinerator + composting plant + pathological incinerator + coal ash

All four of the disposal methods are employed here. The handling capacity of each component will be ultimately determined by the degree of success in separating the organic fraction by air classification and/or other methods. For the purpose of this dissertation, it is assumed that approximately 20% will be composted and approximately 10% will be incinerated.

Larger pieces of rag and rubber materials are also assumed to be separated by hand picking prior to mechanical separation because they cause problems in composting. The remaining wastes are assumed to be buried in landfill operations.

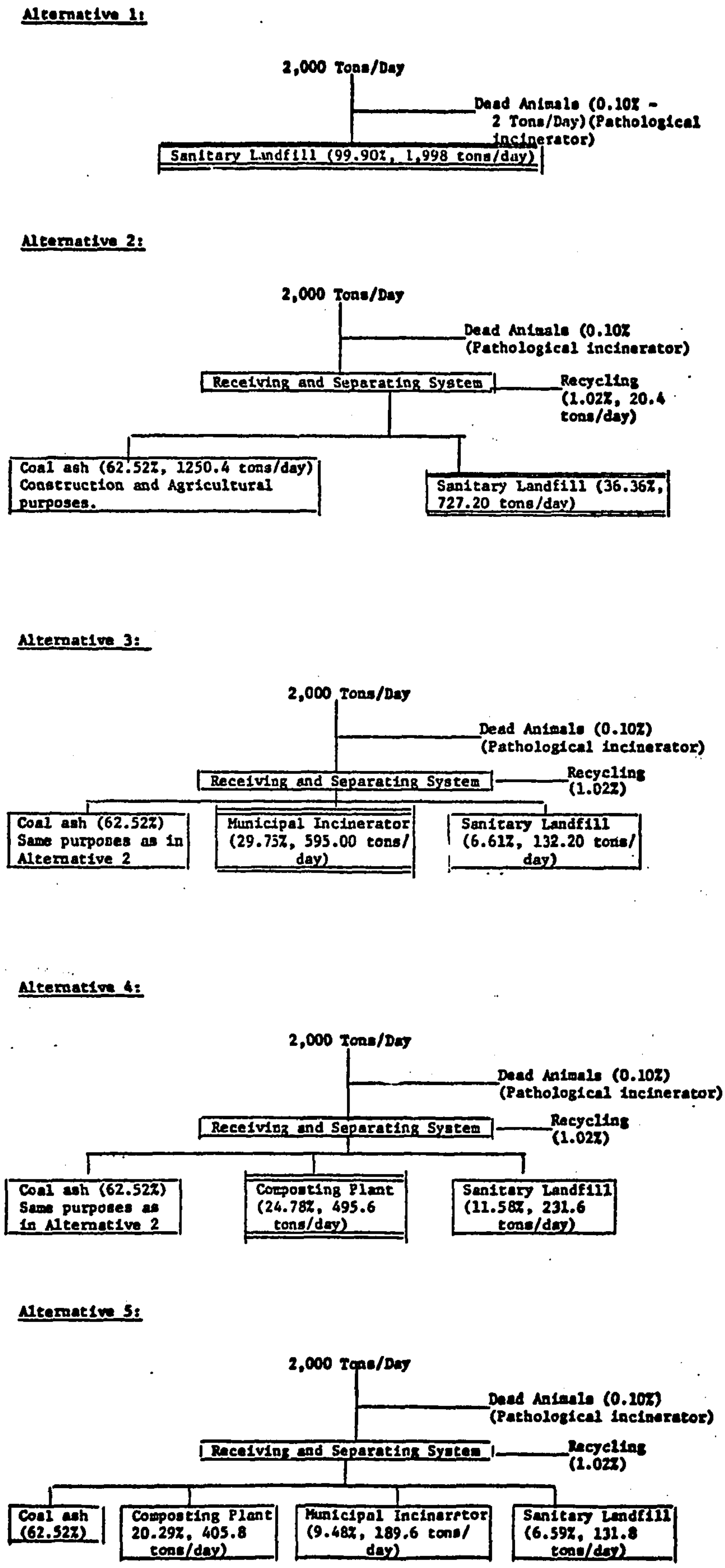

Figure 7

Combination of Three Alternative Methods of Solid Waste Disposal - Flow Diagram
(Based on 2,000 Tons Daily Generation)

Table 7

SOLID WASTE DISTRIBUTION INTO THREE ALTERNATIVE METHODS (BASED ON 859.60 LBS - SURVEY DATA, 1974, FROM TABLE 1)

Category \ Alternative Methods	Recycling	Composting	Incineration	Landfill	Others (Const. & Agri. Use)
Paper	6.09	14.21	14.21	14.21	
Wood & Straw	0.21	20.59	20.59	20.59	
Vegetable		130.60	130.60	130.60	
Rag	1.40		26.52	26.52	
Rubber	0.05		2.43	2.43	
Glass	0.12			4.02	
Metal	0.06			1.32	
Synthetic (plastics)	0.88		13.82	13.82	
Dead Animals (pathological incinerator)			1.00		
Anthracite Briquette Ash (coal ash)					537.40
Demolition				47.88	
Ceramics				3.40	
Garbage		5.00	5.00	5.00	
Others		42.60	42.60	42.60	
TOTAL (lb)	8.81	213.00	255.77	312.39	537.40
PERCENT	1.02	24.78	29.75	36.34	65.52

I. Solid Waste Generation in Study Area

The conceptual design of the alternatives was based on 2,000 ton-generation per day with the following assumption:

The approximated value of 2,000 tons of daily generation of solid waste in the study area was calculated from 1972 to 1985 according to the solid waste generation model.

In 1972:

The solid waste model... $Y_1 = 0.5276 + 8.4x10^{-6}X_1 + 0.2019\ X_2$

where X_1 = 1,300,000 persons per 5600 ha, or 60,141 persons per square mile

X_2 = \$0.87 per person per day

(1) The amount of solid waste generation in ChungGae drainage area will be approximately 785.53 tons per day.

(2) Since there is no separation in collecting briquette ash from the residential solid waste, daily briquette ash will be 892.39 tons, with the assumption that 7.19 pounds ash generation daily per household, and 248,092 households per 5600 ha., based on 5.24 persons per household.

(3) Daily wet sludge generation from the ChungGae Sewage Treatment Plant will be 56.23 tons (Appendix C).

TOTAL = 1734.15 tons per day

In 1985:

Assuming there is only a minimal decrease in population in the study area, about 1.0 percent, due to the Decentralization Plan of the Seoul metropolitan government and the ceiling on the population holding capacity in the area, the following information was obtained.

where X_1 = 68,400 persons per square mile

X_2 = \$2.05 per person per day (graphical value of linear arithmetic increase)

(1) The amount of solid waste generation in the ChungGae drainage area will be approximately 1068.54 tons per day.

(2) Daily briquette ash will be 850.0 tons per day at a 4.5 pounds per 3.9 persons per household (graphical value under linear arithmetic decrease).

(3) Daily wet sludge generation will be 56.23 tons per day without consideration of expansion of the Plant until 1985.

TOTAL = 1977.77 tons per day

Under the assumption that parts of the solid waste generated in the neighborhood drainage areas such as JungRyang, UkChun, KongDuk and Bong-Won drainage areas could be combined into the study area because of short hauling distance and convenience, the total quantity could be approximated at about 2,000 tons per day.

II. Design Consideration

(1) Area requirement of the three alternatives could be the most important factor for the city of Seoul.

(2) The next most important factor could be the capital and operation and maintenance costs. Those values were obtained from previous research reports and personal communications.

(3) In incinerator or composting plant practice, receiving and separating systems of solid waste are necessary.

A. The Necessity of a Receiving and Separating System.

1. Economics of solid waste recycling: our economic system is based on taking natural resources, converting them into consumer products by some industrial or domestic process, and selling these goods to the consumer. The consumer uses them either partially or completely and then discards them as waste. If these wastes are discarded without care or thought to the nation's future needs, these wastes become pollutants. Industry continues to utilize the limited resources, and, even on a smaller scale, adds to the pollution problem in the form of industrial wastes (Figure 8). If these unwanted wastes can be returned economically to the cycle, it will conserve our natural resources.
2. Increase in the operational efficiency of waste disposal.
3. The land can remain free of pollutants for present and future generations and the natural cycle can be continued without interruption.
4. Reduction of the citizen's taxes for solid waste disposal can be accomplished through selling the usable waste.
5. Public safety of controlled handling of solid waste.

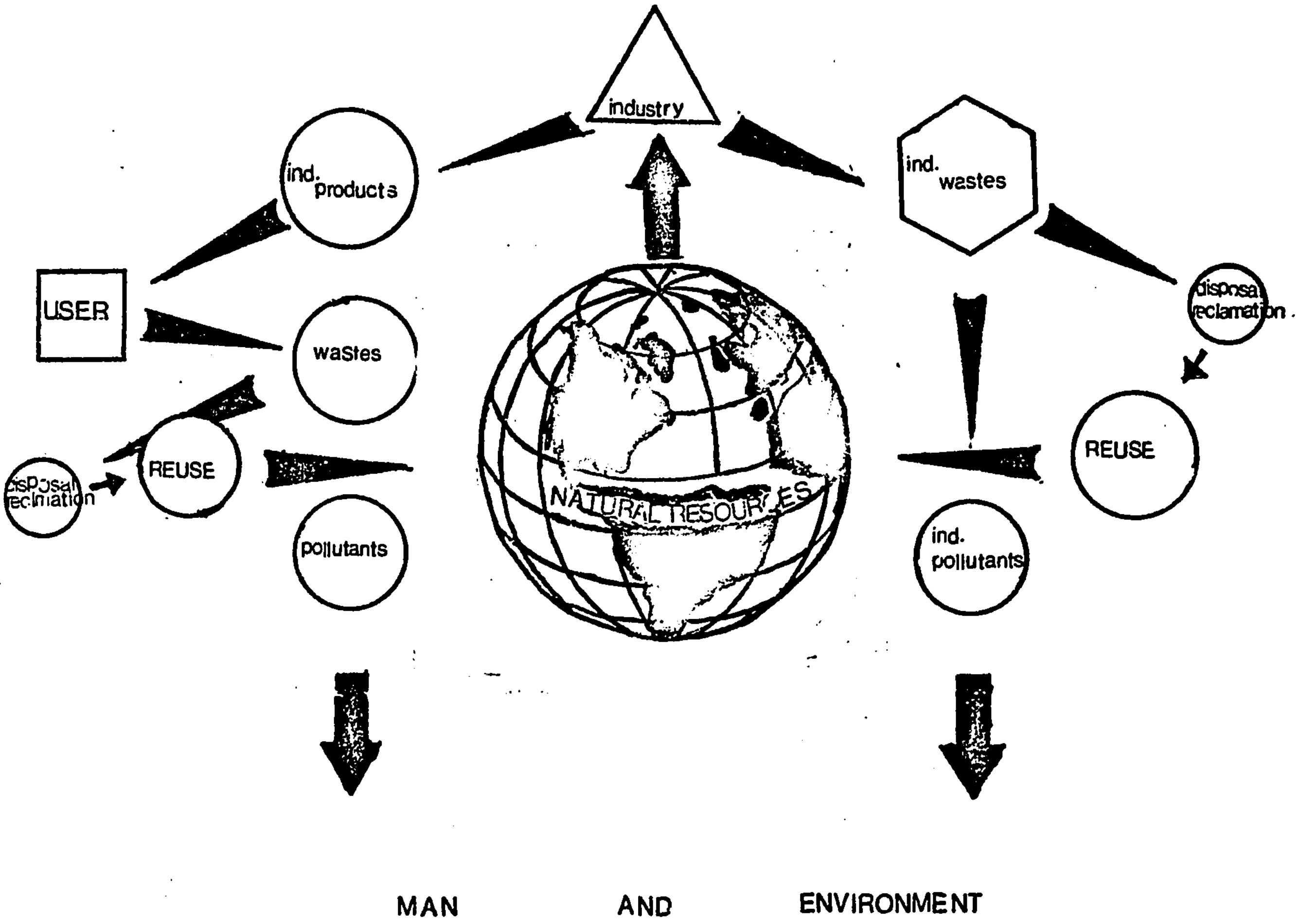

Figure 8

CONSERVATION OF NATURAL RESOURCES AND CLEANUP OF MAN'S ENVIRONMENT BY RECYCLING

B. The Design of Receiving and Separating System.

The design is based upon (1) economics -- minimizing costs of expensive equipment -- (2) efficiency of operations, (3) consideration of availability of labor, and (4) land availability. The design of the system is based on four 500 ton-per-day plants rather than one 2,000 ton-per-day plant. Detailed procedures for designing the receiving and separating system is recorded in Appendix D.

1. Scale system: the scale should be able to weigh the largest and heaviest vehicles anticipated.
2. Platform: the concrete platform is recommended for accomodating the majority of collection trucks.
3. Tipping area: the tipping area is a flat area adjacent to the storage pit where trucks maneuver into position for dumping. The area should be large enough to allow for safe and easy maneuvering and dumping.
4. Storage pit: the total space and number of pit cells depends on the amount of material received (2,000 tons per day), the storage period, and the peak waste delivery.
5. Separation system: the separation of solid waste in this work is designed as manual sorting on a conveyor belt, and follows with mechanical separation such as ballistic, or air classifier.

C. Design Features of Three Major Alternatives (Sanitary Landfill, Incinerator and Composting Plant)

The alternatives were designed with the following information (Appendix D).

1. Sanitary Landfill:

The area required and other necessary information were obtained through personal communications with Canter, 1973.

2. Incinerator:

The procedures of area requirement for major portions of the municipal incinerator were followed with the combination of Danielson's work in 1967 and Corey's work in 1969.

3. Composting Plant:

The design feature of the composting plant is based on the model of Naturizer Company of Norman, Oklahoma, and the model of the Gainsville Composting Plant in Florida.

a. Operational Mechanism of the Plant:

Compostable material from the solid waste is transferred from the sorting system and mixed with wet sludge under controlled conditions. The mixture is ground in primary grinders to a three or four inch size, depending on the characteristics of the material. From the grinder, the moistened material is elevated onto the first digestor, where it will remain for a 24-hour period. Incompletely digested material from the first tank moves down one level through a rotating steel conveyor belt, where it again remains for 24 hours. From here, it is again transferred down one level to the third digestor, where digestion continues for another 24 hours. Another transfer dumps the material into a secondary grinder where the size of the material reduces to three-quarter inch or less, depending upon the degree of composting. This material is sent by another elevator into three additional digestors where it begins a series of 24-hour digestion intervals. After six days of digestion, the size of the compost is reduced to 1/8 inch or less in a tertiary grinder. The material passes across a grading screen. The use of the elevator here is not necessary but is convenient. The screenable material is sent out as compost and the non-screenable material is sent back through the system or to a landfill. The bottom of the cell (Figure 36) in Appendix D) is designed as a rotatable steel conveyor to continuously transfer the composting material into a lower level of the tank. The overlapping steel plates on the bottom gives an important benefit. Through the overlapping orifices or spaces, air penetrates and is distributed into the material.

b. Theoretical Power Requirement of Size Reduction and Oxygen Requirements of the Plant:

The theoretical power requirement for reducing the size of the components of solid waste into two inch and one inch was calculated in Appendix D, which is very close to the horse power being used in size reduction in both Naturizer Company and the Gainsville Composting Plants.

The oxygen requirement for the composting plant for the 595 tons of solid waste was also calculated in Appendix D, to understand the operational characteristics of the composting plant.

c. Advantages of the Naturizer System Over Other Composting Plants:

(i) Reduction of as much as three times the land requirement (especially the digestor area).

(ii) No necessity of oxygen supply equipment during the composting.

(iii) Ease of construction and expansion.

d. Disadvantages of the Naturizer System Over Other Composting Plants:

(i) More time to clean up.

(ii) Dust generation.

D. Information on Five Alternatives

The information necessary for the conceptual design of the five alternatives listed in Tables 8 through 12 indicate area, cost, and employees required for each alternative. The summary table (Table 13) of the five alternatives was inserted in Chapter V, for selection of the most economical and sanitary practices with the DARE Method (Decision Alternative Ration Evaluation).

Table 8

INFORMATION ON ALTERNATIVE 1

SANITARY LANDFILL

Based on 2,000 Ton Generation Per Day

Area

2.6×10^{-1} acres/day, or 94.9 acres/year (p. 202 in Appendix D)

Landfill area required should use the required area being correlated with the lifetime of incinerator and composting plants. Assuming ten year's lifetime of incinerator and composting plants, the required area for ten years = 949 acres.

Volume of Cover Material

126,330 yd^3/10 years

Equipment Investment Cost (Table 32 in Appendix D)

Loader	= $ 71,500 x 2 =	$142,100
Dozer	= $101,500 x 3 =	$304,500
Misc.	=	$257,000
TOTAL	=	$703,000

Operating and Maintenance Cost (Bond and Straub, 1973)

$0.90 per ton

Number of Employees Required at Landfill Site

1 supervisor and 1 assistant	= 2
1 operator per equipment	= 7
2 gate attendants	= 2
1 maintenance operator per equipment	= 7
2 office workers	= 2
TOTAL	20 employees

Table 9

INFORMATION ON ALTERNATIVE 2

SANITARY LANDFILL

Based on 730 Ton Generation Per Day

Area

9.5×10^{-2} acres/day, or 34.7 acres/year

The required area for ten years = 347 acres

Volume of cover material

89,790 yd^3/10 years

Equipment Investment Cost

Loader	= $ 71,500 x 1 =	$ 71,500
Dozer	= $101,500 x 2 =	$203,000
Misc.	=	$ 93,805
TOTAL	=	$368,305

Operating and Maintenance Cost

$1.95 per ton

Number of Employees Required at Landfill Site

16 employees

RECEIVING AND SEPARATING SYSTEM

Based on 2,000 Ton Generation

Area

Length = 140 ft

Width = 490 ft

Subtotal = 68,600 ft^2 for 500 ton holding capacity

68,600 x 4 = 274,400 ft^2, or 6.3 acres

Table 9

(Continued)

Equipment Cost

Cost for one storage pit cell = 475 ft^2 of 1/2-in. of flat steel (1-ft x 1-ft = \$6.32)

475 ft^2 x \$6.32/ft^2 = \$3,002.0 (averaged retail price in Oklahoma City, Oklahoma, 1975)

Total required cells per 500 ton (p. 225) = 49

49 x \$3,002.0 = \$147,098

Total required storage pit cell cost for 2,000 tons = \$588,392

Cost for one hoist required for ten pit cells = \$550 (averaged retail price in Oklahoma City, Oklahoma, 1975)

\$550 x 5 = \$2,750

Total cost of hoist for 2,000 tons = \$11,000

Total conveyor cost for 2,000 tons = \$128,192 (Pierson, 1975)

Grant total equipment cost = \$727,584

Number of Employees Required

112 persons (assumed at 62% of Alternative 3 and 4)

Operating and Maintenance Cost

Unknown (assumed zero dollars)

Table 10

INFORMATION ON ALTERNATIVE 3

SANITARY LANDFILL

Based on 135 Ton Generation Per Day

Area

1.8×10^{-2} acres/day, or 6.4 acres/year

The required area for ten years = 64 acres

Volume of Cover Material

17,155 yd^3/10 years

Equipment Investment Cost

Loader	= $ 71,500 x 1 =	$ 71,500
Dozer	= $101,500 x 1 =	$101,500
Misc.	=	$ 16,962
TOTAL	=	$189,962

Operating and Maintenance Cost

$2.80 per ton

Number of Employees Required at Landfill Site

12 employees

INCINERATOR

Based on 600 Ton Generation Per Day

Area (pp. 204 in Appendix D)

Grate area = 1051.0 ft^2 (width = 24.5 ft and length = 42.9 ft)

Mixing chamber area = 208.7 ft^2

Combustion chamber area = 616.9 ft^2

Table 10

(Continued)

Stack area	=	$260.9\ ft^2$
TOTAL	=	$2137.5\ ft^2$, or 0.05 acres

Equipment Investment Cost

Approximately $3,240,000 (Present cost was assumed to be 35% inflation of Achinger and Daniel's works, 1970)

Rate per unit area of grate -- 47 $lb/ft^2/hr$

Operating and Maintenance Cost

Operating cost (with financing and ownership costs) = 3.36/ton

Repair and maintenance cost = 0.53/ton

Total operating and maintenance cost = $3.89/ton x 35% inflation = $5.25

Number of Employees Required

1 supervisor and 1 assistant	=	2
2 operators	=	2
4 maintenance	=	4
2 gate attendants	=	2
2 office workers	=	2
TOTAL	=	12 persons

Auxiliary Fuel Requirements of Waste

Since average gas temperatures used in Alternative 3 is 726° F at 300% excess air, it is recommended an increase to 1400° F -- 2,000° F (Municipal Refuse Disposal -- APWA, 1970).

Table 10

(Continued)

To increase the gas temperature to 1500° F, kerosine is required at about 196 gal/hr (based on 136,000 BTU/gal), or 112 barrels/day

408,800 barrels/ten years

$78.40/hr ($0.40/gal retail price, Oklahoma City, Oklahoma, 1975), or $1,181.6/day

RECEIVING AND SEPARATING SYSTEM
Based on 2,000 Ton Generation

Area

6.3 acres

Equipment Cost

$727,584 (same as Alternative 2). It is necessary to add the cost of the mechanical separator (as an example, 1 ballistic separator -- 1800 rpm electric motor with 0.4 ton/hr = $23,488) = 54 (ballistic separators with assumed 30% of the total wastes being separated by hand picking except the coal ash) + 6 for replacement purposes x $23,488 = $1,409,280

Total equipment cost = $2,136,864

Number of Employees Required

180 persons

Table 11

INFORMATION ON ALTERNATIVE 4

SANITARY LANDFILL

Based on 235 Ton Generation Per Day

Area

1.8×10^{-2} acres/day, or 6.4 acres/year

The required area for ten years = 64 acres

Volume of Cover Material

17,155 yd^3/10 years

Equipment Investment Cost

Loader	= $ 71,500 x 1	= $ 71,500
Dozer	= $101,500 x 1	= $101,500
Misc.		= $ 16,962
TOTAL		= $189,962

Operating and Maintenance Cost

$2.80 per ton

Number of Employees Required at Landfill Site

12 employees

COMPOSTING PLANT

Based on 500 Ton Generation Per Day

Area

Sewage sludge holding tank area = 116.6 ft^2

Digestor area = (484.9-ft x 8-ft)x 2 = 7758.4 ft^2

Area for mixing, screening, and miscellaneous uses = 0.5 acres

Total area = 0.7 acres

Table 11

(Continued)

Equipment Investment Cost

$1,037,698 (ten times the cost for the design capacity of 50 ton/day -- based on 45% inflation of Pierson's work, 1967)

Operating and Maintenance Cost

$6.00/ton (20% inflation, Breidenbach, 1971)

Number of Employees Required

1 supervisor and 1 assistant	= 2
6 operators (3 shifts/day)	= 6
3 maintenance	= 3
2 gate attendants	= 2
6 bagmaker and 6 transferrers	= 12
TOTAL	25 persons

RECEIVING AND SEPARATING SYSTEM
Based on 2,000 Ton Generation Per Day

Area

6.3 acres (same as Alternative 2)

Total Equipment Cost

$2,136,864 (same as Alternative 3)

Number of Employees Required

180 persons (same as Alternative 2)

Table 12

INFORMATION ON ALTERNATIVE 5

SANITARY LANDFILL

Based on 135 Ton Generation Per Day

Area

1.8×10^{-2} acres/day, or 6.4 acres/year

The required area for ten years = 64 acres

Volume of Cover Material

17,155 yd^3/10 years

Equipment Investment Cost

$189,962 (see Alternative 3)

Operating and Maintenance Cost

$2.80 per ton

Number of Employees Required at Landfill Site

12 employees

INCINERATOR

Based on 190 Ton Generation Per Day

Area

Grate area	= 893.7 ft^2
Mixing chamber area	= 215.2 ft^2
Combustion chamber area	= 636.1 ft^2
Stack area	= 269.0 ft^2
TOTAL	= 2014.0 ft^2, or 0.05 acres

Table 12

(Continued)

Equipment Investment Cost

Cost based on the design burning rate per unit area (45.2 $lb/ft^2/hr$) = \$636,739 (35% inflation rate of Achinger and Daniels' works, 1970)

Operating and Maintenance Cost

Operating cost = \$2.95/(include financing and ton ownership costs)

Repairs and maintenance cost = \$0.5/ton

Total operating and maintenance cost = \$3.45 x (35% inflation of Achinger and Daniels' works) = \$4.66

Number of Employees Required

12 persons (see Alternative 3)

Auxiliary Fuel Required

The waste used in Alternative 5, having an average 36% moisture and 9496 BTU/lb, indicated 1640° F of average gas temperature at 300% excess air. Since the average gas temperature is above 1500° F, the waste could be burned without auxiliary fuel.

COMPOSTING PLANT
Based on 410 Ton Generation Per Day

Area

Total required area = 0.6 acres (assuming approximately 80% of Alternative 4)

Table 12

(Continued)

<u>Equipment Investment Cost</u>

$830,158 (8 times of the cost for the design capacity of 50 ton/day -- based on 45% inflation of Pierson's work, 1967)

<u>Operating and Maintenance Cost</u>

$6.50/ton (20% inflation, Breidenbach, 1971)

<u>Number of Employees Required</u>

23 persons (one person less than Alternative 4 in maintenance and gate attendant)

<u>RECEIVING AND SEPARATING SYSTEM</u>
Based on 2,000 Ton Generation Per Day

<u>Area</u>

6.3 acres (same as Alternative 2)

<u>Total Equipment Cost</u>

$2,136,864 (the equipment cost of air classifier is assumed to be the same as the cost of ballistic separator)

<u>Number of Employees Required</u>

180 persons (Same as Alternative 2)

Consideration of Source Separation

To compare the benefits of source separation with central separation,[1] it is necessary to understand the circumstances of present and proposed disposal operations based on economic and sanitary viewpoints and public support. The source separation could be divided into (1) house-to-house separating system, and (2) central containerized system.

The house-to-house separating system means the solid wastes are separated by each waste generator and removed separately with house-to-house pickup. The central containerized system means that containers would be located in all parts of the city of Seoul based on population, rate of waste generation, and convenience of the location for collection from the waste generator and removal by public workers. The containers should be marked for each waste and removed separately.

The number of containers required for separating the waste should be further studied, depending upon which alternative is best suited for the city of Seoul, Korea. The comparative study requires the following basic information:

1. How many additional employees would need to be used for collecting the separated wastes than are used presently;
2. How much of an economic obligation would be required from the citizens to build the increased number of containers;

---

[1] Indicates a receiving and separating system proposed at a given location.

3. How many pushcarts and vehicles would be required to collect the separated waste;
4. The availability of temporary deposit sites in case of house-to-house collection system use in consideration of the narrowness of residential roads; and
5. The present expenditures for collecting waste from the Seoul Metropolitan Government.

Advantages of Source Separation:

(1) Increase in disposal efficiency.

(2) Reduction of the cost of central separation.

(3) Better selection of alternative disposal methods.

Disadvantages of Source Separation:

(1) Traffic disorders due to increased collection vehicles.

(2) A footpath disorder due to increased collection pushcarts.

(3) Public education cost.

(4) Public health and safety hazards due to generation of dust.

Pathological-Waste Incinerator

Danielson (1969) defined pathological waste as all, or parts of, organs, bones, muscles, other tissues, and organic wastes of human or animal origin.

1. Principal Consideration of the Incinerator:

The principal consideration of the incinerator is how to manage the fluids generated as the waste is burned due to slow evaporation of the fluid. The construction of the incinerator, therefore, requires the use of a solid hearth rather than grates in the ignition chamber. The more detailed information on the pathological-waste incinerator may be obtained from Danielson's work in 1967.

Since pathological-waste incinerators are utilized in all of the five alternatives, their construction costs are not included in this paper.

2. Residual Disposal Consideration:

Since the pathological waste of animals is mainly composed of rats killed by rodenticide (formula unsearched), the residue should be disposed of safely. Depending on the rodenticide's lifetime, it should be buried far from residential areas because of the leachate contamination in ground water and runoff. Also, quenched residue should be treated.

Chapter V

SOLID WASTE DISPOSAL - ALTERNATIVE SELECTION

This work followed the basic idea formulated by Dean and Nishry (1964) from which a decision model involving weighted and unweighted scoring was used to evaluate an alternative allocation decision. The given weights or rating necessary in this model were decided upon after carefully considering the present and future economic, sanitary, and agricultural conditions in Korea.

There are five proposals (alternatives) for solid waste removal (Figure 7). Simple decision criteria were selected to evaluate these alternatives. They are (1) required area, (2) cost of major equipment, (3) operation and maintenance costs, (4) number of employees required, and (5) fuel requirements. Given as the Technical Factor (Table 13), Marketing Factors (Table 14) evaluated as percentage scales in (1) salvageable material recovered, and (2) marketing potential of the final product, and ratio scales in (3) distribution and inventory costs, and (4) the scale of potential increase in crop oroduction.

Table 13

SUMMARY OF FIVE ALTERNATIVE DISPOSAL METHODS (TECHNICAL FACTORS)

Decision-factors / Project	Area Required (acre/ten years)	Equipment Investment Cost ($)	Operation & Maintenance Cost ($/ton)	Number of Employees Required	Fuel Requirements ($/day)
Alternative 1	949	703,000	0.90	20	$50 = (25 gal/dozer x 40¢/gal x 5)
Alternative 2	353.3	1,095,889	1.95	128	$30 = (25 gal/dozer x 40¢/gal x 3)
Alternative 3	70.4	6,294,410	8.05	204	$1881.6 (incinerator) + $20 (25 gal/dozer x 40¢/gal x 2) = 1901.6
Alternative 4	71.0	3,364,524	8.80	217	$20
Alternative 5	64.7	3,793,723	13.96	227	$20

Table 14

INFORMATION ON FIVE ALTERNATIVES FOR MARKETING FACTORS

Decision Factors \ Projects	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Amount of Salvageable Material Recovered[1]	10%	90%	90%	90%	90%
Scale of Marketing Potential of Final Product[2]	0%	0%	20%	100%	60%
Distribution and Inventory Cost[3]	0	0	2	5	4
Scale of Potential Increase in Crop Production[3]	0	0	1	5	3

1. Ninety percent recovery of solid waste of the total salvageable materials is assumed to be done in receiving and separating system.
2. Assumed percentage values (20% for incinerator residue, 100% for composting plant, and 60% for compost and incinerator residue could be sold based on the amount of generation of the final product).
3. Assumed ratio scale based on 5 maximum value.

Another assumption implicit in the use of a model of the form of equation is the factor values as defined on a ratio scale. The value of scale has an absolute or hypothetical evaluation that has definite empirical meaning.

The necessary information of the factors (j) in technical factors among the five projects was obtained from the conceptual designs of the five alternatives (Chapter IV).

Principal of Scoring the Model

The scoring of the model was constructed to identify the relevant factors that affect allocation decisions, to obtain unbiased variables of an objective function, and to measure their relative importance as factors and variables.

The form of the total score evaluation of technical and marketing factors used here is:

$$Wi = Wi' + Wi'' = a \sum_j wij'\ yij' + b \sum_k wk'\ yik'' = \text{total score}$$

where wi' is the technical score for the ith project

wi" is the market score for the ith project

wj' is the weighted value for the jth technical factor

wk" is the weighted value for the kth market factor

yij' is the value for the technical factor j in the ith project

yik" is the value for the market factor k in the ith project

a,b are decision variables, a + b = 0

Wi is $\sum_{j=1}^{j=n}$ wj yij

where i is the set of projects (i=i=1,2,3...m)

j is the factor that is considered to be important in affecting the project (j:j=1,2,3...n)

wj is a weighted factor which measures the relative importance of the factors

$0 \leqq wj \geqq 1$

$\sum_{j=1}^{j=n} wj = 1$

yij is the value of the ith project with respect to the jth factor

Wi, therefore, is the total weighted score of the ith project

Matrix Formation

The matrix was formed from the information obtained for the conceptual design of the five alternatives and from the marketing factors in Table 14. Each factor in the five projects was scored as six scale values, and then Technical and Marketing matrices were obtained.

Technical Factors: (60)

A. Area Usage (40%)	Score Value
More than 930 acres	1
Between 770 and 930 acres	2
Between 530 and 770 acres	3
Between 330 and 530 acres	4

	Score Value
Between 130 and 330 acres	5
Less than 130 acres	6
B. Equipment Cost (30%)	
More than $6,000,000	1
Between $4,800,000 and $6,000,000	2
Between $3,600,000 and $4,800,000	3
Between $2,400,000 and $3,600,000	4
Between $1,200,000 and $2,400,000	5
Less than $1,200,000	6
C. Operating and Maintenance Cost Per Ton (15%)	
More than $13	1
Between $10.4 and $13	2
Between $7.8 and $10.4	3
Between $5.2 and $7.8	4
Between $2.6 and $5.2	5
Less than $2.6	6
D. Number of Employees Required (5%)	
More than 220	1
Between 176 and 220	2
Between 132 and 176	3
Between 88 and 132	4
Between 44 and 88	5
Less than 44	6

	Score Value
E. Fuel Requirement (10%)	
More than $1,500	1
Between $1,200 and $1,500	2
Between $900 and $1,200	3
Between $600 and $900	4
Between $300 and $600	5
Less than $300	6
Marketing Factors: (40)	
A. Amount of Salvageable Material Recovered (10%)	
Less than 50%	1
Between 50 and 60%	2
Between 60 and 70%	3
Between 70 and 80%	4
Between 80 and 90%	5
More than 90%	6
B. Scale of Marketing Potential of Final Product (40%)	
Less than 20% (no demand)	1
Between 20 and 40% (little demand)	2
Between 40 and 60% (increasing demand)	3
Between 60 and 80% (medium-increasing demand)	4
Between 80 and 100% (high demand)	5
More than 100% (very high demand)	6

	Score Value
C. <u>Distribution and Inventory Cost (30%)</u>	
Less than 1 (no cost)	6
Between 1 and 2 (little cost)	5
Between 2 and 3 (increasing cost)	4
Between 3 and 4 (medium cost)	3
Between 4 and 5 (high cost)	2
More than 5 (very high cost)	1
D. <u>Scale of Potential Increase in Crop Production (20%)</u>	
Less than 1 (no effect)	1
Between 1 and 2 (little effect)	2
Between 2 and 3 (increasing effect)	3
Between 3 and 4 (medium effect)	4
Between 4 and 5 (high effect)	5
More than 5 (very high effect)	6

To evaluate the ranking of the five alternatives, the decision factors of each alternative were assigned a score value and all of the score values were added algebraically, giving the unweighted value in $\sum_{j=1}^{5} Yij$ and $\sum_{j=1}^{4} Y'ij$ columns in Technical and Marketing factors (Table 15 and 16). The weighted values Wi and W'i columns in Technical and Marketing factors (Table 15 and 16) were obtained by the multiplication of factor weights and score values. For the final ranking score, the relative weights were given hypothetically; 60% for Technical factor and 40% for Marketing factor.

Table 15

TECHNICAL FACTORS (THE WJI MATRIX)

Factors j	1	2	3	4	5	$\sum_{j=1}^{5}$ Yij	Wi
Factor Weights wj	40	30	15	5	10	30	600
Project i							
Alternative 1	1	6	6	6	1	20	350
Alternative 2	3	6	6	4	6	25	470
Alternative 3	6	1	3	2	6	18	385
Alternative 4	6	4	3	2	6	21	475
Alternative 5	6	3	1	1	6	17	410

Table 16

MARKETING FACTORS (THE W'IJ MATRIX)

Factor j	1	2	3	4	$\sum_{j=1}^{4}$ Y'ij	W'i
Factor Weights W'j	10	40	30	20	24	600
Project i						
Alternative 1	1	1	6	1	9	250
Alternative 2	6	1	6	1	14	300
Alternative 3	6	2	4	2	14	300
Alternative 4	6	6	1	6	19	450
Alternative 5	6	4	2	4	16	360

Table 17

TOTAL PROJECT SCORES AND RANKS

	(a) Unweighted Scores				(b) Weighted Scores			
	Technical Score (30)	Market Score (24)	Total (54)	Scoring Rank	Technical Score (600)	Market Score (600)	Total 1200*	Scoring Rank
Project i								
Alternative 1	20	9	29	5	350	250	310	5
Alternative 2	25	14	39	2	470	300	402	2
Alternative 3	18	14	32	4	385	300	351	4
Alternative 4	21	19	40	1	475	450	465	1
Alternative 5	17	16	33	3	410	360	390	3

* where a (Technical Factor) = 60% and b (Marketing Factor) = 40% (a+b=1)

$$W_1 = a\, W_1 + b\, W'_1$$
$$= .6 \times 350 + .4 \times 250$$
$$= 210 + 100 = 310$$

$$W_2 = a\, W_2 + b\, W'_2$$
$$= .6 \times 470 + .4 \times 300$$
$$= 282 + 120 = 402$$

$$W_3 = a\, W_3 + b\, W'_3$$
$$= .6 \times 385 + .4 \times 300$$
$$= 231 + 120 = 351$$

$$W_4 = a\, W_4 + b\, W'_4$$
$$= .6 \times 475 + .4 \times 450$$
$$= 285 + 180 = 465$$

$$W_5 = a\, W_5 + b\, W'_5$$
$$= .6 \times 410 + .4 \times 360$$
$$= 246 + 144$$
$$= 390$$

Results of Scoring Model

The empirical inferences drawn from the five projects (Figure 7) indicated that the composting project (Alternative 4) was the most beneficial practice of disposing of solid waste in both unweighted and weighted ranking decision tests (Table 17). The next favorable project was the sanitary landfill (Alternative 2). The third ranked project was the combination of three alternatives (sanitary landfill, incinerator, and compost). The least favorable project was indicated to be the sanitary landfill practice without separating the coal ash, mainly due to the low values of the marketing factors.

Since composting practice is the most favorable alternative in handling the solid waste generated in the city of Seoul, Korea, as shown from the scoring model, if source separation is necessary, the minimum number of containers required will be two for the containerized separating system and one[1] for the house-to-house collection system for separated collection of coal ash and other wastes. Since recycling of the salvage materials is also extremely important in a country with limited natural resources available such as Korea, the central separation system should be installed in order to increase the recycling efficiency of salvageable materials and to help ensure public health standards. (Further research is needed in this regard.)

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1 The original one container prepared in each house could be substituted as a separating container.

Chapter VI

KOREAN COAL-ASH STUDIES

Definition of Korean Coal Ash (Briquette Ash)

The briquetted ash is a solid waste resulting from the combustion of briquetted coal. Coal briquettes are used as one of the sources of fuel, in cooking and in heating, an residential, commercial, and industrial facilities. An anthracite briquette is a molded cylinder about 15 centimeters in diameter, and about 14 centimeters in length, formed under approximately 25 kg/cm^2 pressure.

An average residential type briquette weighs 3.5 - 3.6 kgm and has 22 holes with 1 centimeter diameter, forming a circular pattern. More than one million tons of briquetted ash is produced annually in the city of Seoul, Korea.

Problems

Over 62% of the total solid waste of the coal ash could be the most important portion of the management of the city of Seoul because of (1) a serious shortage in the production of disposal areas, (2) increasing costs of disposal, (3) increasing production of the ash waste, (4) public health problems caused by dust generation from poor collection systems, and (5) aesthetic considerations. Ash waste has become a problem that requires immediate action.

Solution: This work is designed to operate in conjunction with the solid waste disposal management for the city of Seoul and is directed at two purposes, the use of ash in construction material and/or use as a soil conditioner for agricultural purposes.

Review of Coal Ash Utilization as Construction Material

In the United States and Europe, the major outlet for flyash has been utilized for construction materials such as concrete blocks and roadbed stabilization.

> The term "flyash" is defined by the TVA as an artificial pozzolan. A pozzolan is defined as "siliceous and aluminous material like volcanic ash, which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties."

The general characteristics of physical and chemical analysis of incinerator flyash are shown below in Table 18.

Table 18

PHYSICAL AND CHEMICAL ANALYSIS OF INCINERATOR FLYASH[1]

Physical		Chemical	
Sieve Mesh	Percent by Weight	Element	Percent by Weight
+20	4.9	Si	18.64
20 x 40	8.3	Al	10.79
40 x 60	12.5	Fe	2.13
60 x 100	12.8	Ti	2.24
100 x 200	24.4	Ca	4.70
200 x 325	12.8	Mg	0.98
-325	24.3	C	11.62
		Ignition Loss	14.45

[1] Institute for Solid Waste of American Public Works Association, 1970.

1. Ash Utilization in the United States:

The United States is presently very active in studying potential uses of ash and identifying the technical and economical factors inhibiting its use.

a. Road Construction.

A 4.6 mile test road was constructed in West Virginia (State Route 2) made of flyash and slag. Its constituent was 15.5% fly-ash, 83% slag, and 1.5% lime. Flyash from lignite coal has been approved as mineral filler for bituminous highway surfaces in North Dakota. Similar projects involving flyash are being conducted in Maryland, Kentucky, Indiana and New York.[1]

b. Building Construction.

Flyash has been used as a constituent in the concrete for building of the Salem Nuclear Generating Station in New Jersey.[2] It is known that flyash was used in all of the concrete structures throughout the plant including the reactor contaminant building, the turbine generator foundation, and the auxiliary and service buildings.

> The construction of a nuclear power plant differs somewhat from that of a general fossil fuel plant in that the reactor contaminant, auxiliary and fuel handling buildings are classified by the Atomic Commission as Class I structures; that is, the structure must be able to withstand severe seismic loadings.

The lightweight flyash aggregate was also used in the construction of the light weight concrete (109 lbs/ft)^3 for the roof section, and the seat riser of the West Virginia University's new coliseum.[3]

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[1] National Ash Association, Vol. 1, No. 3, 1969.

[2] National Ash Association, Vol. 1, no. 4, 1970.

[3] National Ash Association, Vol. 1, No. 1, 1969.

c. Brick.

The acceptance of lignite flyash as mineral filler by the North Dakota Highway Department was reported in the production of full size brick from the mixtures of 12% water, 65% flyash, and 35% bottom ash or sand, with forming pressure of 2300 psi.[1]

Another type of flyash brick as a testing source showed the achievement of all ASTM's requirements for grade-SW (severe weather) brick and was composed of 75% flyash, 25% bottom ash, and small amounts of binder material.[2]

A project was conducted by the National Ash Association, which is approved by the Fire Council of Underwriter's Laboratories, Inc. An eight inch block was tested which was made with cement/aggregate ratios of about 1 to 8.5,[3] which proved the flyash brick was superior to commercial brick in fire endurance.

d. River Embankment.

The Minnesota Highway Department approved the use of flyash for an embankment to bridge the Chicago, Milwaukee, St. Paul and Pacific Railroad tracks in St. Paul. The flyash used for the project was about 90% silt size (under 200 mesh), an optimum moisture content of 27%, and a dry density of 85.7 pounds per yard.[4]

e. Filler of Mine Cave

Flyash is used for filling voids and cave areas in mines and for controlling and containing mine fires. An experiment indicated

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[1] National Ash Association, Vol. II, No. 1, 1970.

[2] National Ash Association, Vol. II, No. 1, 1969.

[3] National Ash Association, Vol. II, No. 4, 1970.

[4] National Ash Association, Vol. II, No. 3, 1970.

that the flyash was the most effective of dry material in forming tight and stable seals in inaccessible openings.[1]

f. Mineral Wool Formation.

The possibility of the mineral wood formation from coal-slag has been studied in the Coal Research Bureau, West Virginia University. Detailed information on this work has not been published.[2]

2. Ash Utilization in Europe and Other Countries:

Most European countries have been accepting flyash-aerated concrete since World War II.

Aerated concrete, also known as gas beton, cellular concrete, gasing concrete, and formed concrete, is manufactured through autoclaving (7 - 20 hours at 150 to 175 psi at 300° F for high quality) and by mixing lime and/or cement to slurries of siliceous material such as flyash, sand, or mixtures of these materials, which has an advantage of reducing drying shrinkage. Aerated concrete containing flyash has a bulk density range of 40 to 50 pounds per foot and a compressive strength of 600 to 800 psi. Thermal conductivity (K_{22} value) of aerated concrete ranges from 1.30 - 2.20 BTU-in/ft^2-hr-F° (4.0 for plaster, 8.0 for brick).[3]

High quality light weight aggregate is being produced in a sintering plant near Essen, West Germany. The plant was constructed as a means of lowering flyash disposal costs during the winter months when construction activity is low. West Germany also has been using flyash as an asphaltic filler for paving secondary and access areas, called "GOOSE" paving. The paving consists of slurrying 10 to 20% asphalt with 0 x 1/4 inch aggregate and 28% flyash. It is reported

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[1] National Ash Association, Vol. II, No. 3, 1970.

[2] National Ash Association, Vol. 1, No. 1, 1969.

[3] National Ash Association, Vol. III, No. 1, 1971.

that West Germany expects close to one hundred percent utilization of flyash by 1971.[1]

In England, two and one-half million tons of flyash are being used annually as load-bearing fill and embankments. British engineers cite the following advantages of flyash as a filler: (1) compacted bulk density of 80 to 90 lbs/ft^3 compared to 140 to 150 lbs/ft^3 for common borrow, and (2) less settlement in enbankments in comparison with common borrow. Complete utilization of the ash is projected for England by the mid-1970's.[1]

World-wide utilization of coal ash (flyash and bottom ash) was estimated to be 30% in nine countries reporting, ranging from under 20% for Spain, Czechoslovakia, to a high of 69% in West Germany and 96% in Denmark.[1]

A short statement of flyash use for oil spillage at sea in Hong Kong has been reported with a mixture of cement and flyash.

Korean Ash Testing for Engineering Utilization

1. Sampling:

Korean briquette ash or coal ash was collected randomly from the areas of SungBuk-Ku, DongDae Moon-Ku, YongDeoung Po-Ku, and JongRo-Ku. The collected samples were divided into completely burned and incompletely burned ashes, broken by washed hands for storage in clean plastic bottles for ease in transporting into the United States.

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[1] National Ash Association, Vol. II, No. 1, 1971.

Sampling time: August 12-15, 1974.

Total sample weight: 2000 gm.

The tests selected in this section for evaluating the Korean briquette ash were only those which are generally used for identification of highway and construction soil material.

2. Specific Gravity:

The specific gravity (S) of the briquette ash was determined in accordance with the ASTM designation D854-65 (AASHO designation T-100-60). The specific gravity of the passing of the 0.0787 inch opening showed 2.42 complete burned ash (CBA) and 2.67 of incompletely burned ash (IBA). The results of the test indicated a slight similarity with the quartz material (S = 2.65).

3. Grain Size Analysis:

Grain size distribution was determined in accordance with the ASTM designation D422-63 (AASHO designation T88-57). Calgon was used as the dispersing agent. Iowa jet dispersion pressure of 10 psi was maintained for about ten minutes.

The tests were conducted with 375.40 grams of IBA and 343.40 grams of CBA at 25^{o} C. A particle size distribution curve using the definition for sand, silt, and clay was drawn and is shown in Figures 9 and 10 with the composition of the ash sample being shown in Table 19.

The results of the test indicated the Korean briquette ash classified as sandy loam, as is shown in Figure 11.

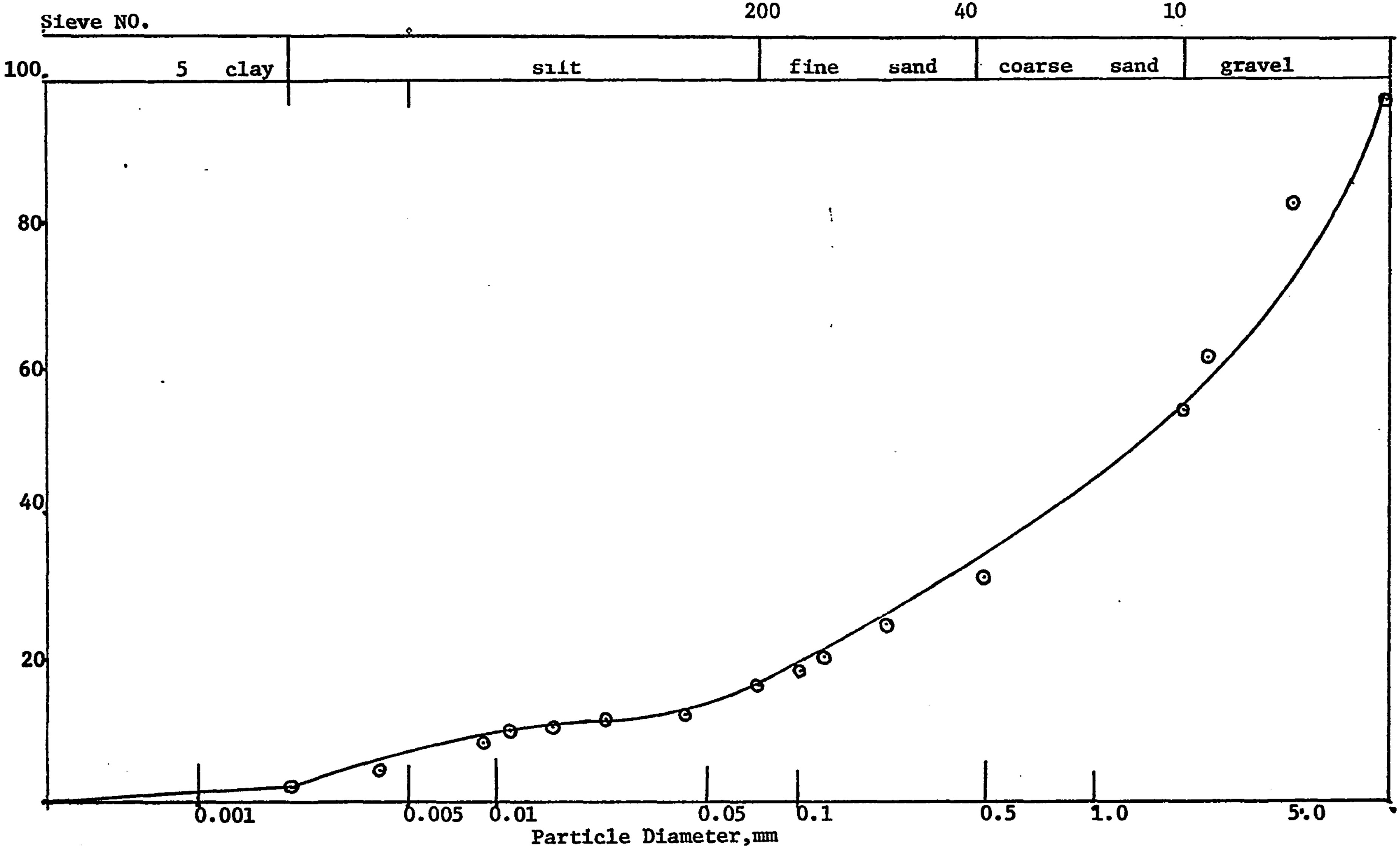


Figure 9 Grain Size Distribution Curves for CBA

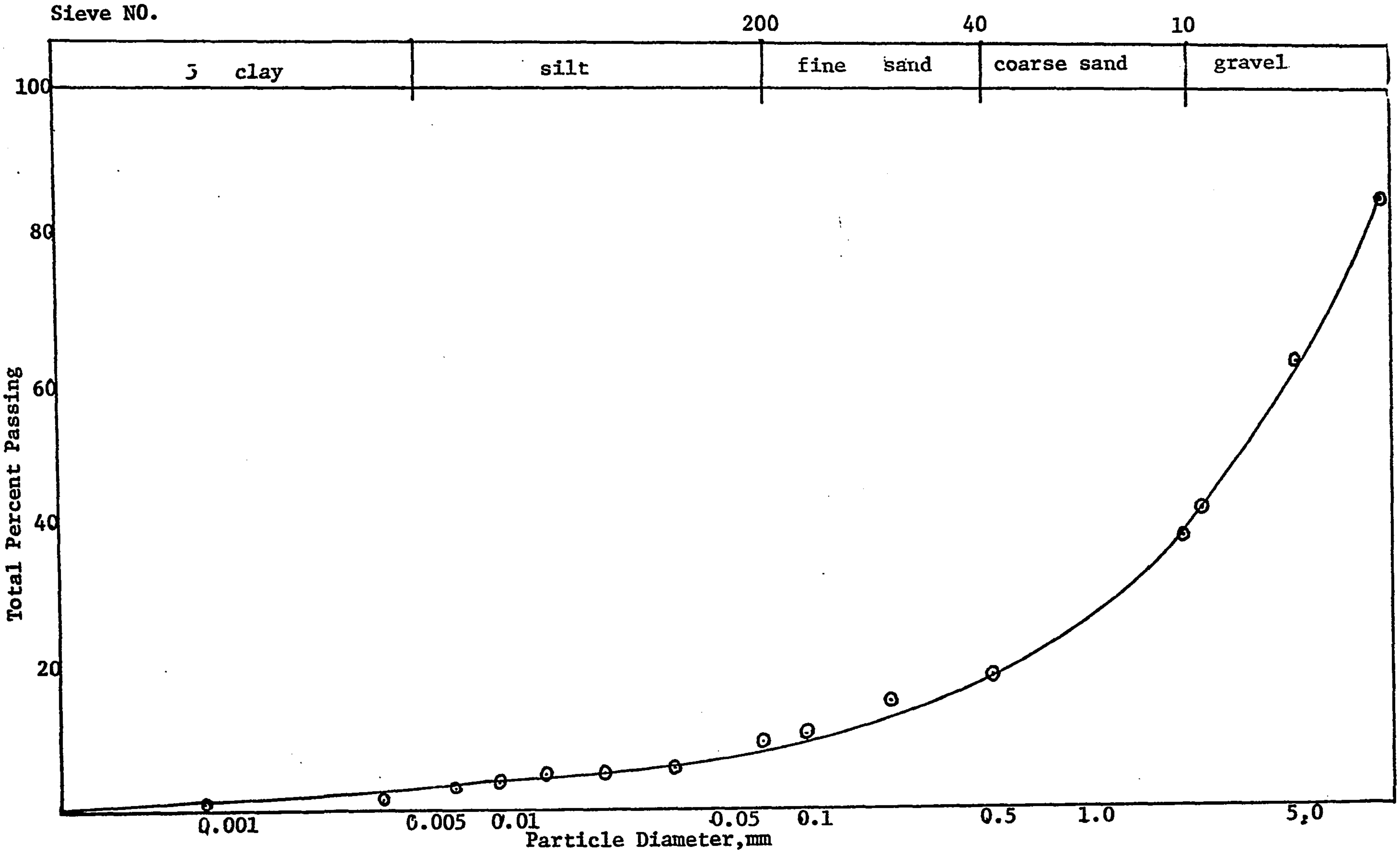


Figure 10 Grain Size Distribution Curves for IBA

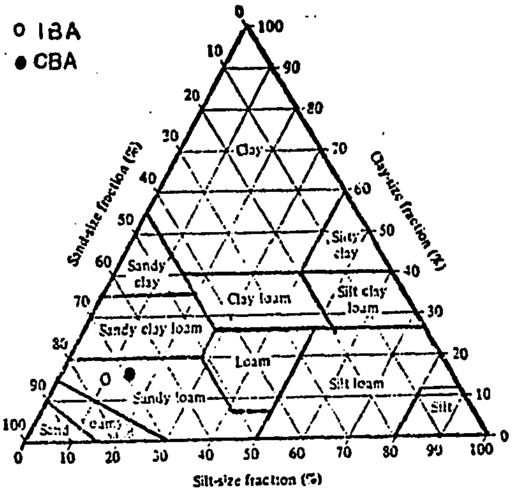


Figure 11

Textural Classification (USDA) of IBA and CBA

Table 19

GRAIN SIZE ANALYSIS OF KOREAN COAL ASH

	IBA	CBA
Sand (%)	75.0	69.0
Silt (%)	10.0	12.8
Clay (%)	15.0	12.2

4. Ash Consistency Test:

Tests were run in accordance with the ASTM designation D423-66 (AASHO designation T89-60) for the liquid limit, and with ASTM designation D424-65 (AASHO designation T90-61) for the plastic limit.

The results of the Atterberg limits of the ash sample passing the 0.0165 inch opening showed about 58.95% with 25 blows. The tests of the plastic limit with the same size sample used in the Atterberg limit showed an average 52.38%, with a wide range between 45.61 and 61.54 percent. As the ash plasticity index is 6.57%, the Korean briquette ash could be described as a non-cohesive or partly cohesive material.

As the results of the consistency test and grain size analysis show, the tested ash comes under the A-2-7, according to AASHO classification, with a group index of zero in an evaluation of highway subgrade material (Karol, 1960).

5. Moisture-Density Tests:

These tests were run in accordance with the ASTM designation D698-66 (AASHO designation T-99-61), with the standard proctor compaction apparatus. The samples were compacted in five layers under a compactive effort of 25 blows per layer, using a 20 pound spring loaded rammer. A typical value of optimum density could not be obtained due to the continued increases in the density of the ash (with increase in moisture).

The compaction curve of the Korean briquette ash (Figure 12) might be within the range of a and b (marked) of a typical compaction curve for cohesionless soil, as shown in Figure 13.

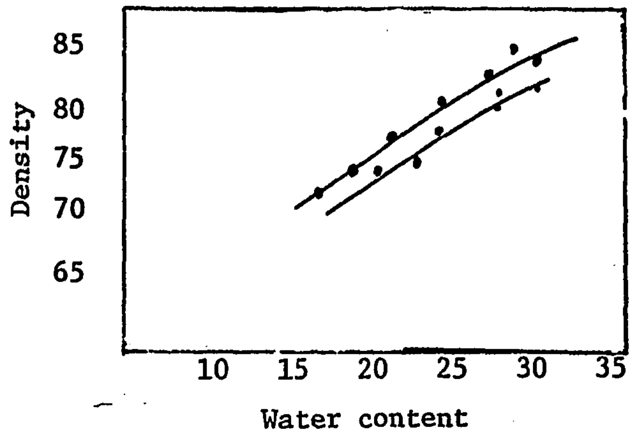


Figure 12

COMPACTION CURVE FOR KOREAN BRIQUETTE ASH

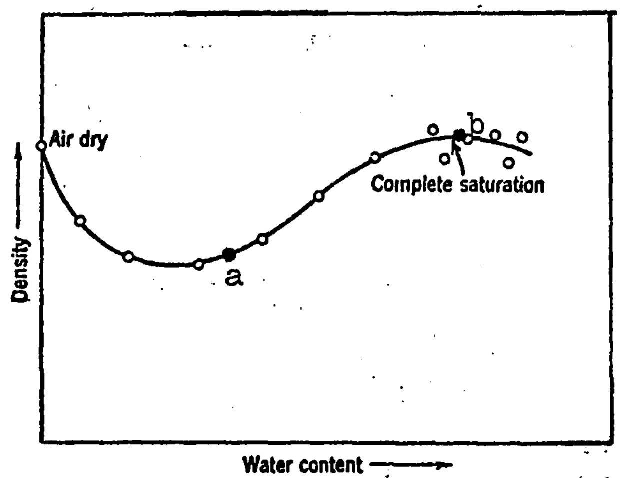


Figure 13

TYPICAL COMPACTION CURVE FOR COHESIONLESS SANDS
AND SANDY GRAVEL

(Lambe and Whitman, 1969)

6. Compressive Strength Test:

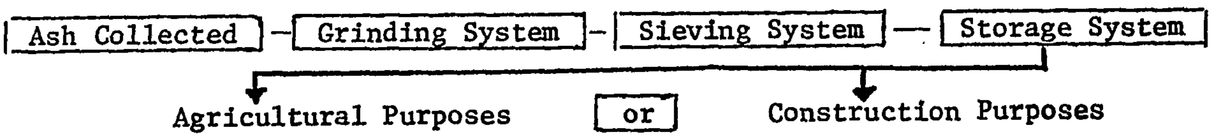
The quantity (200 gm) of randomly selected coal ash sample was mixed with 27% distilled water based on an optimum moisture content (Ash at Work, Vol. II, No. 3, 1970). The distilled water added included about one percent more water to allow for evaporation losses during mixing and handling. The mixed samples were cured for 48 hours at or near 100% relative humidity in glass desiccators. The specimens were prepared with the Harvard Miniature Compaction apparatus and then wrapped with clear plastic wrap paper. The speciman was cured for 24 hours prior to testing to bring about even distribution of moisture throughout the specimen. Dimensions of the specimens were measured. The specimens were then tested in an unconfined compression machine, showing an average of 62.37 lbs/sq.in. If the direct shear test or triaxial compression test was done, more reliable information for this cohesionless soil could be obtained; however, this procedure was not used because of the shortage of the testing sample.

a. Prerequisites of the Use of Korean Briquette Ash for Construction.

i. Ash should be separated according to size, coarseness, or fineness, using a 0.0165 inch opening sieve (National Ash Association, Vol. II, No. 3, 1970). Its cementitious value increases as its fineness increases, the finely divided silica combining more readily with the free lime in the cement.

Since present collection of the ash is accomplished as a mixture with other solid wastes, it is necessary to seperate them as much as possible for use in construction. For use as a soil conditioner the ash may not necessarily be separated from the mixture of solid waste (further research is required in this regard) because the ash has nutritional value and high water availability.

The collected briquette ash could be stored through the following steps:



The required storage space of the sieved ash material is dependent upon (1) the amount of ash collected in a given period, (2) the removal time, and (3) peak delivery.

ii. Ash might be separated into low and high carbon content, usually 12% carbon content as separating base.[1]

iii. It is necessary to modify the present storage and collecting system of the city of Seoul to increase the ash quality.

iv. When it is used as the siliceous component, it should contain more than 50% silica oxide.

The problems of (1) and (2) could be solved through adjustment of the settling time of the flyash slurry in the holding tank by adjusting the temperature, water quality, and aeration to obtain a high quality ash.

b. Possibility of Utilization of the Ash as Construction Material as an Example.

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[1] Institute for Solid Wastes, American Public Works Association, 1970.

1. Concrete.
   i. It is possible to use the Korean briquette ash as fine and course aggregate for use as an inert filler material to increase its bulk.
   ii. Ash can be used to precast building blocks by adding cement.
2. Advantages of Utilization of Ash for Concrete Material.
   i. Increase in heat insulation and fire endurance.
   ii. Easy work ability.
   iii. Ease in surface skimming.
   iv. High carbon and high iron content does not affect the engineering property of cement, but does affect the color.
   v. Slight minimization of harmful effects of alkali-aggregate reactivity.
   vi. Increase in resistance to sulphate attack due to reduction of the amount of free lime liable to attack (Akroyd, 1962).
   vii. Decrease in the thermal expansion of the ash concrete.
3. Advantages of Usage of Korean Briquette Ash.
   i. Reduction of the requirement of a disposal area for the ash.
   ii. Reduction of disposal cost.
   iii. Reduction of the construction material costs.
   iv. Increase in the public health and landscape of the area.
   v. Availability of the ash materials.

Review of Agricultural Utilization of Coal Ash

Adam (1971) applied the flyash of bituminous coal from coal-fired plants to reclaim acidic surface mined coal lands in Northern West Virginia. The addition of flyash to the soil increased the pH to a range tolerable for some plants such as rye, orchard grass, and birdfoot trefoil, a legume, while the untreated soil remains acidic (Figure 14). Flyash also improved the texture of the soil (Figure 15), and increased the available water content (Figure 16).

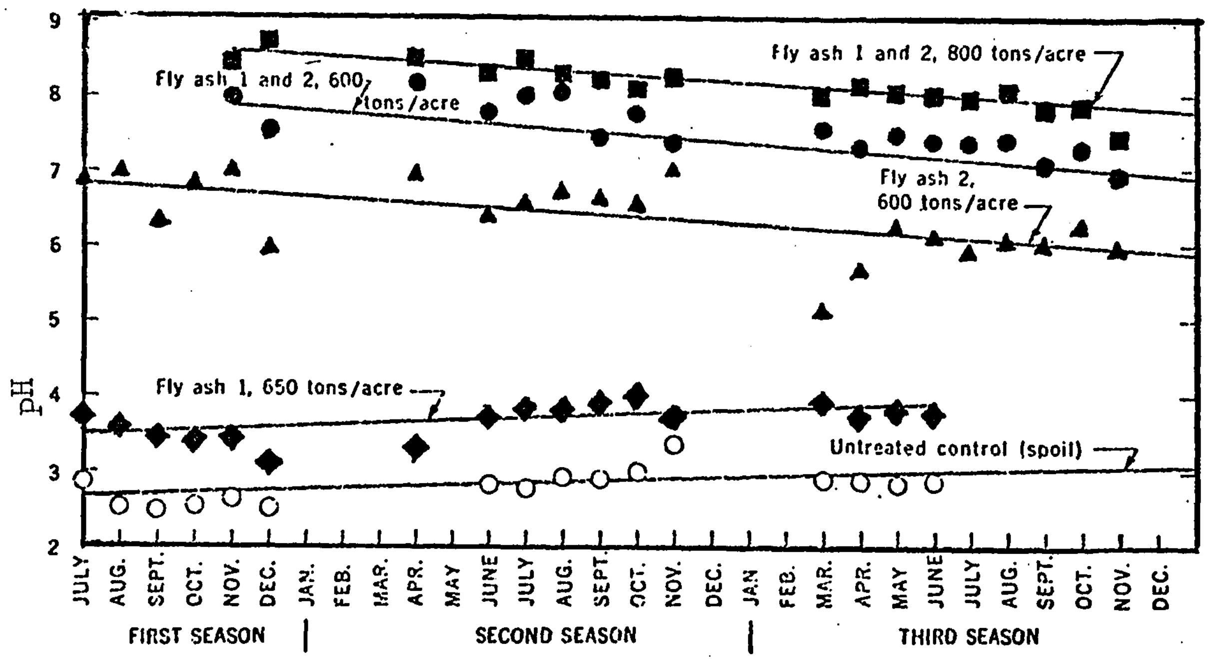

Figure 14

pH EFFECT OF FLYASH APPLIED TO ACIDIC SURFACE MINED COAL

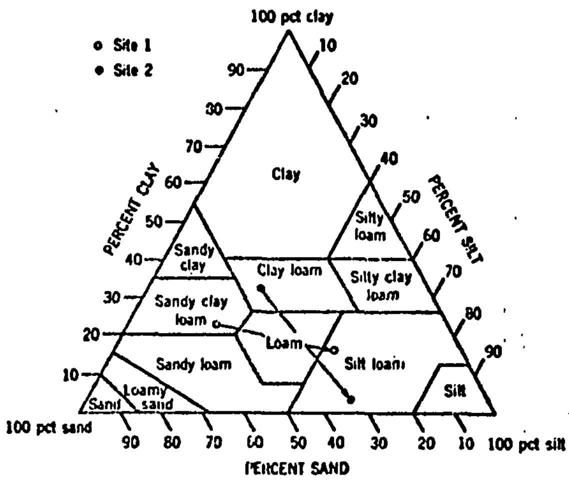

Figure 15

SOIL CHANGE BY FLYASH APPLIED TO ACIDIC SURFACE-MINED COAL

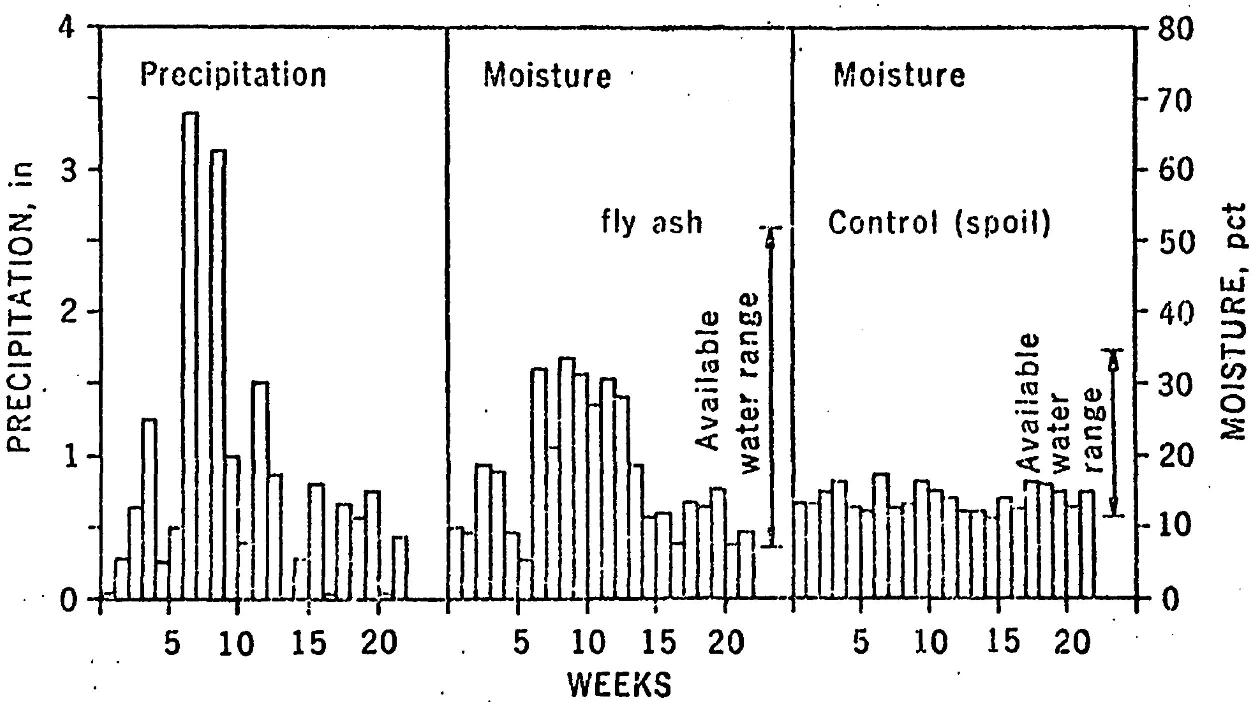

Figure 16

MOISTURE CONTENT INCREASE WITH ADDITION OF FLYASH INTO THE SPOILED LAND

Studies on plant nutrients and the neutralizing power of flyash were conducted by Martins (1971) mainly on boron, phosphorus, and zinc. The total content of flyash ranged from 48 to 613 ppm of boron, 0.03 to 0.28% of phosphorus, and 13 to 353 ppm of zinc. Flyash exhibited neutralizing power ranging from 0.04 to 3.37 meqH_3O^+/gm in defined reactions.

Utah State University investigators report that flyash has been used successfully in the control of snowmold, a disease which reduces winter wheat yields.

Czechoslovakia's Institute for Experimental Botany has developed an artificial fertilizer composed of power plant flyash and industrial waste. Test work has shown the mixture to be as effective as manure in tree planting and reforestation.[1]

Korean Ash Testing for Agricultural Utilization

1. Analysis of Korean Briquette Ash for Agricultural Utilization:

The analysis of the ash passing the 0.0098 inch opening sieve followed the procedures outlined in the Soil Chemical and Physical Analysis Laboratory, Department of Agronomy, Oklahoma State University. This manual is a combination of the Methods of Soil Analysis by Black (1965) and of Soil Chemical Analysis by Jackson (1958), except for boron determination, which was determined by Wolf's method (1974). The soil elements were determined with a flame photometer (Perkin Elmer) according to the manufacturer's directions. The results are recorded in Table 20.

2. Interpretation of Coal Ash Analysis:

a. Chemical Analysis.

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[1] National Ash Association, Vol. I, No. 3, 1969.

Table 20

ANALYSIS OF KOREAN BRIQUETTE ASH

Chemical Species	Used Sample & Preparation	Method Used	Average Test Results	Remarks
pH	Soil: dH_2O (1:2)	Glass-electrode	5.7	
Total Nitrogen	1.5 gm	Microkjeldahl (Black)*	250 ppm	
Chloride	$d\text{-}H_2O$ Extraction	Mohr (Black)*	95.3 ppm	Range of 81 - 105 ppm
Sulfate	$d\text{-}H_2O$ Extraction	Ignition	6088 ppm	Range of 4500 - 7679 ppm
Boron	10 gm + Azomethine-H	(Wolf)*	13 ppm	Range of 3 - 13 ppm
Phosphorus	1 gm + NH_4F Extraction	(Jackson)*	2.65 ppm	Range of 1.3 - 2.65
Cation-Exchange Capacity	5 gm	(Black)*	2.43 meq/ 100 gm	

*Original source of the used method.

Table 20

(Continued)

Volume of Used Extraction / Volume of Sample	d-H_2O(100ml) / 10 gm	HCL(100ml) / 1 gm	HF / 1 gm	NH_4OAc(200ml) / 10 gm
Concentration of Extraction Used \ Chemical Species (PPM)		Concentrated	48%	Normal
Ca	160	3040	170	210
Mg	120	880	180	100
K	390	1580	16900	420
Na	90	270	3250	110
Fe	5	825	100	10
Zn	trace	8	40	4
Mn	56	194	730	118
Cu	9	56	380	2
Cr	trace	6	50	4
Al	51	4250	27750	50

High concentrations of the phosphorus, sulfate, boron, and mineral elements could explain a good nutritional value of the ash for agricultural purposes, but low nitrogen concentration might not be a perfect fertilizer. The high concentration of these chemical species could be used as a soil conditioner or incomplete fertilizer.

The high water availability of the ash provides highly significant values in Korean agricultural and forestry land. In the elemental analysis of the ash, the concentration in deionized water extract is low, as expected, because of the low solubility of the element in water. Hydrochloric acid extraction yeilded high concentrations of the elements due to partial dehydration of silicates (a major constitutent of the ash) and the subsequent release of silicate bounded elements into the solution. The samples were digested with Hcl and the residue was then digested with HF which also showed concentrations of elements, because of the complete evaporation of the silica by the HF-acid, i.e.,

$$SiO_2 + 4HF \longrightarrow SiF_4\uparrow + 2H_2O$$

The elemental concentration from the HF- and HCL extraction are considered much higher than the available concentration in the briquette ash for plant growth.

b. Water Availability (Table 21).

The results of the water availability, measured using the procedures outlined by Peters (1965, Methods of Soil Analysis by Black) indicated an average of 61.7% and 28.3% moisture of the fine and coarse ash materials, respectively, at 1/3 Bars (close to field capacity or

Table 21

WATER AVAILABILITY TEST

Imposed Pressure		Mass of Wet Sample (gm)	Mass of Dry Sample (gm)	Percent Moisture
1/3 Bar (25.8 cm Hg)	Fine (0.0041-in sieve opening)	28.41	17.57	61.7
	Coarse (0.0098-in seive opening)	22.57	17.59	28.3
15 Bars	Fine	16.04	13.94	15.1
	Coarse	18.72	17.60	6.4
"Available" Water	Fine	46.6%		
	Coarse	21.9%		

moist end range). At 15 Bars (close to wilting point or dry end range), an average reading of 15.1% and 6.4% moisture was observed for those samples. The available water content is estimated by taking the difference between 1/3 Bars and 15 Bars. This difference was approximately 46.6% of the fine ash and 21.9% of coarse ash materials. The values indicated that Korean coal ash has a high water holding capacity, which absorbs and retains water and can provide plants with the available water, much the same as a soil conditioner might.

A. X-Ray Studies on the Korean Coal Ash

1. Sample Preparation:

The individual samples of air-dried bulk material, unburned coal, completely burned ash, and incompletely burned ash, separated by sight, were hand-powdered in a porcelain mortar and passed through 0.0041-, 0.0029-, and 0.0017-inch openings. The powdered samples were kept in plastic bottles for studies by X-ray diffractometer and spectrometer.

2. X-Ray Powder Diffraction:

The mineral analysis of X-ray diffraction is generally qualitative. However, approximate proportions of minerals in a sample were usually estimated from the relative intensities of the peaks on an X-ray diffraction pattern.

An X-ray powder packed slide was prepared by randomly selecting the bulk powder samples to determine the major crystalline minerals. The identification of the various minerals was accomplished by using the X-ray powder diffraction method with a Norelco X-Ray Diffractometer, located in the Department of Geology, University of Oklahoma. Diffractograms were obtained by using copper radiation (K-alpha) with a nickel filter with a setting of 40 kv and 20 milliamp. A scanning rate of 1^o 2θ/min. was used as a scale factor. The angstrom spacings were read from the diffractogram and the identification of the minerals was aided by comparing the determined d-spacing of those known minerals listed in the X-ray data (ASTM file).

3. X-Ray Spectrometer:

A total of four samples were selected for bulk chemical analysis by the General Electric X-ray spectrometer, located in the Department of Agronomy, Oklahoma State University. Samples were passed through 0.0017 inch openings and were pressed into discs at approximately 24 tons/$inch^2$ pressure with about one gram of bakelite as bottom packing-bed. Analysis was done with a chromium tube (K-a, b) with PET (Pentaerythrital) analyzing crystals, except for the verification of the questionable elements. A scanning rate of 5^o 2θ/min. and setting of 50 kv and 30 milliamp were selected.

4. Interpretation of the Diffractogram (Figures 17, 18, and 19):

The general shape of the diffractogram ash samples showed close resemblance to the type of clay mineral diffractograms (Grim, 1968).

The X-ray diffractograms invariably yielded two peaks in all three samples; 26.62^o 2θ($3.34\mathring{A}$) and 20.83^o 2θ($4.26\mathring{A}$). This is believed to be quartz (SiO_2).

Peaks at 12.34° 2θ(7.18Å) and at 19.88° 2θ(4.46Å); 19.88° 2θ (4.46Å) and at 26.50° 2θ(3.36Å); 28.58°2θ(3.12Å) and at 33.08° 2θ(2.70Å), are most probably attributable to the presence of small quantities of Kaolinite ($Al_2O_3.SiO_2.H_2O$), Illite 1.3(k.Na)$_2$O.0.6(Mg,Fe)O 3.3(Fe,Al)$_2$ O_3.16(Si,Al)O_2.5H_2O, and pyrite (FeS_2), respectively.

In the diffractogram of the ICB and CBA, there was no difference among the minerals found, except the slight shift of peaks in the diffractogram of the incomplete burned ash.

The peaks of ICB and CBA's diffractogram of Kaolinite, Illite, and pyrite were not clearly shown or not shown as much as in the coal.

Information from these diffractograms made it evident that the minerals in the samples were either of extremely poor crystalline structure or the presence of amorphous or metamict minerals was found.

5. Interpretation of the X-Ray Spectrogram:

One of the major objectives of this work was to determine whether toxic elements in the samples had any relation to plant growth.

In coal and ash (Figures 20, 21, and 22), the same spectrum occurred, except sulfur at 75.75°2θ in coal was obtained. Major elements in the spectrum of ash and coal are Ni (19.54°), Fe (25.03° and 83.24°), Cr (30.36 and 63.11), Mo (33.60 and 69.18), Cu (36.80 and 57.02), Ca (41.14 and 45.15 and 100.28), K (50.64), and Si (109°2θ).

In the compost spectrum (Figure 23), in addition to the above elements, P (83.10° and 89.40°) peaks showed strongly.

Although x-ray florescense spectrograms for questionable elements were analyzed with Ammonium Dihydrogen phosphate, pentaerythrital and Lithium floride crystals, no heavy or toxic elements in the spectrograms were revealed during this research.

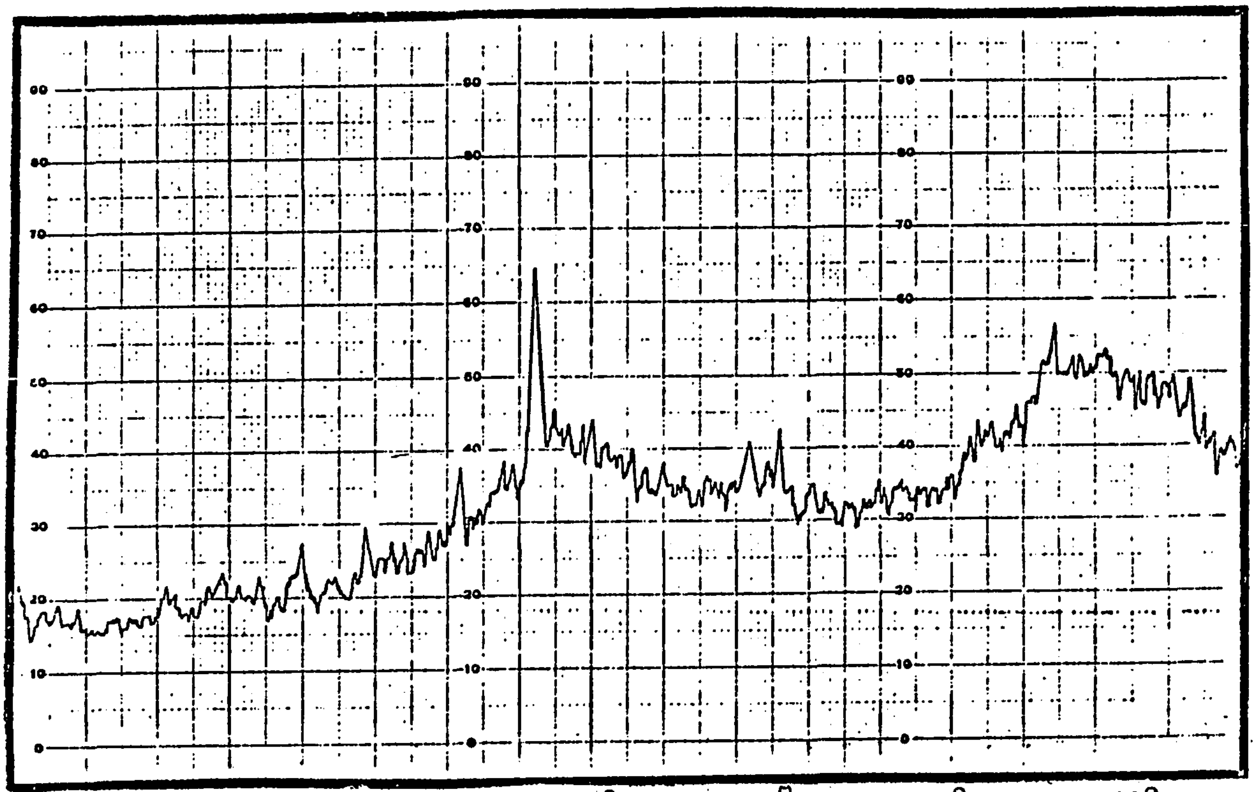


Figure 17

X-RAY DIFFRACTOGRAM FOR UNBURNED COAL

DIFFRACTION ANGLE 2θ

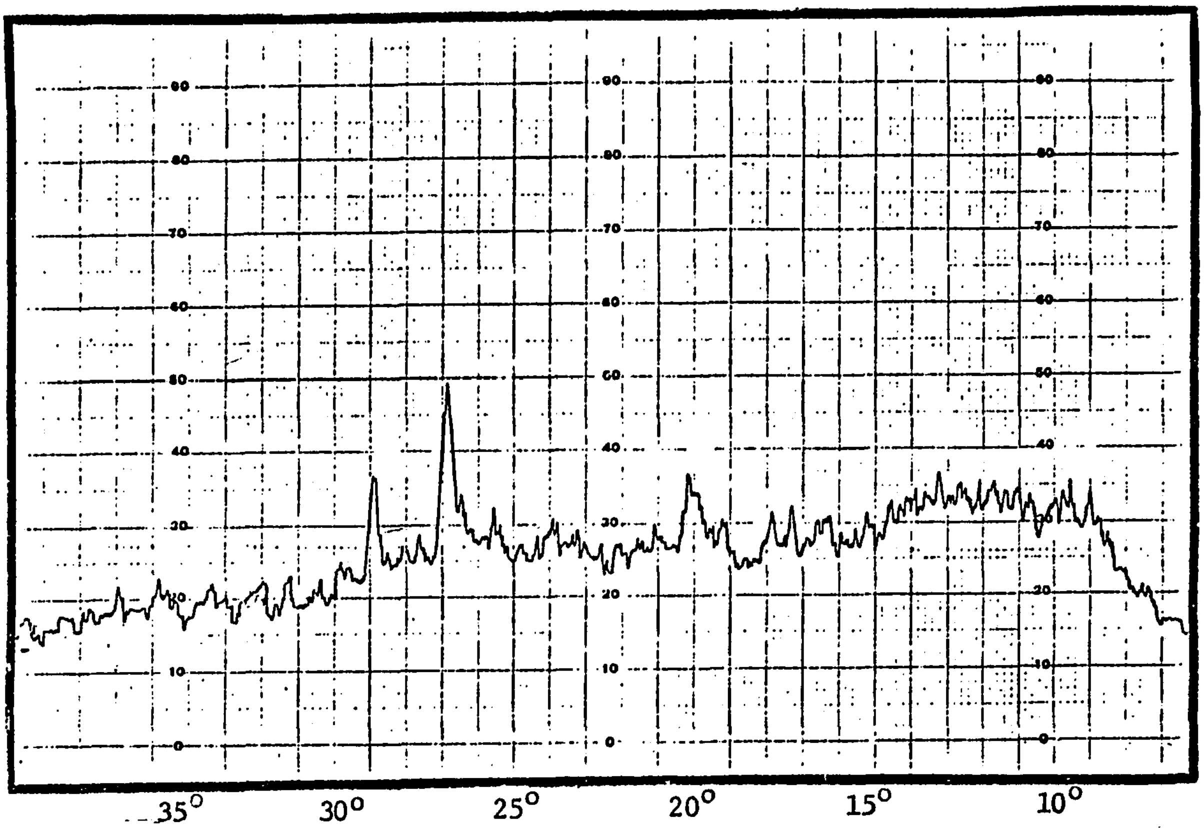


Figure 18

X-RAY DIFFRACTOGRAM FOR INCOMPLETE BURNED ASH

DIFFRACTION ANGLE 2θ

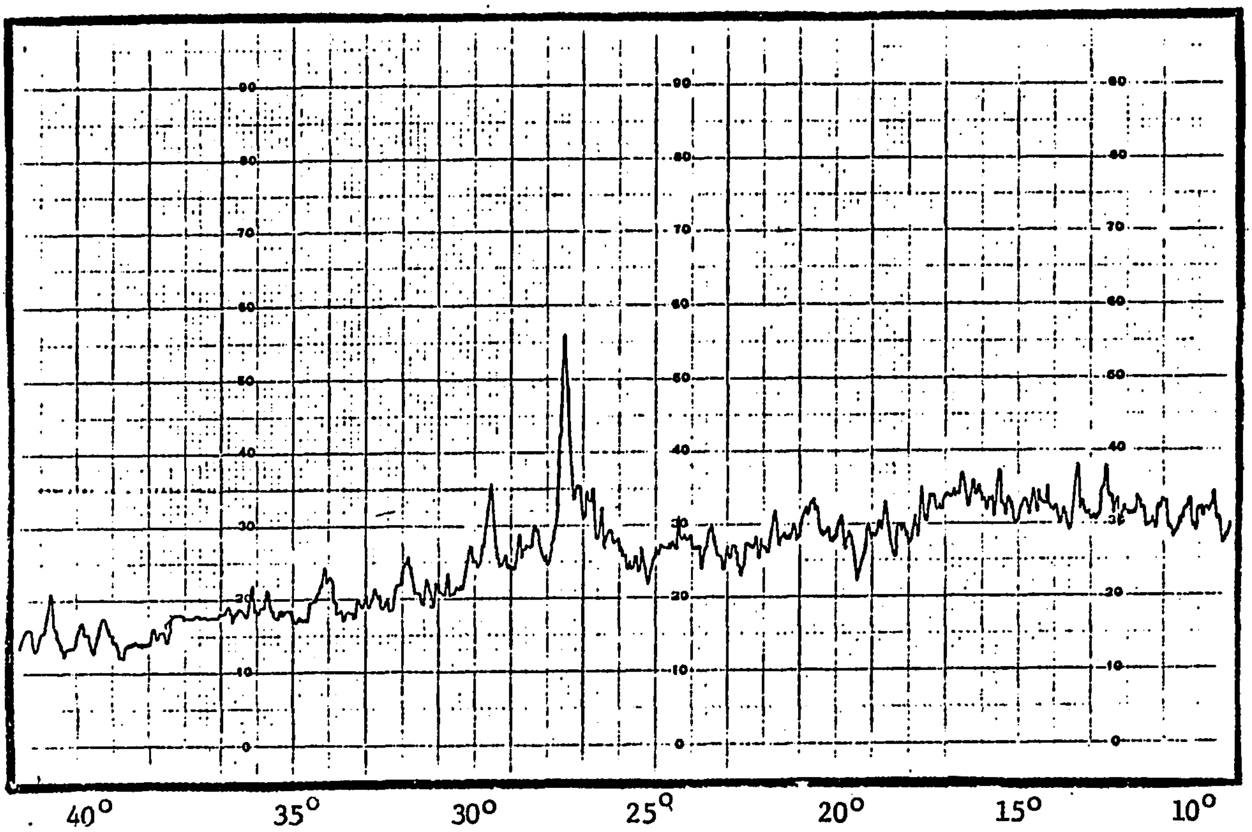


Figure 19

X-RAY DIFFRACTOGRAM FOR COMPLETE BURNED ASH

DIFFRACTION ANGLE 2θ

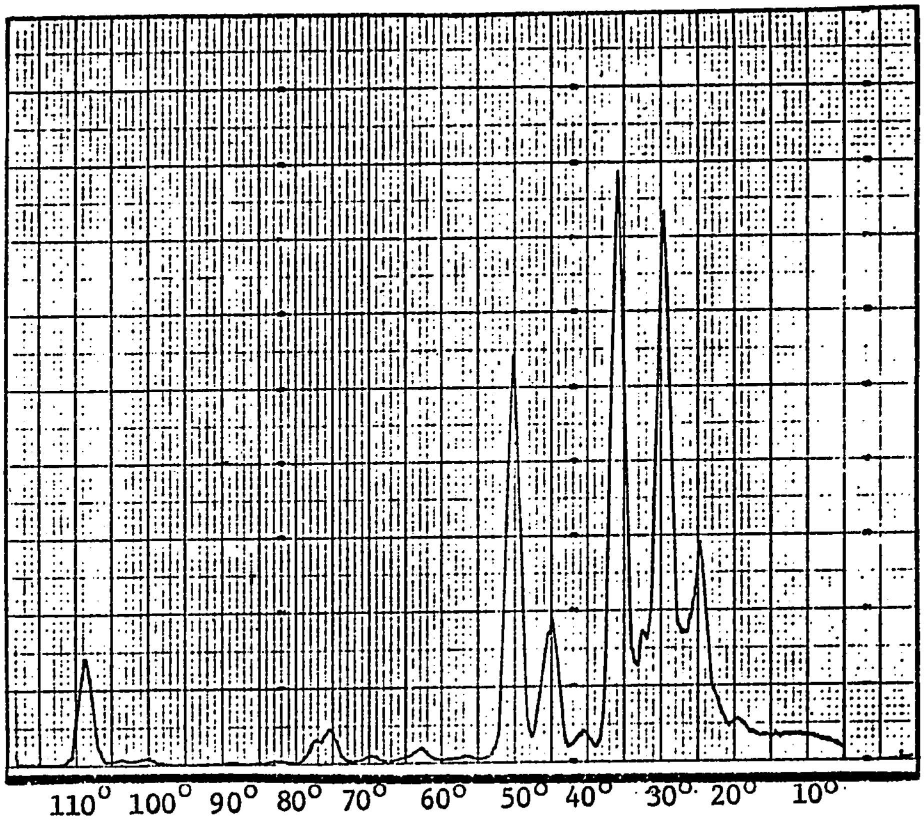


Figure 20

X-RAY SPECTROGRAM FOR UNBURNED COAL

DIFFRACTION ANGLE 2θ

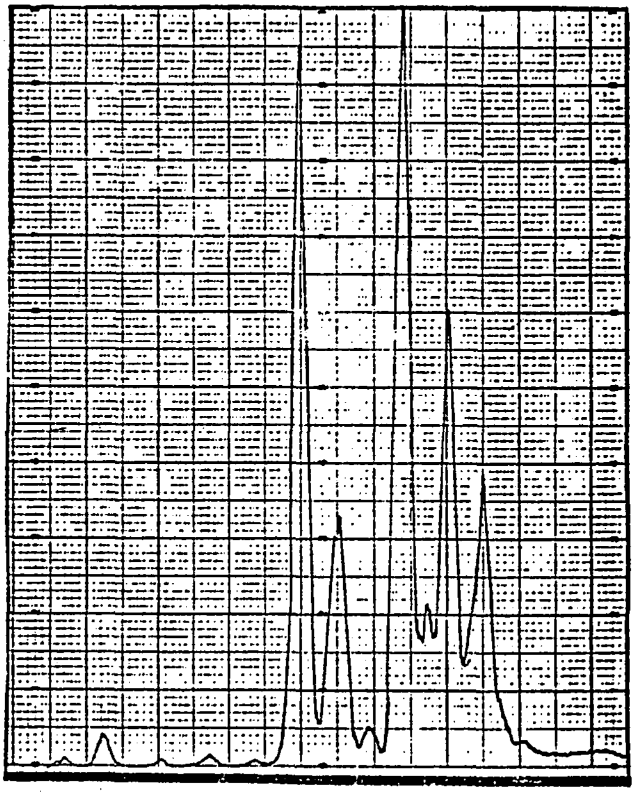


Figure 21

X-RAY SPECTROGRAM FOR COMPLETE BURNED ASH

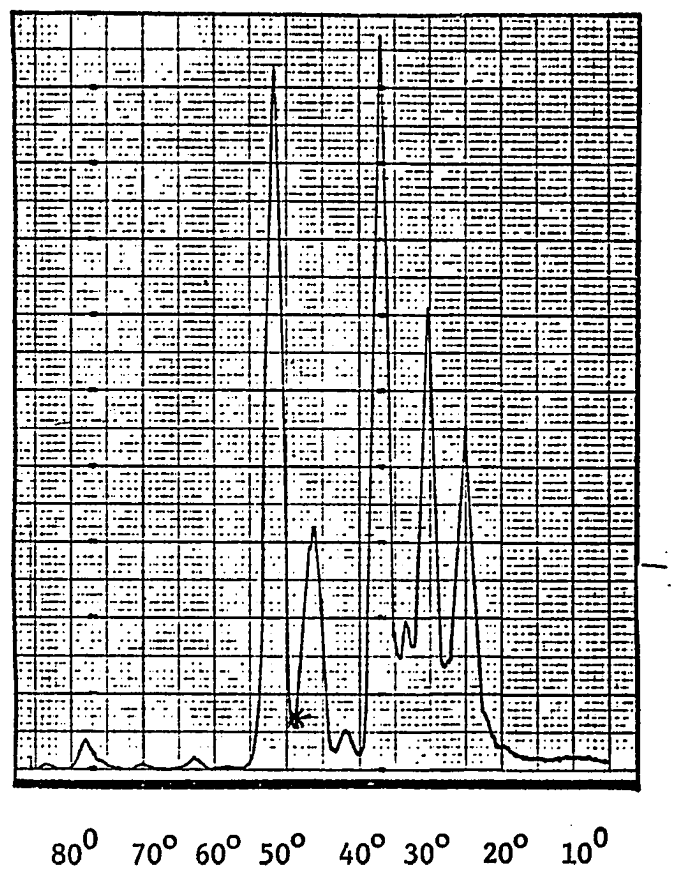


Figure 22

* Synchronized Point

X-RAY SPECTROGRAM FOR INCOMPLETE BURNED ASH

DIFFRACTION ANGLE 2θ

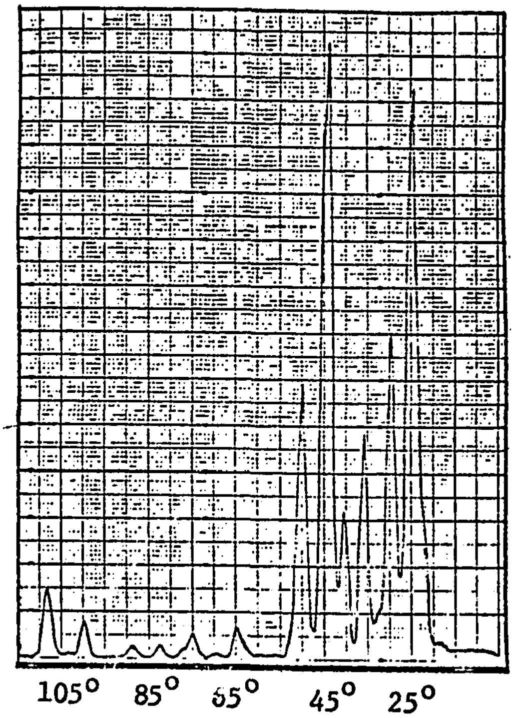


Figure 23

X-RAY SPECTROGRAM FOR COMPOST

DIFFRACTION ANGLE 2θ

Chapter VII

EVALUATION AND REQUIREMENTS OF COMPOST IN KOREAN LAND

Evaluation of Compost

One of the purposes of this work is to assist in verifying the importance of compost in agricultural soil for plant growth. Tests were performed with the compost product (provided by the Naturizer Company of Norman, Oklahoma) of six day's digestion period. The results are as follows.

A. Chemical and Physical Analysis of Compost

Since there is no specific method for analyzing compost, the method of plant material analysis was used here (Black, 1965; Jackson, 1958). The results of the test are recorded in Table 22.

B. Experimental Design Conditions

Test Plant -- lettuce (*Lactuca* spp.) and swiss chard (*Beta Vulgaris* variety cicla)

Test Soil -- sandy loam with 86.67% sand and 13.33% clay. The testing soil was obtained from Norman, Oklahoma.

Test Location -- temperature controlled green house, authorized by the Department of Botany at the University of Oklahoma.

TABLE 22

CHEMICAL AND PHYSICAL ANALYSIS OF COMPOST

Chemical-Physical Characteristics	% of Concentration Range	Remarks of Analysis
Calcium	0.37 - 2.35[1]	1 indicates the analysis by atomic absorption (Perkin-Elmer)
Potassium	0.52 - 2.80[1]	
Magnesium	0.06 - 0.35[1]	
Manganese	0.02 - 0.04[1]	2 indicates colorimetric method
Iron	1.96 - 6.53[1]	
Copper	0.02 - 0.05[1]	
Nickel	0.007 - 0.01[1]	3 indicates analysis by titrational method
Lead	0.02 - 0.07[1]	
Cadmium	0.001 - 0.01[1]	
Zinc	0.02 - 0.068[1]	
Cromium	0.001 - 0.03[1]	4 indicates analysis by ignition method
Phosphorus	0.13 - 0.26[2]	
Organic-chloride	0.04[3]	
Nitrate-nitrogen	0.032[3]	5 indicates analysis by glass-electrode method (Beckman)
Ammonia-nitrogen	1.09[3]	
Sulfate	0.01 - 0.30[4]	
Ash residue	53.5 - 68.2[4]	
PH	6.9 - 7.6[5]	

C. Chemical and Physical Analysis of Testing Soil

The analysis of the soil followed the procedures recommended by Black (1965) and Jackson (1958).

Total nitrogen = 249.7 ppm

Phosphorus = 0.088 ppm

Potassium = 10 ppm

Calcium = 15 ppm

Sulfate = 738 ppm

Magnesium = 8 ppm

pH = 6.9

Dry density = 25.56 gm/inch^3

D. Test for Comparison of Compost and Artificial Fertilizer with Swiss Chard

1. Testing Box Preparation:

The test boxes were designed for the availability of a pot holding desk in the green house. The dimensions of the test boxes were 20 inches wide by 20 inches long by 11 inches deep, made of pine wood. The total holding capacity was 4,400 cubic inches. The number of testing boxes used in this work was two for compost and two for the same amount of compost and fertilizer. It is necessary to prepare holes in the box for air circulation and water drainage purposes. There were 81 holes 1/2 inch in diameter, 9 holes in the side wall two inches above the bottom, and 1/2 inch in diameter. For seeding and growing bed preparation for swiss chard, the test box was filled to a depth of three inches with one-half inch of marble chips which were washed and oven-dried. Soil was then mixed with compost and added to the box until it was filled to within one inch of the top.

2. Fertilizer Application:

A fertilizer test was conducted with the swiss chard in the 85-ton per acre test boxes.

Fertilizer applied[1] -- nitrogen - 100 lbs/acre

P_2O_5 - 30 lbs/acre

K_2O - 200 lbs/acre

CaO - 461 lbs/acre

MgO - 20 lbs/acre

Since no artificial fertilizer containing these chemicals in the above mentioned proportions is available, laboratory chemicals were used in this experiment as follows:

KNO_3 - 0.0259 lbs

$Ca(NO_3)_2 \cdot 4H_2O$ - 0.0129 lbs

NH_4NO_3 - 0.0037 lbs

MgO - 0.0040 lbs

3. Soil and Fertilizer Application:

Amount of soil used[2] -- 20 inches by 20 inches by 7 inches = 2800 $in.^3$

---

[1] The amount of fertilizer applied was suggested by Dr. Ray Campbell, Department of Horticulture, Oklahoma State University.

[2] Volume weight calculation: 1 acre = 6,272,640 in^2
= 42,026,688 in^3 (assumed at 6.7 in. depth)
= 42,026,688 in^3 x 25.56 gm/in^3 = 2,366,106 lbs

Amount of compost used - 11.33 lbs/box

4. Seeding of Swiss Chard (for 85 tons/box):

   Time: February 2, 1975

   Water: Controlled application of 0.5 liter per day

   Temperature: Controlled at 55-65° F

   Spacing of seeds: Two inch spaces between seeds in five rows

   Number of seeds applied: 45 per box

   Depth: One-half inch

5. Preplanned Experimental Design:

   For evaluating the effect of compost against chemical fertilizer, one-way analysis of variance design was preplanned as follows:

Design of Test	No. of Plants/Box
Compost + fertilizer	16
Compost only	16
Fertilizer only	16
Soil only	16

E. Test for Economical Feasibility of Compost Use

1. Testing Box Preparation:

   To examine the economic feasibility of compost usage, compost was applied at rates equivalent to 6-, 12-, 24-, 48-, and 85-tons per acre.

   Dimensions of the test box -- 42.5 inch length x 5.5 inch width, with 7.8 inch depth.

   Air circulating holes -- 40 holes in the bottom two inches in diameter, 20 holes in the side wall one-half inch in diameter and one inch above the bottom.

Amount of soil used per box - 42.5 in. x 5.5 in. x 6.0 in. = 1402.5 in^3, or 95.41 lbs/box.

Amount of compost applied - 0.48 lbs at 6 tons/acre
0.98 lbs at 12 tons/acre
1.96 lbs at 24 tons/acre
3.92 lbs at 48 tons/acre

2. Seeding of Swiss Chard (for 6-, 12-, 24-, and 48-tons/box):

   Time: February 23, 1975

   The applied conditions were identical to the 85 tons/box experiment of seeding swiss chard.

   Spacing of seeds - 1.8 inch spaces in two rows, two inches apart.

   Number of seeds applied - 40 each per box.

F. Test for Compost with Lettuce

1. Seed Bed Preparation:

   22.5 inch length x 15 inch width x 2.2 inch depth

   Soil holding capacity - 41.8 lbs

   Seeding time: February 2, 1975

   Water: 1/2 Litter every two days

   Control conditions were the same for lettuce seeding as for the chard plants.

   Spacing: Two inches of space between seeds in five rows.

   Depth: 3/15 inch

   Number of seeds applied: 45 per box

   Applied compost: 20 tons/acre

2. Transplanting:

Hand transplanting was done for the lettuce at a depth of one-half inch. Plants were randomly selected for transplanting into the pots.

Transplanting time: February 23, 1975. The plants were transferred to plastic pots six inches high and four inches wide.

Applied compost: 6 tons/acre

Number of pots used: 20 pots for soil without compost, 20 pots for soil with compost.

3. Growth Condition After Transplanting:

Temperature: Not controlled.

Watering: Not given regularly but whenever soil was dry. The purpose of this test was to verify plant growth differences between compost-applied soil and uncomposted soil under a minimum controlled condition.

Results of Compost Evaluation Test

A. Compost Evaluation with Swiss Chard

1. Germination and Growth After 25 Days From Seeding:

Generally, the germination of the swiss chard began five to six days after seeding and rapid growth of the chard necessitated thinning them out after 25 days. Assuming that treatment conditions of 85 tons per acre of compost and lower levels of compost application are the same because of controlled room temperature and watering, and moisture content in the green house, growth and germination of the chard were examined 25 days after seeding (Figures 24, 25, Table 23, and Appendix E). The chard growth at lower levels of compost shown in Figure 26 is 46 days old because of failure of photographic process. The thinning of plants was done randomly, leaving 16 plants in the 85 tons per acre box for application of fertilizer for further experiment, and 10 plants in lower compost application boxes for studying the growth variation in later days as a control. The random thinning was done with the tag method.

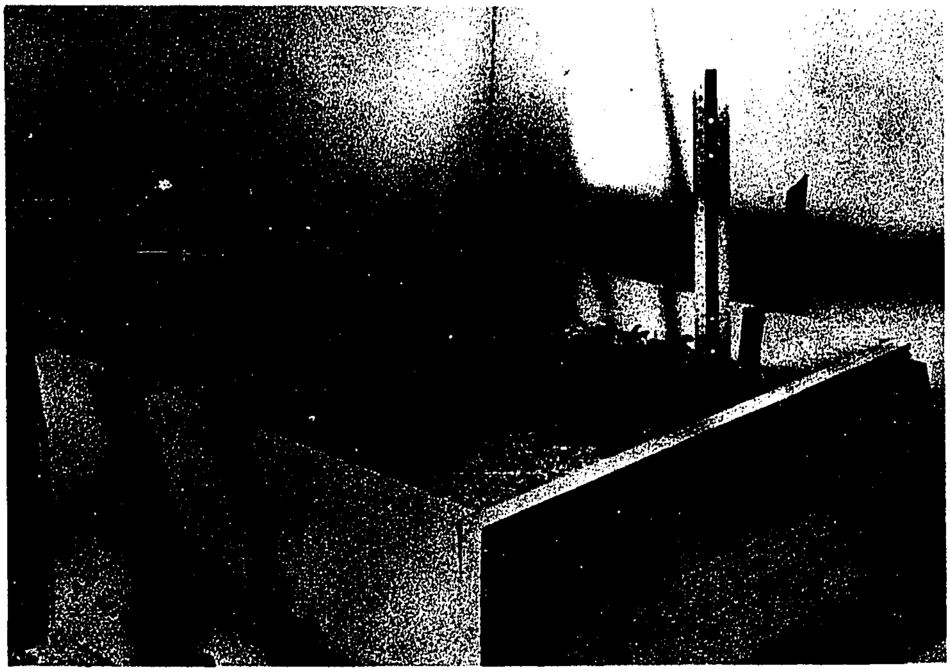
Table 23

MEAN GROWTH AND NUMBER OF GERMINATIONS OF SWISS CHARD

6-Ton	12-Ton	24-Ton	48-Ton	85 Tons/Acre With Compost		45 Seeds/Box Without Compost	
a	b	c	d	e	f	g	h
No. of Germinations							
26	28	30	29	31	35	16	17
Mean Growth (cm)							
1.82	2.38	2.52	2.40	2.41	2.03	1.18	1.70

a. Statistics of Growth and Number of Germinations:

As shown in Appendix F, it is necessary to simplify the calculations involved and to make an equal number of observations. To make an equal number of observations, a random drawing was practiced as follows. The observations of the chard growth were written on tags and



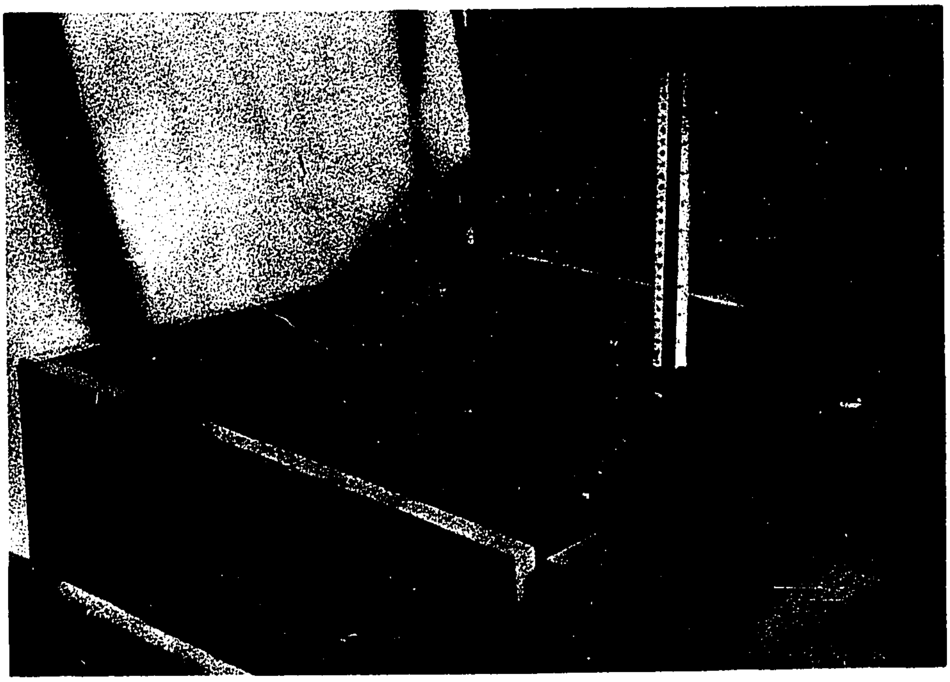


FIGURE 24

SWISS CHARD GROWTH AFTER 25 DAYS (0 TON OF COMPOST/ACRE)

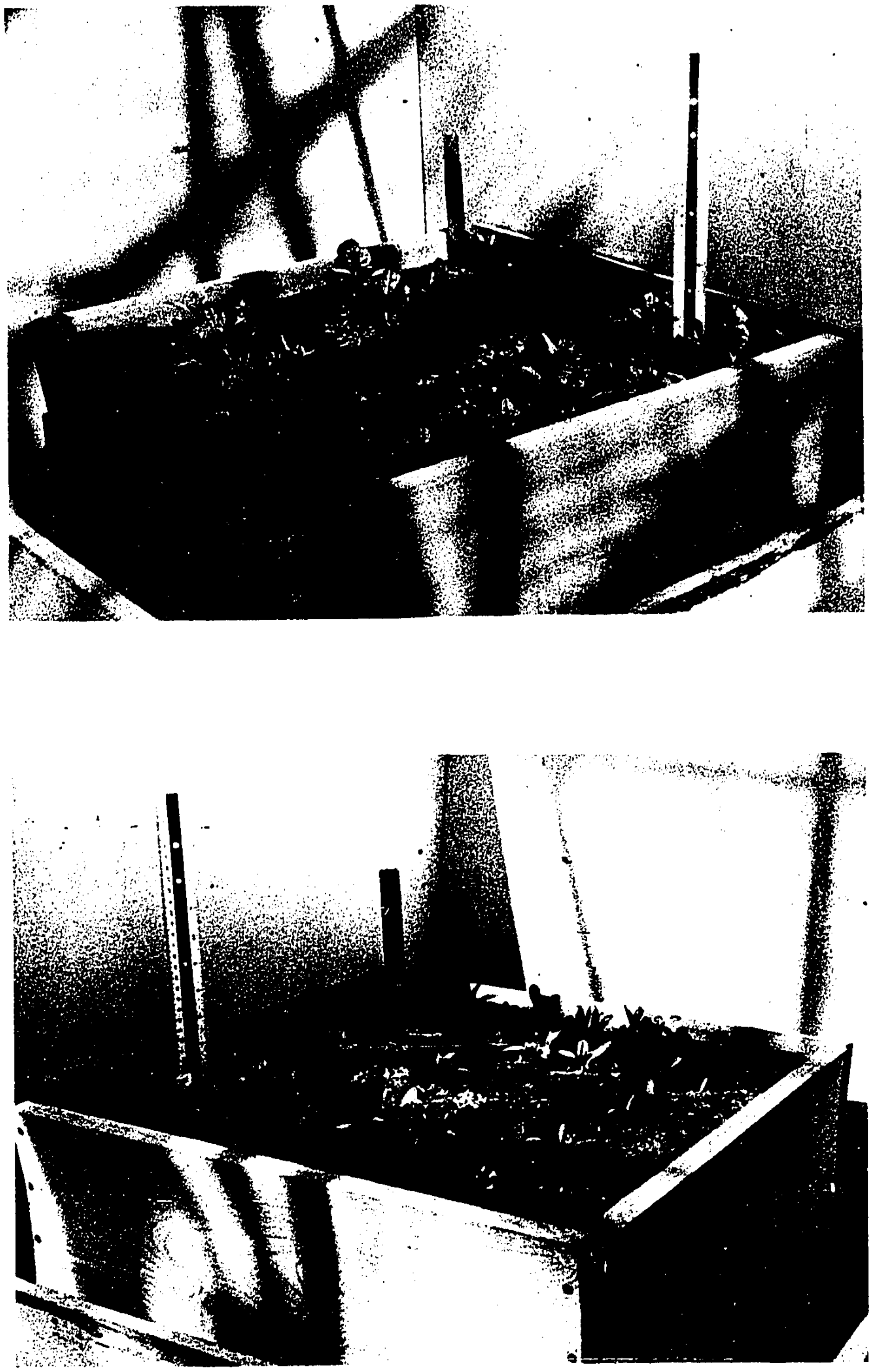


FIGURE 25

SWISS CHARD GROWTH AFTER 25 DAYS (85 TONS OF COMPOST/ACRE)

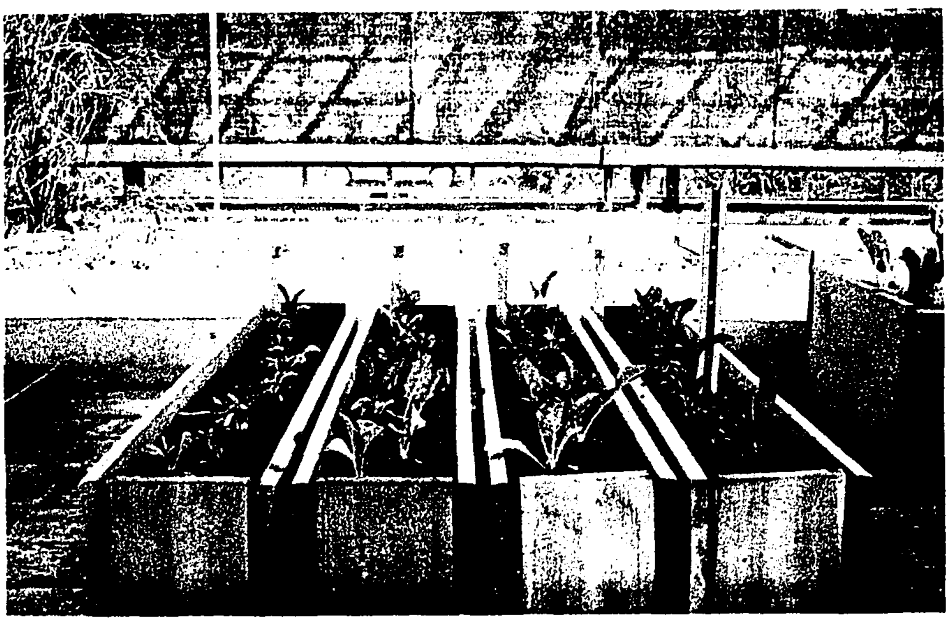


FIGURE 26

SWISS CHARD GROWTH AFTER 46 DAYS

Where,

1 = 6 TONS OF COMPOST/ACRE
2 = 12 TONS OF COMPOST/ACRE
3 = 24 TONS OF COMPOST/ACRE
4 = 48 TONS OF COMPOST/ACRE

placed in a basket. After the numbered tags in the basket were thoroughly shuffled, one tag was drawn and recorded without replacing it in the basket. The remaining tags in the basket were again thoroughly shuffled before drawing again. This process was repeated until 16 observations were recorded. The drawing was done by persons other than the research personnel to eliminate bias. If the new mean of the chard plant growth gave a value that varied greatly from the old mean value, then the tag drawing process was started again until the new observation mean was close to the original mean.

The seventeen observations of tags from boxes having no compost (control H in Appendix E) were changed to sixteen observations, ignoring a 5.25 cm of an unusual growth value. The two observations of the chard growth without compost and with 85 tons of compost per acre again were combined and changed into 16 observations each because of difficulty in obtaining the tabulated values over one hundred degrees of freedom (Li, 1969).

To accomplish the purpose of the test, the error mean square within observations was calculated by one-way analysis variance, and the New Multiple Range Test (Li, 1969, and Dunn et. al., 1974) was conducted to directly compare the mean of each observation.

b. New Multiple Range Test Procedure of Economical Evaluation Test.

1. The mean values of the six treatments are arranged according to their magnitudes as follows:

A	B	C	D	E	F
1.41	1.82	2.33	2.34	2.43	2.55

2. The standard error ($S\bar{y}$) of the means (Table 24)

$$S\bar{y} = S^2 / n = 0.26$$

where n = the number of observations

S^2 = the residual mean of the square

3. At the 90 degree of freedon and 5% significant level:

Group (g):	2	3	4	5	6
Shortest Significant Range (SSR)	0.73	0.77	0.79	0.81	0.83

Table 24

ANALYSIS OF VARIANCE FOR SWISS CHARD GROWTH
(From Appendix E)

Source of Variance	Sums of Squares	d.f	Mean of Squares
Due Treatment	15.35	5	3.07
Residual	99.22	90	1.10
TOTAL	114.56	95	

Table 25

NEW MULTIPLE RANGE TEST FOR SWISS CHARD
(ECONOMICAL CONSIDERATION)

g	Treatments	Difference	SSR	Conclusion
6	F - A	1.14	0.83	Significant
5	F - B	0.73	0.81	Insignificant
5	E - A	1.02	0.81	Significant
4	E - B	0.61	0.79	Insignificant
4	D - A	0.93	0.79	Significant
3	D - B	0.52	0.77	Insignificant
3	C - A	0.92	0.79	Significant
2	C - B	0.51	0.77	Insignificant
2	B - A	0.41	0.30	Insignificant

c. Statistical Results of Compost Evaluation with Swiss Chard:

i. The conclusions of economical evaluation of compost application shown in Table 25 indicates that treatment of compost over 12 tons per acre has better growth yield for the chard plant at a 95% significant level. However, among the tests applied with a different rate of compost, any significant result has not been yielded.

ii. The treatment of the compost with a fertilizer (Tables 26 and 27) has not clearly been demonstrated superior to fertilizer application alone. However, fertilizer application differs significantly to the application of compost alone. (Figures 27, 28, 29, and 30)

iii. The results shown in Table 27 also indicate that treatments of compost have significantly higher growth than plants grown in soil alone. (Figures 24 and 25)

Table 26

ANALYSIS OF VARIANCE OF SWISS CHARD AT FOUR DIFFERENT CONDITIONS
(From Appendix G)

Source of Variance	Sums of Squares	Degrees of Freedom	Mean of Squares
Due Treatment	3290.02	3	1096.67
Residual	804.07	60	13.40
TOTAL	4094.08	63	

TABLE 27

THE MULTIPLE RANGE TEST
(FERTILIZER vs COMPOST)

g	Treatment Difference	SSR	Conclusion
4	D - A (16.40)	2.83	Significant
3	D - B (12.66)	2.74	Significant
2	D - C (.90)	2.60	Insignificant
3	C - A (15.50)	2.74	Significant
2	C - B (11.76)	2.60	Significant
2	B - A (3.74)	2.60	Significant

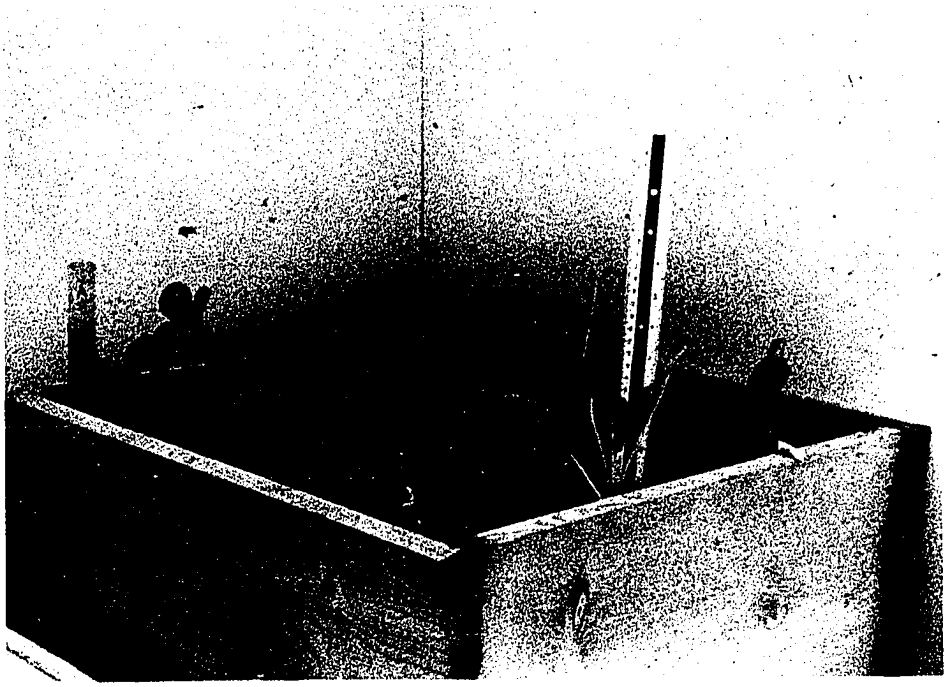


FIGURE 27

SWISS CHARD GROWTH AFTER 71 DAYS (85 TONS OF COMPOST/ACRE)

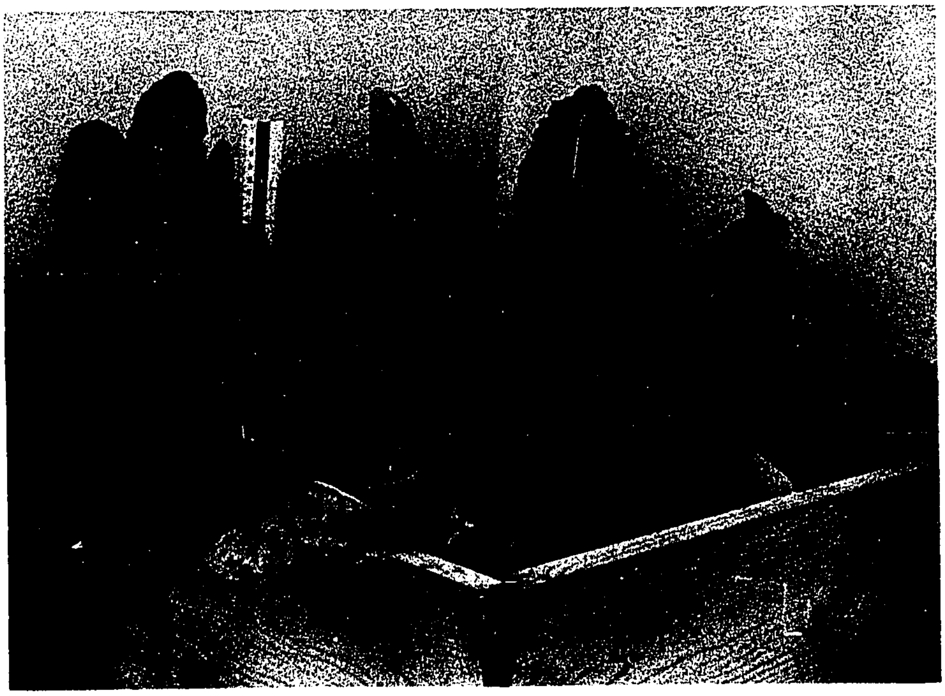


FIGURE 28

SWISS CHARD GROWTH AFTER 71 DAYS (85 TONS OF COMPOST + 100 LBS. OF NO_3 + 30 LBS. OB P_2O_5 + 200 LBS. OF K_2O + 461 LBS. OF CaO + 20 LBS. OF mgo/ACRE)

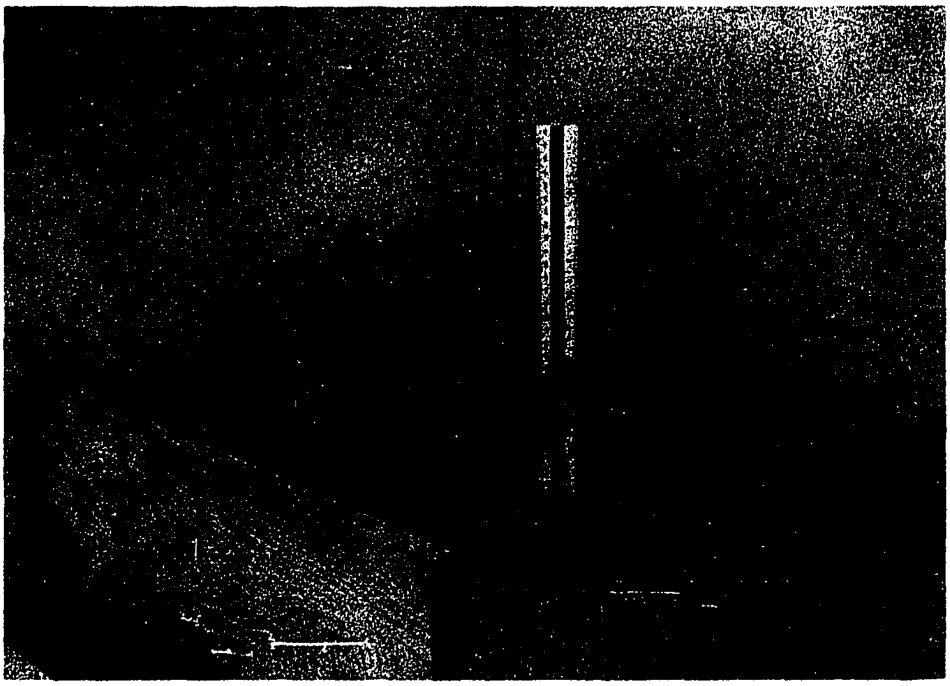


FIGURE 29

SWISS CHARD GROWTH AFTER 71 DAYS (0 TONS OF COMPOST/ACRE)

FIGURE 30

SWISS CHARD GROWTH AFTER 71 DAYS (100 LBS. OF NO_3 + 30 LBS. OF P_2O_5 + 200 LBS. OF K_2O + 461 LBS. OF CaO + 20 LBS. OF mgo/ACRE)

2. Swiss Chard Root Examination:

To evaluate the effect of compost on growth of the chard tested in this research, the roots were examined after 61 days of growth (Figure 31). The root growth clearly showed a difference between the test conditions. The roots grown at compost with fertilizer were much longer than those grown by the other three treatments. Roots grown in compost alone are very similar in size to those grown in fertilizer alone.

Another interesting point is that roots grown in fertilizer and soil have many more root hairs than the specimens grown in compost.

B. Compost Evaluation with Lettuce

The growth of lettuce plants under controlled conditions showed a definite difference between compost application (6 tons per acre) and soil alone. The one-way analysis of variance was used to evaluate the effects on the lettuce growth for 61 days (Tables 28 and 29). The results of the analysis showed the compost stimulates lettuce growth (Figure 32).

FIGURE 31

AN AVERAGE ROOT GROWTH OF SWISS CHARD AFTER 71 DAYS

Where

A = COMPOST ONLY

C = SOIL ONLY

B = COMPOST + FERTILIZER

D = FERTILIZER ONLY

Table 28

LETTUCE GROWTH FOR 61 DAYS AT UNCONTROLLED CONDITIONS

Treatment \ Observation	Growth (cm)									
Compost	6.0	5.5	6.0	5.0	6.0	6.0	5.5	4.5	6.0	6.0
(6 Tons/Acre in 86.67% sand & 13.33% clay)	5.5	8.0	6.0	4.5	6.0	7.0	5.0	5.5	6.0	6.5
Soil Only	2.0	2.0	4.0	2.0	3.0	4.0	2.5	2.5	3.0	3.5
(86.67% sand & 13.33% clay)	4.0	3.0	2.5	4.5	3.5	4.0	3.5	1.0	6.0	3.0

Table 29

ANALYSIS OF VARIANCE FOR LETTUCE

Source of Variation	Sums of Squares	Degrees of Freedom	Mean of Squares	Computed F-Value	Tabled F-Value
Due Treatment	70.22	1	70.22	75.51	8.55 (at 0.5% level)
Residual	35.28	38	0.93		
TOTAL	105.50	39			

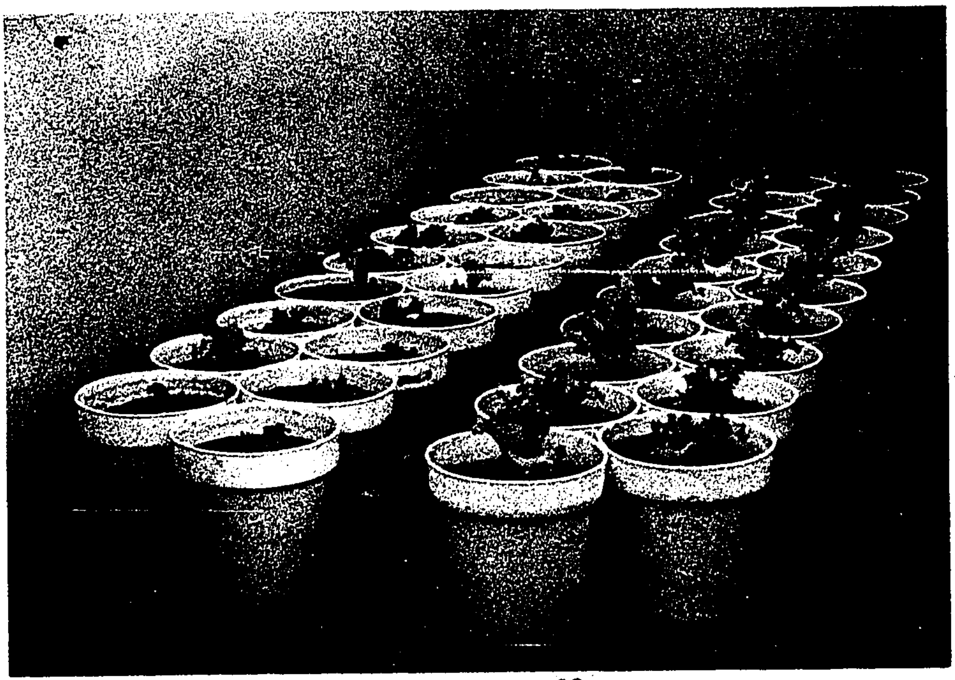


FIGURE 32
LETTUCE GROWTH AFTER 71 DAYS UNDER UNCONTROLLED CONDITIONS
Where,

A = 6 TONS OF COMPOST/ACRE B = 0 TONS OF COMPOST/ACRE

Requirement of Organic Matter in Korean Land

A. Process of Soil Formation

Many theories of soil forming processes have been proposed, none of them is simple. Man can, nevertheless, obtain maximum benefits from the soil within range of his understanding and his ability to control the complexity of soil properties.

For a typical example, Jenny (1941) explained the complexity of the soil forming factors in the mathematical model as five major independent variables.

$$F\ (CL,\ O,\ R,\ P,\ T) = 0$$

where CL = climate, mainly moisture, air, and temperature

O = soil organisms (organic matters)

R = topography (slope)

P = parent materials (mineral elements)

T = time (age)

The relationship between the soil properties and the forming factors are:

$$S = f(CL,\ O,\ R,\ P,\ T)$$

$$dS = \left(\frac{\partial s}{\partial CL}\right)_{o,r,p,t} dCL + \left(\frac{\partial s}{\partial O}\right)_{cl,r,p,t} dO + \left(\frac{\partial s}{\partial R}\right)_{cl,o,p,t} dR + \left(\frac{\partial s}{\partial P}\right)_{cl,o,r,t} dP + \left(\frac{\partial s}{\partial T}\right)_{cl,o,r,p} dT$$

A close functional relationship of the set of five factors cannot be explained simply due to the complexity of the factors themselves.

Man can handle, to some extent, one factor -- soil organisms -- among the five factors. The equation then will change to:

$$S = f(O)_c + C$$

while assuming the four factors beyond man's control are constant. In fact, soil property, or soil productivity, can be evaluated through examination of the functions of soil organisms.

The functions of these organisms are very difficult to define analytically. If the functions are characterized as activities of soil micro-organisms such as bacteria fungi, protozoa, algae, etc., then their activities depend on the amount of nutrient sources available under the given conditions. Generally, the nutrients for heterotropic micro-organsism are supplied by the amount of organic matter present.

Now, we face a problem of how to maintain or supply the required organic matter to obtain maximum benefits from the soil.

The quantity of organic matter required for plant growth, depending on the plant, is generally low in percent by weight. For example, in silty loam soil for favorable plant growth there is around five percent organic matter, compared with 20 percent air, 30 percent water, and 45 percent minerals. The relatively small percentage of organic matter appearing in soil tends to be misleading when considered in regard to its functional importance.

B. Importance of Organic Mátter for Soil Fertility

An adequate supply of available plant nutrients tends to ensure success in the production rate of crop and forestry land. Man, therefore, has endeavored to correct nutrient deficiency in order to increase maximum production, with a long history of increasing soil fertility through academic and practical experiments.

The maintenance of fertility at a satisfactory level in cultivated soil is generally recognized as a major problem of agricultural production. Some regions of European and Oriental countries have been farmed successfully for thousands of years because the soil has been enriched by fertilization with manure or compost.

As long as man disturbs a naturally self-sufficient balanced agricultural ecosystem, an adjustment should be made to balance the system by maintaining, as nearly as possible, its original state in order to guarantee continuing production of crops.

The organic matter in a given soil is determined by the incoming and outgoing nitrogen, carbon, phosphate, potassium, the amount of tillage, and crop plants. The organic substances in soil are partially derived from plants and macro- and micro-organism residues. The total amount of soil organisms are mainly dependent upon the content of organic matter. Organic matter provides the micro-organism's constituents and energy sources through transformation processes of organic residues. The main transformation products are humic substances such as hymatomelonic, a- and b-humic acid through humification processes.

Residues-organic $\xrightarrow{\text{humification}}$ Humus substances $\xrightarrow{\text{mineralization}}$ CO_2 + H_2O + minerals

[transitional stage
carboric acid + nitric acid]

Humification produces relatively stable organic and humus compounds that are amorphous and dark brown in color.

The humified products of the soil may be dispersed in the mineralization process which releases nutrients for organisms inhabiting the soil and for plants.

The organism's activity, the important elements for growth in plants, especially carbon, nitrogen, and phosphorus, are kept in a constant nutrient cycle. As explained above, the soil is not a dead system but rather is teaming with life.

1. Physical-Chemical Property of Organic Matter in Soil:

It is also known that organic matter plays an essential role in securing soil structure and physical-chemical property, in order to increase the productivity.

The general effect of humus colloids on the mineral soil may perhaps best be summed up as that of a buffer substance. Particles of organic matter or humus form different physical and chemical combinations with the clay and mineral portions of soil, by colloidal formation. Certain organic compounds act as peptizers for clay-water systems, and modify the wetting characteristics of the clay by absorption on the clay surface (van Olephe , 1963). The colloids in soil improve water holding capacity and dissolve salts present, thus swelling and shrinking in such a way as to make soil structure loose and porous. Furthermore, the colloid's action on the soil prevents leaching of plant nutrients from soil and provides a source of nutrients for plant life.

The amount of water and of nutrient salts absorbed by the colloidal system is of great agricultural significance. McGeorge (1930) stated that the exchange capacity of soil high in organic matter is generally in a direct linear relationship with the amount of organic matter present, such as lignin, ligno-cellulose, and ligno-hemicellulose.

It has also been demonstrated in Broadbent's research (1955) on the detailed mechanism of the increment of cation-retention capacity by humic substances that the increased exchange capacity is due in part to formation of carboxylic group through hydrolysis of ester or lactone linkages and by oxidation of side chains of aromatic rings and in part to exposure of the phenolic or hydroxyl group.

Stelmach (1962) reviewed a general function of organic matter in soil by saying that soil aggregation, reduction of runoff, and soil temperature are greatly improved.

It is known that the ability of organic matter or humus substances interacting with rock or minerals accelerates the soil pedgenesis through chelation or complex formation.

The structure of humus or organic matter depends on the nature of materials from which it originated, upon the degree of their decomposition, upon the reaction of the soil, and upon the environmental condition under which decomposition is taking place.

In summary, the following are some of the important resulting characteristics of organic matter or humus materials in soil fertility:

a. Supply of nutrients.

b. Increase in soil aeration.

c. Change in characteristic structure.

d. Increase in water holding capacity.

e. Increase in properties of cohesion and adhesion.

f. Increased soil permeability in entering water faster.

g. Heat capacity and absorption.

h. Coagulation by electrolytes.

i. High buffering property.

j. Shrinkage on drying and vice versa.

k. Acceleration of soil pediogenesis.

l. Less soil baking and less crust formation.

m. More uniform temperature. In winter, soils with an organic mulch are warmer and in summer they are cooler than soils with no such organic blanket (Rodale, 1973).

n. Protection against drought.

2. Green Manure Practice in Korea:

Understanding of the value of organic matter in crop production and soil improvement goes far back beyond recorded Korean history. From 1962 to 1974, Korean farmers produced an average of about 9.7 to 25 million tons per year of green manure and raw plant materials (the difference between green manure and raw plant materials is unclear) for maintaining organic matter in their farmlands (Table 30). In Korea, the green manure decomposition method has been practiced under a semi-anaerobic condition and has the following disadvantages:

a. Delayed decomposition time.

Table 30

AMOUNT OF UTILIZATION OF MANURE IN KOREAN AGRICULTURAL LAND[1]

Item / Year	Green Manure (Ton)	Raw Materials For Manure	TOTAL
1962	1,343,562	9,996,102	11,339,664
1963	1,551,408	8,204,390	9,755,798
1964	1,839,313	9,937,137	11,776,450
1965	2,481,589	14,012,495	16,494,084
1966	1,827,084	15,731,877	17,618,961
1967	1,883,659	16,819,800	18,703,459
1968	2,206,216	16,722,736	18,928,952
1969	1,289,905	21,283,433	22,573,338
1970	1,430,662	22,907,664	24,338,326
1971	1,776,338	24,260,023	26,036,361
1972	1,402,778	23,298,420	24,701,980
1973	2,426,053	23,322,713	25,748,766

[1] Annual report of the Ministry of Agriculture and Forestry (1973 and 1974).

b. Loss of nutritional value by leaching and overflow of rainfall.

c. Unsanitary conditions and health hazards.

d. Loss of rural beauty.

C. Korean Forest Soil Study

The work done here is defined solely for the purpose of describing the necessity and possibility of using compost as an aid in reforestation of the Korean woodlands.

Chung (1974), Forest Soil Survey Section, Forest Resources Survey and Research Center, Seoul, kindly provided an unpublished five year study (Appendix H) on a survey encompassing, randomly, all areas of Korean forest land except the islands (Figure 33).
The detailed chemical composition of these island samples was not provided but a general soil profile is shown in the following three qualitative ways: (1) favorable -- high amount of organic matter and good conditions for plant growth. Generally B upper-subsoil or transitional zone between A and B horizon. (2) Acceptable -- shallow cover of organic matter and fair conditions for plant growth, usually middle or lower portion of B horizon. (3) Unfavorable -- low in organic matter, generally calcareous, aridic and erosion conditions, usually C and lower portion of B horizon.

The letters A, B, and C are designated conventionally as soil layer or horizons, as A for horizon incorporated with humus, B for accumulative horizon, and C for parent material. (Wilde, 1958)

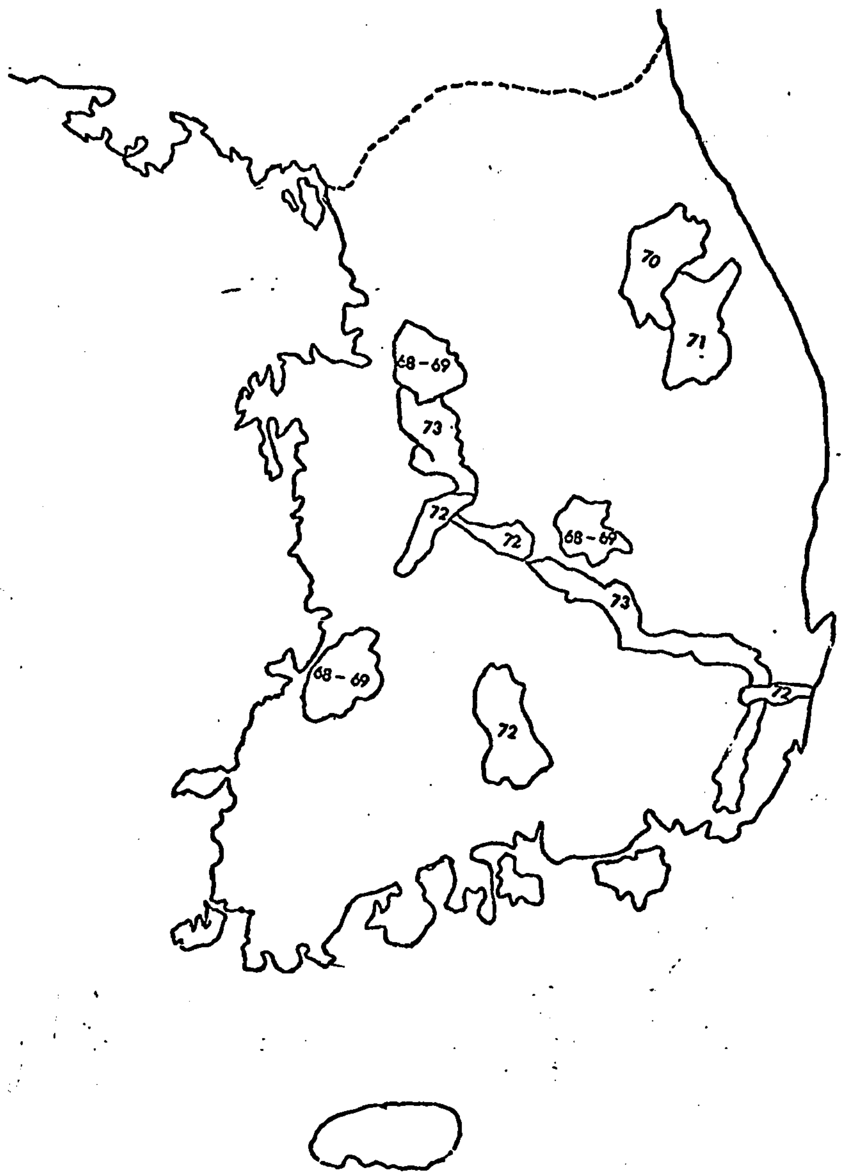


Figure 33

MAP OF FOREST AREA SURVEYED AND SURVEYING YEARS

Research indicates 21.19% as favorable, 15.22% as acceptable, and 63.59% as unfavorable conditions in Korean forestry land. (Appendix H)

To maintain proper levels of organic matter for the 63.59% of unfavorable Korean forest land is a difficult problem in practical terms. However, before applying organic matter during planting, detailed practical points such as economy and source of supply must be considered.

1. Economical View:

   The following conditions provide economic advantages for application of organic materials to Korean forest land:

   a. The Korean government practices of planting activity involve large expenditures annually as a long-range project of major national policy.

   b. The general procedure for planting a sapling (2 or 3 years of age) is to make a hollow hole (around 10 inches x 10 inches) for the purpose of adding chemical fertilizers and water. At this time, organic humus materials could be applied about two inches from the bottom (approximately 1.8 to 2.0 pounds) without altering the efficiency of the basic procedure.

   c. The labor is available.

   d. By adding the organic material, the amount of fertilizer can be reduced more than 40%, depending on the topography of the forest land.

e. The compost provides an adequate supply of organic materials required (Table 22).

f. By pelletizing the compost, the labor force and its volume required for applying the compost during planting would be reduced.

g. Efficient use of the compost would greatly reduce the problem of municipal solid waste disposal in the large Korean cities.

h. As a source of supply, the continuous supply of organic matter of compost is secured.

As a long-term benefit of organic compost, the following assets would be derived:

a. Increase of the forest productivity and fertility.

b. Reduction of the amount of government reforestation expense.

c. Future reduction of importation of expensive foreign hard wood.

d. Reduction of the municipal solid waste cost.

e. Increase in the public attention on protection of forestry land.

f. Increase in the efficiency of survival and growth of newly planted trees.

To know the actual benefits (cost balance) of using compost in planting, a descriptive balance form is formulated in Table 31.

Table 31

COST BALANCE OF PLANTING WITH AND WITHOUT COMPOST

Planting Cost	Maintenance Cost	Labor and Equipment Cost
Conventional		
Seeding	Property Tax	
Shipping	Fire Protection	
Fertilizing Artificial & Inorganic- Nutrients	Maintenance Cost	
Compost Adding		
Same except reducing amount of fertilizer but adding hauling costs.	Same except reduce maintenance cost.	No difference except that more manpower is required.

To obtain a detailed cost balance it is necessary to compare those two methods. In short range, if an increase in the number of workers required for planting is not considered a problem associated with the adding of compost, then by a free-labor adjustment project of the Korean government, compost adding practices will definitely bring much more effective results over the conventional method. Furthermore, low ranges (0.7 - 4.0 percent) of the required organic content at the planting site (Appendix I) indicate that the usage of organic compost provides nutrient requirements (Table 22).

D. Profile of Korean Agricultural Land

The chemical composition of Korean cultivated soil for both upland and bottom land is kindly provided by Park (1974), Soil Fertility and Chemistry Division, Institute of Plant Environment, Office of Rural Development, Suwon, Korea (Appendix J).

There is no single means to evaluate the quality standard of agricultural land because of varying requirements of nutrients for each particular crop.

Production capability or general requirements of a given land could be determined by: (1) soil structure (texture, surface, drainage), (2) climate (temperature, rainfall, water availability), (3) adequate supply of plant nutrients.

Plant nutrients most commonly lacking in cultivated soil are nitrogen, phosphorus, and potassium. The minor or trace elements for plant growth include calcium, magnesium, sulfur, aluminum, iron, manganese, copper, zinc, boron and molybdenium, with varying requirements for each plant.

Generally, it is known that three to four percent of organic matter in crop land is required, but the range (0.1 - 6.0 percent) for upland and (0.6 - 5.0 percent) for bottom land of organic matter, based on the given information in Appendix J, makes it difficult to reach any quantitative conclusions.

In the Korean farmer's harvesting practices, all residues of crop plants except the roots are removed for use as ensilage, green manure is used for burning for cooking and warming the houses, and in manufacturing goods; therefore, one of the farmer's major problems in Korea is securing organic matter to replace the removed organic matter. As a reference, general information on nutrient requirements (assuming three to four percent organic matter is present) for Korean major upland crops is shown in Appendix K.

1. Need for Study:

Personal communications with Hinkle (1975), Department of Agronomy, University of Arkansas, and Lynd (1975), Department of Agronomy, Oklahoma State University, indicated that the nutritional requirements of the rice plant, one of the major crops in the Korean bottom land, is available but the necessity of organic matter has not been studied clearly. They emphasized that organic matter in paddy land is extremely important for continuous rice production, not only in providing nutritional supply and holding the nutrients in irrigated land, but also for improving the soil's physical-chemical property.

2. Possibility of the Usage of Municipal Compost in Cultivated Land in Korea:

   a. Similarity of the municipal compost with the conventional Korean manure:

      i. Municipal major compostable material derives from vegetable, food waste, and paper materials.

      ii. Its nutritional value may be equal or better because of the addition of sewage sludge during the decomposition stage.

iii. Similarity of decomposition product -- one from the anaerobic process with a longer period, and the other from the aerobic mechanical process with a shorter period.

iv. The toxic effect on plants from municipal compost has not been recorded.

v. European countries, Israel, and other countries in the world consider the municipal compost as a perfect humus material.

vi. Safe usage by complete destruction of pathogenic organisms.

b. Advantages for Korean farmers from the use of municipal compost:

i. Reduction of farmer's labor and time of preparing the manure.

ii. More compost required for both cultivated and cultivating land.

iii. Protection of the agricultural and forestry land by preventing the removal of green manurable plants.

iv. Reduction of the amount of artificial fertilizer required by as much as forty percent.

v. An increase in the Korean national welfare for both municipal and rural residents:

1. Reduction of solid waste disposal fees.

2. Clean environment.

vi. Sanitary aspects -- municipal composting allows many pathogenic organisms in the plant and animal materials to be destroyed before the residue is put back on the land.

Chapter VIII

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

One of the aims of this work on solid waste disposal management for the city of Seoul, Korea, is to help decision makers of the city and national government deal with the problems of major concern in the field of solid waste management.

In solid waste management in Korea, as in other aspects of administration, good decision making is essential where natural resources are limited and agriculture has been the most important industry. This work includes a specific guideline providing facts covering broad but specific problems and answers.

The conclusions, discussions, and recommendations necessary for further research have been considered in each chapter.

On the basis of the data obtained in this work, the following general conclusions are drawn:

I. Development of Solid Waste Model

1. Major constituents of solid waste generated in the city of Seoul, Korea, are briquette ash and vegetable material.

2. An increase in the population and income shows a general tendency toward increasing solid waste generation.

3. The best mathematical model of residential solid waste is:

$$Y_1 = 0.5276 + 8.4 \times 10^{-6} X_1 + 0.2019 X_2$$

where Y_1 = the amount of solid waste generation (lb/person/day)

X_1 = population density (person/sq. mile)

X_2 = income level (\$/person/day)

For developing a more definite model, the following are recommended for further work:

1. Increase the number of observations to obtain a better solid waste model.

2. Estimate solid waste characteristics and composition through detailed investigations periodically (survey data are provided in Appendix B).

II. The Combination of Alternatives for Disposing of Solid Waste

1. Land requirement of landfill practices has created a serious problem of lack of space in the city of Seoul, Korea. This problem will become more acute in the future. (949 acres/10 years/5600 ha of ChungGye Drainage Area based on 2,000 tons generation per day.)

2. Based on 2,000 tons/day generation of solid waste, the DARE score indicated the best alternative method of disposing of the solid waste that is generated in the city of

Seoul, Korea, was the combination of composting and landfill practice, along with separation of coal ash.

3. The composting practice developed by hhe Naturizer Company of Norman, Oklahoma, has a small area requirement (0.7 acres/500 ton) due to the continuous elevation construction of digestive tanks.
4. The second most favorable alternative was found to be the sanitary landfill operation along with separation of coal ash. However, land requirements (353.3 acres/10 years) for 730 tons generation per day could be a limiting factor for the city of Seoul.
5. The third most favorable alternative method is the operation of the combination of three alternatives (sanitary landfill, incinerator, and composting).
6. A pathological incinerator, in small scale, should be built for disposing of dead animal and combustible radioactively contaminated waste for public health.

For further work:

1. It would be valuable to study the source separation system (house-to-house and containerized separation) for comparison with central separation system.
2. The coal ash separation system should be further studied.
3. The seasonal variation and its characteristics should be investigated.

III. Korean Coal Ash Studies

A. Construction of Ash Utilization

1. Ash tests indicate the ash could be used as a highway submaterial.
2. The ash might also be used in brick and concrete making for a high quality filler.
3. There are many other possibilities for use of ash in other construction projects besides 1 and 2 above.
4. After burning the coal at a high temperature, the mineral and chemical and physical characteristics are changed.

For further work:

1. It is essential to verify the above conclusions with field or laboratory tests.
2. Study is needed on separation of ash by size.

B. Agricultural Purposes of Ash Utilization

1. The ash test showed that ash has some characteristics of compost, including high water holding capacity (46.6% in fine ash and 21.9% in coarse ash).

For further work:
Long-range study (probably over ten years) is necessary for verifying whether the application of ash will react with unknown substances and harden in agricultural land.

C. Landfill Cover Material

The ash material could be used as a partial landfill cover material.

IV. Evaluation and Requirements of Composting in Korean Land

A. Evaluation of Compost

1. Swiss chard experiments generally showed that compost provides better germination and growth when applied as application rates were increased up to 12 tons/acre.
2. Root growth of swiss chard in compost plus soil showed greater increase than in fertilized soil, or non-fertilized soil.
3. Compost plus fertilizer was the most effective treatment among the treatments tested, such as fertilizer alone, soil alone, and compost alone.
4. Lettuce experiments indicate that compost at six tons per acre provides better growth than soil alone.
5. Requirement of compost for plant growth is dependent on the type of plant.

B. Requirements of Compost

1. Korean soil for both agriculture and forestry requires a source of organic matter.
2. In 1973, the Korean farmer applied over 25 million tons of organic matter at a great expenditure of time and labor.
3. Based on Korean agricultural practices, it is possible to apply municipal compost to agricultural land and forestry land.

4. Sewage sludge could provide a supply of moisture and nutrients during digesting periods, thus improving the quality of the compost.

For further work:

1. For utilizing municipal compost, it is necessary to seek more economical means of application to the soil.
2. It is necessary to study further the transportation system of compost into rural areas and the storage system of compost.
3. To verify the above conclusions in the evaluation of compost, field studies should be conducted.

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APPENDICES

APPENDIX A

COMPUTER PROGRAM OF THE REGRESSION COEFFICIENT FOR ESTIMATING SOLID WASTE GENERATION MODEL IN THE CITY OF SEOUL, KOREA

```
//WASTEGEN JOB NUINUZIT,'TAE B YIM           ',CLASS=A                JOB  918
// EXEC BUSLIB,PROG=OLSQ
XXBUSLIB PROC                                                         00000010
********************************************************************* 00000020
***  PROCEDURE TO EXECUTE PROGRAMS IN SYS6,BUSLIB,MODULES         *** 00000030
***                                                               *** 00000040
*** TECHNICAL CONSULTING -- R & E COMPUTING SERVICES              *** 00000050
***                                                               *** 00000060
********************************************************************* 00000070
XXGO       EXEC PGM=&PROG                                             00000080
IEF653I SUBSTITUTION JCL - PGM=OLSQ
XXSTEPLIB  DD DSN=SYS6.BUSLIB.MODULES,DISP=SHR                        00000090
XXFT05F001 DD DDNAME=SYSIN                                            00000100
XXFT06F001 DD SYSOUT=A                                                00000110
XXFT07F001 DD SYSOUT=B                                                00000120
//SYSIN      DD *                 GENERATED STATEMENT
//
IEF236I ALLOC. FOR WASTEGEN GO
IEF237I 156     ALLOCATED TO STEPLIB
IEF237I 604     ALLOCATED TO FT05F001
IEF237I 646     ALLOCATED TO FT06F001
IEF237I 683     ALLOCATED TO FT07F001
IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF285I   SYS6.BUSLIB.MODULES                             KEPT
IEF285I   VOL SER NOS= UOK110.
IEF373I STEP /GO       / START 75106.1633
IEF374I STEP /GO       / STOP  75106.1633 CPU   0MIN 00.96SEC STOR VIRT 128K
UOK000I 156    EXCP COUNT        58
UOK000I 604    EXCP COUNT        25
UOK000I 646    EXCP COUNT       285
UOK000I 683    EXCP COUNT         0
UOK001I  PAGE-INS        104
UOK002I  PAGE-OUTS        16
IEF375I  JOB /WASTEGEN/ START 75106.1633
IEF376I  JOB /WASTEGEN/ STOP  75106.1633 CPU   0MIN 00.96SEC
```

```
SPACE ALLOCATED FOR 30 VARIABLES,  506 OBSERVATIONS
    9     9     4
(F5.0,3F5.3,F8.3,F8.1,F4.2,F8.2,F5.2)
$NOTRANS
```

OBSERVATION	YEAR	SWG/P	SWG/P/BA	SWG/H/BA	DWG/H	PDSM	DIPP	NHPM
1	1964,00	1,66900	0,708000	4,10600	9,68000	14467,8	0,360000	2674,49
2	1965,00	1,73400	0,735000	4,19000	9,88100	14664,2	0,360000	2743,21
3	1966,00	1,96400	0,763000	4,42500	11,3910	16068,9	0,480000	3102,51
4	1967,00	2,01500	0,790000	4,66100	11,8910	16769,7	0,610000	3186,70
5	1968,00	1,99200	0,817000	4,55900	11,1170	18314,9	0,640000	3537,80
6	1969,00	2,12300	0,844000	4,47300	11,2680	20182,2	0,740000	4062,24
7	1970,00	2,21300	0,871000	4,59000	11,6640	23390,8	0,780000	4634,21
8	1971,00	2,27100	0,898000	4,70600	11,9000	24719,8	0,800000	4863,25
9	1972,00	2,26500	0,925000	4,78200	11,7120	25671,3	0,870000	4996,64
MEAN	1968,00	2,02733	0,816778	4,49911	11,1671	19361,1	0,626667	3755,67
VARIANCE	7,50000	0,474178D-01	0,551495D-02	0,521430D-01	0,691668	0,187626D 08	0,362250D-01	828041,
STANDARD DEVIATION	2,73861	0,217756	0,742626E-01	0,228348	0,831666	4331,58	0,190329	909,968

OBSERVATION	DIPH
1	2,10000
2	2,06000
3	2,76000
4	3,60000
5	3,58000
6	3,90000
7	4,11000
8	4,21000
9	4,50000
MEAN	3,42444
VARIANCE	0,822803
STANDARD DEVIATION	0,907085

REGRESSION 1 DEPENDENT VARIABLE SWG/P

VARIABLE NAME	REGR. COEFFICIENT	STANDARD ERROR	T STATISTICS
CONSTANT	1,2935766	0,11216280	11,533027
PDSM	-0,63289439D-05	0,14844958D-04	-0,42633626
DIPP	0,97535297	0,33784779	2,8869597

NUMBER OF OBSERVATION = 9

R-SQUARED= 0,94585324

THE DURBIN WATSON STATISTIC= 1,6523996

THE STANDARD ERROR OF REGRESSION= 0,58511958D-01

THE VARIANCE-COVARIANCE MATRIX

```
 0,125805D-01-0,129080D-05 0,204114D-01
-0,129080D-05 0,220373D-09-0,474870D-05
 0,204114D-01-0,474870D-05 0,114141
```

NO. OF OBSER.	ACTUALS	PREDICTED	RESIDUALS	RES./ACT.
1	1,6690	1,7363	-0,672690-01	-0,403050-01
2	1,7340	1,7375	-0,351240-02	-0,202560-02
3	1,9640	1,8634	0,10056	0,511990-01
4	2,0150	1,9947	0,203240-01	0,100860-01
5	1,9920	2,0337	-0,417170-01	-0,209420-01
6	2,1230	2,1431	-0,200700-01	-0,945360-02
7	2,2130	2,2024	0,106090-01	0,479380-02
8	2,2710	2,2305	0,406910-01	0,179180-01
9	2,2650	2,3046	-0,396060-01	-0,174860-01

ESTIMATION OF HENRY THEIL U TEST

YEAR	ACTUAL RATE OF CHANGE	PREDICTED RATE OF CHANGE
1	0,38206E-01	0,71500E-03
2	0,12455	0,69972E-01
3	0,25635E-01	0,68054E-01
4	-0,11480E-01	0,19383E-01
5	0,63690E-01	0,52374E-01
6	0,41519E-01	0,27304E-01
7	0,25871E-01	0,12596E-01
8	-0,26458E-02	0,32769E-01

HENRY THEIL INEQUALITY U COEFFICIENT 0,60611

VARIANCE PROPORTION	0,22010
COVARIANCE PROPORTION	0,77299
BIAS PROPORTION	0,00691
REGRESSION PROPORTION	0,00466
DISTURBANCE PROPORTION	0,98843

REGRESSION -2- DEPENDENT VARIABLE-SWG/P/BA

VARIABLE NAME	REGR, COEFFICIENT	STANDARD ERROR	T STATISTICS
CONSTANT	0,52762786	0,18116618D-01	29,123972
PDSM	0,83999727D-05	0,23977686D-05	3,5032457
DIPP	-0,20188958	0,54569425D-01	-3,6996832

NUMBER OF OBSERVATION = 9

R-SQUARED= 0,98785426

THE DURBIN WATSON STATISTIC= 2,0581293

THE STANDARD ERROR OF REGRESSION= 0,94508948D-02

THE VARIANCE-COVARIANCE MATRIX

```
0,328212D-03-0,336756D-07 0,532513D-03
-0,336756D-07 0,574929D-11-0,123889D-06
0,532513D-03-0,123889D-06 0,297782D-02
```

NO. OF OBSER.	ACTUALS	PREDICTED	RESIDUALS	RES./ACT.
1	0.70800	0.72184	-0.138370-01	-0.195440-01
2	0.73500	0.72349	0.115130-01	0.156640-01
3	0.76300	0.75951	0.348680-02	0.456990-02
4	0.79000	0.79165	-0.164550-02	-0.208290-02
5	0.81700	0.81068	0.631820-02	0.773340-02
6	0.84400	0.84656	-0.255600-02	-0.302850-02
7	0.87100	0.88158	-0.105840-01	-0.121510-01
8	0.89800	0.89679	0.121490-02	0.135290-02
9	0.92500	0.91891	0.609000-02	0.658380-02

ESTIMATION OF HENRY THEIL U TEST

YEAR	ACTUAL RATE OF CHANGE	PREDICTED RATE OF CHANGE
1	0.37426E-01	0.22824E-02
2	0.37387E-01	0.48595E-01
3	0.34774E-01	0.41436E-01
4	0.33606E-01	0.23761E-01
5	0.32513E-01	0.43300E-01
6	0.31489E-01	0.40543E-01
7	0.30527E-01	0.17095E-01
8	0.29623E-01	0.24371E-01

HENRY THEIL INEQUALITY U COEFFICIENT	0.46060
VARIANCE PROPORTION	0.61501
COVARIANCE PROPORTION	0.34085
BIAS PROPORTION	0.04415
REGRESSION PROPORTION	0.92390
DISTURBANCE PROPORTION	0.03196

REGRESSION 3 DEPENDENT VARIABLE DWG/H

VARIABLE NAME	REGR. COEFFICIENT	STANDARD ERROR	T STATISTICS
CONSTANT	8.7377221	0.63967830	13.659557
NHPM	-0.49939485D-03	0.42038941D-03	-1.1879339
DIPH	1.2571239	0.42172549	2.9809056

NUMBER OF OBSERVATION = 9

R-SQUARED= 0.80204413

THE DURBIN WATSON STATISTIC= 1.6344914

THE STANDARD ERROR OF REGRESSION= 0.42734507

THE VARIANCE-COVARIANCE MATRIX

0.409188	-0.105973D-03	0.265845D-02
-0.105973D-03	0.176727D-06	-0.162875D-03
0.265845D-02	-0.162875D-03	0.177852

NO. OF OBSER.	ACTUALS	PREDICTED	RESIDUALS	RES./ACT.
1	9.6800	10.042	-0.36205	-0.37402D-01
2	9.8810	9.9575	-0.76451D-01	-0.77372D-02
3	11.391	10.658	0.73299	0.64349D-01
4	11.891	11.672	0.21905	0.18422D-01
5	11.117	11.471	-0.35447	-0.31885D-01
6	11.268	11.612	-0.34384	-0.30515D-01
7	11.664	11.590	0.73798D-01	0.63270D-02
8	11.900	11.602	0.29846	0.25081D-01
9	11.712	11.899	-0.18748	-0.16008D-01

ESTIMATION OF HENRY THEIL U TEST

YEAR	ACTUAL RATE OF CHANGE	PREDICTED RATE OF CHANGE
1	0.20552E-01	-0.84606E-02
2	0.14221	0.67990E-01
3	0.42958E-01	0.90877E-01
4	-0.67506E-01	-0.17325E-01
5	0.13491E-01	0.12162E-01
6	0.34539E-01	-0.18655E-02
7	0.20031E-01	0.97704E-03
8	-0.15924E-01	0.25356E-01

HENRY THEIL INEQUALITY U COEFFICIENT 0.70743

VARIANCE PROPORTION	0.20317
COVARIANCE PROPORTION	0.79310
BIAS PROPORTION	0.00373
REGRESSION PROPORTION	0.00029
DISTURBANCE PROPORTION	0.99598

REGRESSION 4 — DEPENDENT VARIABLE SWG/H/BA

VARIABLE NAME	REGR. COEFFICIENT	STANDARD ERROR	T STATISTICS
CONSTANT	3,7479411	0,13089581	28,633010
NHPM	-0,88655143D-04	0,86023262D-04	-1,0305950
DIPH	0,31658536	-0,86296661D-01	-3,6685702

NUMBER OF OBSERVATION = 9

R-SQUARED= 0,89007958

THE DURBIN-WATSON STATISTIC= 1,2710418

THE STANDARD ERROR OF REGRESSION= 0,87446581D-01

THE VARIANCE-COVARIANCE MATRIX

0,171337D-01	-0,443736D-05	0,111316D-03
-0,443736D-05	0,740000D-08	-0,681997D-05
0,111316D-03	-0,681997D-05	0,744711D-02

NO. OF OBSER.	ACTUALS	PREDICTED	RESIDUALS	RES./ACT.
1	4,1060	4,1757	-0,69662D-01	-0,16966D-01
2	4,1900	4,1569	0,33093D-01	0,78982D-02
3	4,4250	4,3467	0,78337D-01	0,17703D-01
4	4,6610	4,6051	0,55869D-01	0,11987D-01
5	4,5590	4,5677	-0,86727D-02	-0,19023D-02
6	4,4730	4,6225	-0,14949	-0,33420D-01
7	4,5900	4,6383	-0,48261D-01	-0,10514D-01
8	4,7060	4,6496	0,56385D-01	0,11982D-01
9	4,7820	4,7296	0,52402D-01	0,10958D-01

ESTIMATION OF HENRY THEIL U TEST

YEAR	ACTUAL RATE OF CHANGE	PREDICTED RATE OF CHANGE
1	0,20251E-01	-0,45019E-02
2	0,54569E-01	0,44636E-01
3	0,51960E-01	0,57762E-01
4	-0,22127E-01	-0,81673E-02
5	-0,19044E-01	0,11929E-01
6	0,25820E-01	0,34064E-02
7	0,24958E-01	0,24441E-02
8	0,16021E-01	0,17055E-01

HENRY THEIL INEQUALITY U COEFFICIENT 0,58554

VARIANCE PROPORTION	0,04992
COVARIANCE PROPORTION	0,91678
BIAS PROPORTION	0,03331
REGRESSION PROPORTION	0,02929
DISTURBANCE PROPORTION	0,93741

stop

Appendix B

FORM 1
(FOR RESIDENTIAL INFORMATION)

Location:__________________
Date:______________________
Unit Weight:_______________

Description / Item	Source of Waste	Type of Waste	Amount of Solid Waste	Moisture Content	Storage Period	Type of Removal	Bal. Waste	REMARKS			
								Inc.	No. & Age of Family	No. of Rooms	Level of Education
Briquetted Ash											
Paper											
Veg. Material[1]											
Food Waste											
Rags											
Rubber											
Glass											
Metal & Cans											
Synthetic Chemical											
Demolition											
Dead Animals											

[1] Vegetable material generation follows the Vegetable Material Survey Sheet.

Appendix B

(Continued)

FORM 2

(FOR VEGETABLE MATERIALS FOR RESIDENTIAL AND COMMERCIAL AREA)

Location:________________
Date:________________
Unit Weight:________________

Item / Date	Amount of Veg. Purchased or growing except Kimchi preparation	Waste of Vegetable Material	Removal Type & Storage Period	Amount of Vegetable Purchased for Kimchi preparation Nov. - Dec.							Waste Other Than Veg.	Removal Type & Storage Period	Amount of Vegetable Production If Any	Waste Generation	Removal Type & Period
				Redish	% Waste	Cabbage	% Waste	Seasoning	% Waste	TOTAL WASTE GENERATION					

Appendix B

(Continued)

FORM 3
(COMMERCIAL WASTE & INDUSTRIAL WASTE)

Commercial Type:________________ Type of Industry:__________
Date:___________________________ Location:__________________

Commercial Waste				Industrial Waste				
A	Amount of Currency Handled For Comm. Activity	Price of Materials Handled	No. of Employees Including Employer	A	Amount of Raw Material	Indus. Production Method	Amount of Water or Fuel Used	No. of Employees Including Employer

$$Y_1 = a_1 + a_2X_1$$

where Y_1 = lb/person/day
X_1 = currency vol./period

$$Y_2 = a_1 + a_2X_2$$

where Y_2 = lb/person/day
X_2 = amount of water or electricity used per period

A. Use the form of Residential Survey Sheet or continue with this form.

Appendix C

DAILY WET SLUDGE GENERATION FROM THE CHUNG-GAE SEWAGE TREATMENT PLANT

Amount of wet sludge generation from the ChungGye Channel Treatment Plant:

250,000 tons/day = treatment capacity of sewage

350 ppm BOD

300 ppm dissolved solids

Calculation:

$$\frac{350(250,000)}{10^6} = 87.5 \text{ tons/day}$$

Assuming that 30% of the total BOD is converted to biological solids

0.3(87.5) = 26.25 tons/day.

Assuming that 60% of the total dissolved solids are removed

$$\frac{0.6(300)(250,000)}{10^6} = 45 \text{ tons per day}$$

The plant is designed so that 60% of the total sewage passes through secondary treatment.

Assuming that 75% of the BOD in the effluent from the primary treatment is removed.

$$\frac{350(150,000)(.75)}{10^6} = 39.4 \text{ tons per day}$$

Assuming that 95% of the BOD is removed in secondary treatment

0.95(39.4) = 37.43 tons per day

Assuming that 30% of the BOD removed is converted to biological solid

0.3(37.43) = 11.23 tons per day

Total wet sludge = 45 tons from primary treatment + 11.23 tons from secondary treatment = 56.23 tons.

APPENDIX D

CALCULATION EXAMPLES OF CONCEPTUAL DESIGN OF THREE ALTERNATIVES FOR DISPOSING OF SOLID WASTES

I. Sanitary Landfill

A. Daily Land Requirement for 2000 Tons of Waste

$$V = 1.2 \frac{R}{D} \left(1 - \frac{P}{100}\right)$$

assuming 1,977,77 tons/1,409,587 persons/5600 ha.and 22.23 tons/ 15,844 persons from other areas

where $V = yd^3$/person/day

R = lb/person/day (2.806/person/day)

P = percent volume reduction by compaction at landfill (assume 40% reduction)

D = density (850 lbs/yd^3)

$V = 2.377 \times 10^{-3}$ yd^3/person/day

$$A = \frac{27(V)(N)}{d(43560)}$$

where A = acres/day

N = population

d = compacted depth (assume 8 feet)

$A = 2.6 \times 10^{-1}$ acres/day, or 94.9 acres/year

Volume of cover material required (c) = $\frac{(A)(3500)(Tc)}{27}$

where Tc = top covered required (assume 1.0 feet enough for intermediate cover because of 65% of ash waste of the total waste)

$c = 34.61$ yd^3/day, or 12,633 yd^3/year

B. Sanitary Landfill Equipment Requirements

Equipment required to operate a sanitary landfill varies with the characteristics of the site, but the minimum requirements of equipment for burying 2,000 tons of refuse per day is theoretically shown in Table 32.

Table 32

SANITARY LANDFILL EQUIPMENT REQUIRED (2000 TON/DAY)

Machine Type	Number	Max. Waste Handled (Ton/8 Hours)	Approx. Cost* Per 1 Machine	Function
<u>Main Equipment</u>				
Crawler Loader	2	250	$71,050	Spreading
Crawler Dozer	3	500	$101,500	Excavating & Spreading
<u>Accessories</u>				
Dozer blade (U-shape)	3		$6,000	
Multiple bucket	1		$4,000	
<u>Special Equipment</u>				
Scraper	1		$200,000	Hauling
Water truck	1		$35,000	Dust Control & Fire Prevention

*Oklahoma retail price, Oklahoma City, Oklahoma (1975)

C. Associated Sanitary Landfill Improvements

1. Fencing.
2. Building - a building is needed for office space and employee facilities.
3. Road - a large site may have to have permanent roads that lead from the entrance to the vicinity of the working area.
4. Scales for recording amounts of material.
5. All sanitary landfill sites should have electrical, water, and sanitary services. Water should be available for dust control, fire prevention, and employee sanitation.

II. INCINERATOR (Figure 34)

Daily quantity = 600 tons

Anticipated operating days = 350 days per year

Total operating day tonnage = 625.7 tons

A. Consideration of Use vs. Theoretical Design

Design capacity = 625.7 tons per day

Rated capacity = 625.7 tons per day

Dependable capacity (assuming 80% of rated capacity) = 782.1 tons per 24 hour per day

Anticipated operating time = 12 hours continuous cycle

Actual capacity = 1564.3 tons per 24 hours, or 65.2 tons per hour

B. Design of Incinerator Based on Rate of 65.2 Tons Per Hour (without Consideration of Peak Loading)[1]

---

[1] Danielson (1967)

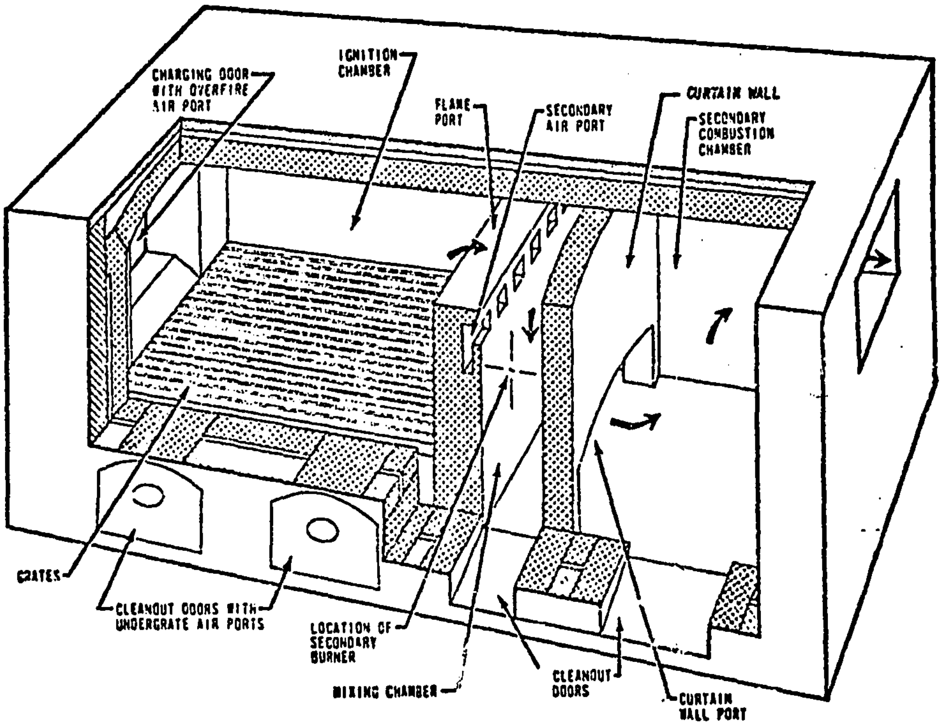

Figure 34

CUTAWAY OF MULTIPLE CHAMBER INCINERATOR

(Danielson, 1967)

Moisture content of combustible materials = 58.7% (w/w)

Weight of dry combustible solid waste = 26.9 tons/hr, or 53,800 lbs/hr

Weight of moisture = 38.3 tons/hr, or 76,600 lbs/hr

The gross heat of combustion of one pound:

444,441,800 BTU/hr = (53,800 lb/hr)(8261 BTU/lb - weighted arithmetic means of Table 33)

Heat losses:

(1) Assume 20% radiation, convection, and storage heat losses

(0.2)(444,441,800 BTU/hr) = 88,888,360 BTU/hr

(2) Evaporation of moisture (assume the gross heat of vaporization of water at 60° F is 1,060 BTU/lb)

(76,600 lbs/hr)(1,060 BTU/lb) = 81,196,000 BTU/hr

(3) Evaporation of water formed by combustion

(0.56 H_2O lb/hr)* (76,600 lbs/hr)(1,060 BTU/lb) = 45,469,760 BTU/hr

Total heat losses = 215,554,120 BTU/hr

Net heat available = 228,887,680 BTU/hr

Weight of products of combustion with 300% excess air:

(53,800 lbs/hr)(23.15 lbs-gas/lb) =	1,245,470
Moisture =	76,600
TOTAL =	1,322,070

---

* 0.56 lb of water formed at zero excess air as in Table 34.

Table 33

COMPOSITION AND ANALYSIS OF AN AVERAGE REFUSE, SEOUL, KOREA

	Moisture (%)	Dry Weight (Ton)	Analysis (% by Dry Weight - Corey, 1969) C	H	O	N	S	BTU/1b
Paper	40.0	33.04	43.4	5.8	44.3	0.3	0.2	7572
Wood & Straw	40.0	47.9	50.5	6.0	42.4	0.2	0.05	8613
Grass & Vegetables	75.0	303.80	43.3	6.0	41.7	2.2	0.05	7693
Rubber	10.0	5.7	77.7	10.4	--	-	2.0	11,330
Plastic	10.0	32.1	60.0	7.2	22.6	-	-	14,368
Rags	50.0	61.70	55.0	6.6	31.2	4.6	0.13	7652
Garbage (food waste)	80.0	11.6	45.0	6.4	28.8	3.3	0.52	8484
						weighted average (unseparated)		8261
Metal and Cans	10.0	3.1						
Dead Animals (Pathological incinerator)	90.0	2.0	58.2	8.7	20.76	.7	.13	12,255.5
						(separated)		
Demolition & Ceramics	5.0	111.4						
Glass	1.0	9.3						
Briquetted Ash	15.0	1250.4						
Others	12.0	100.0						

Table 34

CALCULATION OF AIR REQUIREMENT AND GAS COMPOSITION AT ZERO EXCESS AIR

Chemical Species	Weight	Atomic Weight	Atomic Unit	Mole of O_2 Required	Combustion Product	Moles of Effluent			
						From Combustion	From Air	Total	Percent
C	47.63	12.01	3.97	3.97	CO_2	3.97	.006	3.976	16.71
H	6.24	1.00	6.24	1.56	H_2O	3.12	.264	3.384	14.22
O	38.39	16.00	2.40	-1.20	-	--	--	--	--
N	1.94	14.00	0.14	--	$N_x(N_2)$	0.07	16.361	16.431	69.03
S	0.12	32.06	0.01	0.01	SO_2	0.01	--	0.01	0.04
				TOTAL = 4.34				23.801	

Moles of air required per 100 lb fuel = 4.34/.2069 = 20.97

Table 34
(Continued)
EFFLUENT OF EXCESS AIR ON GAS COMPOSITION

Excess Air	Moles of Excess Air	Total Moles		Gas Composition CO_2 (mw. 44)	O_2 (32)	N_2 (28)	H_2O (18)	SO_2 (64)	Flue Gas With % Excess Air Indicated (lbs)	Flue Gas With Excess Air Indicated (ft^3)*
0	0.0	100.0	a	16.71	0.00	69.03	14.22	0.04	6.45	86.3
			b	16.71	0.00	69.03	14.22	0.04		
50	44.0	144.0		16.72	9.10	103.36	14.77	0.04	9.22	124.3
				11.62	6.32	71.78	10.26	0.03		
100	88.0	188.0		16.74	18.21	137.69	15.33	0.04	12.01	162.3
				8.90	9.69	73.24	8.15	0.02		
200	176.0	276.0		16.76	36.41	206.35	16.44	0.04	17.55	238.2
				6.07	13.19	74.76	5.96	0.01		
300	264.0	364.0		16.79	54.62	275.00	17.55	0.04	23.15	314.1
				4.61	15.01	75.55	4.82	0.01		

a = calculated value
b = % of the total

Moles of air per mole of gas = $\frac{20.97}{23.80}$ = 0.88

* Based on 0.082 liter atmosphere per mole per degree Kelvin (R) at 25° C and 1 atmospheres pressure.

Average Gas Temperature:

$Q = W_p C_p (T_2 - T_1)$

where Q = net heat available (228,887,680 BTU/hr)

W_p = weight of products of combustion (1,322,070 lbs/hr)

C_p = specific heat of products of combustion (assume 0.26 BTU/lb-$^\circ$ F)

T_2 = average gas temperature

T_1 = initial temperature (assume 60° F)

T_2 = 726° F

Combustion Air Port Area:

Primary Air Port Area

Assuming primary air at 100% excess air

(162.3 cf/lb)[1](53,800 lb/hr) = 8,731,740 cf/hr, or 145,529 cf/min

Assuming the average air velocity through the primary port is 900 fpm, area = 161.7 ft^2

Over Fire Air Port Area

Assuming 90% of the primary air port area

(.9)(161.7 ft^2) = 145.5 ft^2

Under Fire Air Port

Assuming 10% of the primary air port area

(161.7)(.1) = 16.2 ft^2

Secondary Air Port Area

Assuming 50% of theoretical air required

---

1 Conversion value of flue gas from Table 34.

(43.2 cf/lb)[1](53,800 lb/hr) = 2,324,160 cf/hr, or 38,736 cf/min.

Assuming 1000 fpm air velocity through the secondary port area, the area = 38.8 ft^2

Volume of Products of Combustion:

Volume through flame port

Assuming 100% excess air through flame port

combustible = (162.3 cf/lb)(53,800 lb/hr) = 8,731,740 cf/hr

moisture = (76,600 lb/hr)$\left(\frac{379 \text{ cf/lb mole}}{18 \text{ lb/lb mole}}\right)$ = 1,612,855.5 cf/hr

total = 26,881 cf/min, or 448 cf/sec.

Volume through mixing chamber

Assuming 50% theoretical air is added through secondary port to combustion products from primary chamber

(53,800 lb/hr)(43.2 cf/lb) = 2,324,160 cf/hr, or 645.6 cf/sec.

total volume = 448 cf/sec. + 645.6 cf/sec. = 1093.6 cf/sec.

Volume through combustion chamber

Assuming 50% theoretical air is added through cooling air ports in curtain wall

total volume = (1093.6 cf/sec. + 645.6 cf/sec.) = 1739.2 cf/sec.

---

[1] Half value of zero excess air in Table 34.

Incinerator Cross Sectional Area:

Flame Port Area

Designing for an average velocity of 50 fps and 1500° F as gas temperature

$$\text{Area} = \frac{(448 \text{ cf/sec.})(1960^\circ \text{ R})}{(25)(520^\circ \text{ R})} = 208.7 \text{ ft}^2$$

Curtain Wall Port Area

Designing for 20 fps velocity and 1400° F gas temperature

$$\text{Area} = \frac{(1739.2)(1860^\circ \text{ R})}{(20)(520^\circ \text{ R})} = 311.1 \text{ ft}^2$$

Grate Area:

The grate loading = L_G = 10 log R_c

where L_G = grate loading (lb/ft^2-hr) =

R_c = combustion rate (lb/hr) = 65.2 tons/hr

Grate loading (L_G) = 51.2 lb/ft^2/hr

$$\text{Area} = \frac{(53{,}800 \text{ lb/hr})}{(51.2 \text{ lb/hr-ft}^2)} = 1051.0 \text{ ft}^2$$

Horizontal Dimension of Ignition Chamber:

Assuming the length to width ratio = 1.75 (let W = width and L = length) L = 1.75 W,

Grate area = 1.75 W^2 = 1051 ft^2

Width = 24.5 ft^2

Length = 42.9 ft^2

Combustion Chamber Area:

Designing the combustion chamber for 9 fps with a velocity of 1200° F

$$\text{Area} = \frac{(1739.2)(1660^\circ \text{ R})}{(9 \text{ fps})(520^\circ \text{ R})} = 616.9 \text{ ft}^2$$

Stack Height:

Designing stack with an effective draft of 0.25 in. W.C. (water column) in the combustion chamber. Assuming 12.5% friction losses at 20 fps at 1200° F

Theoretical draft required = 0.286 in W.C. = $\frac{0.25}{1 - 0.125}$

$$D_t = 0.52\ PH\ \left(\frac{1}{T} - \frac{1}{T_1}\right)$$

where D_t = theoretical draft, in W.C. (0.286 in W.C.)

T = ambient air temperature (90° F)

T_1 = average stack gas temperature (1100° F)

P = atmospheric pressure (assume 14 lb/in^2)

H = stack height

Stack height = 31.7 ft

Stack Area:

Designing for 20 fps velocity and 1100° F gas temperature

$$\text{Area} = \frac{(1739.2)(1560^\circ\ R)}{(20)\ (520^\circ\ R)} = 260.9\ ft^2$$

III. COMPOSTING PLANT (Figure 35)

The composting plant is designed and based on modern and scienticic composting concepts - the rapid but partial decomposition of moist, solid organic matter by the use of aerobic micro-organisms under mechanically controlled conditions.

A. Size Reduction

1. Principles of Size Reduction:

Size reduction of municipal solid waste means the mechanical separation of bodies of material into small pieces by

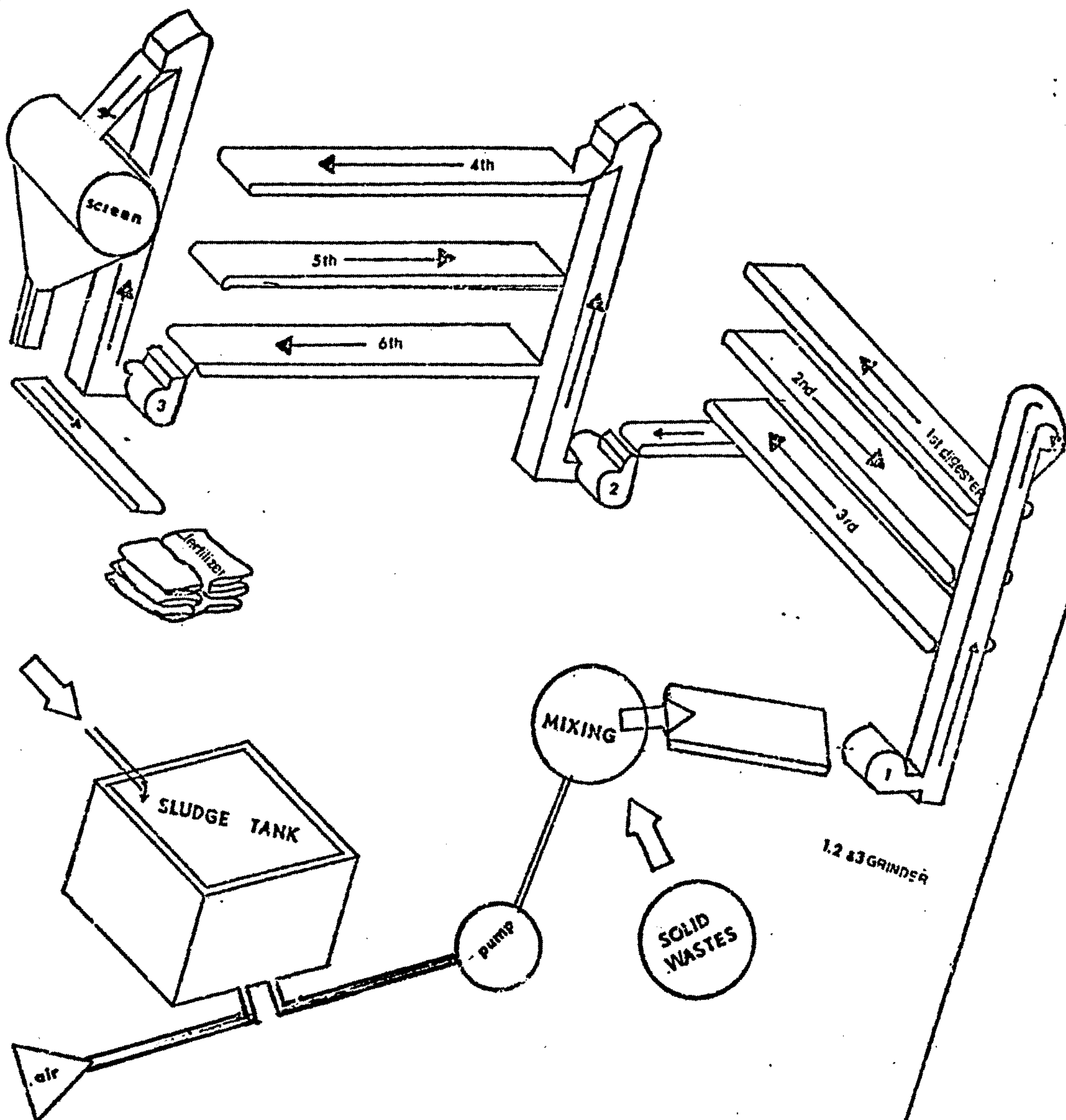

Figure 35
CONCEPTUAL FLOW DIAGRAM OF PROPOSED COMPOST PLANT

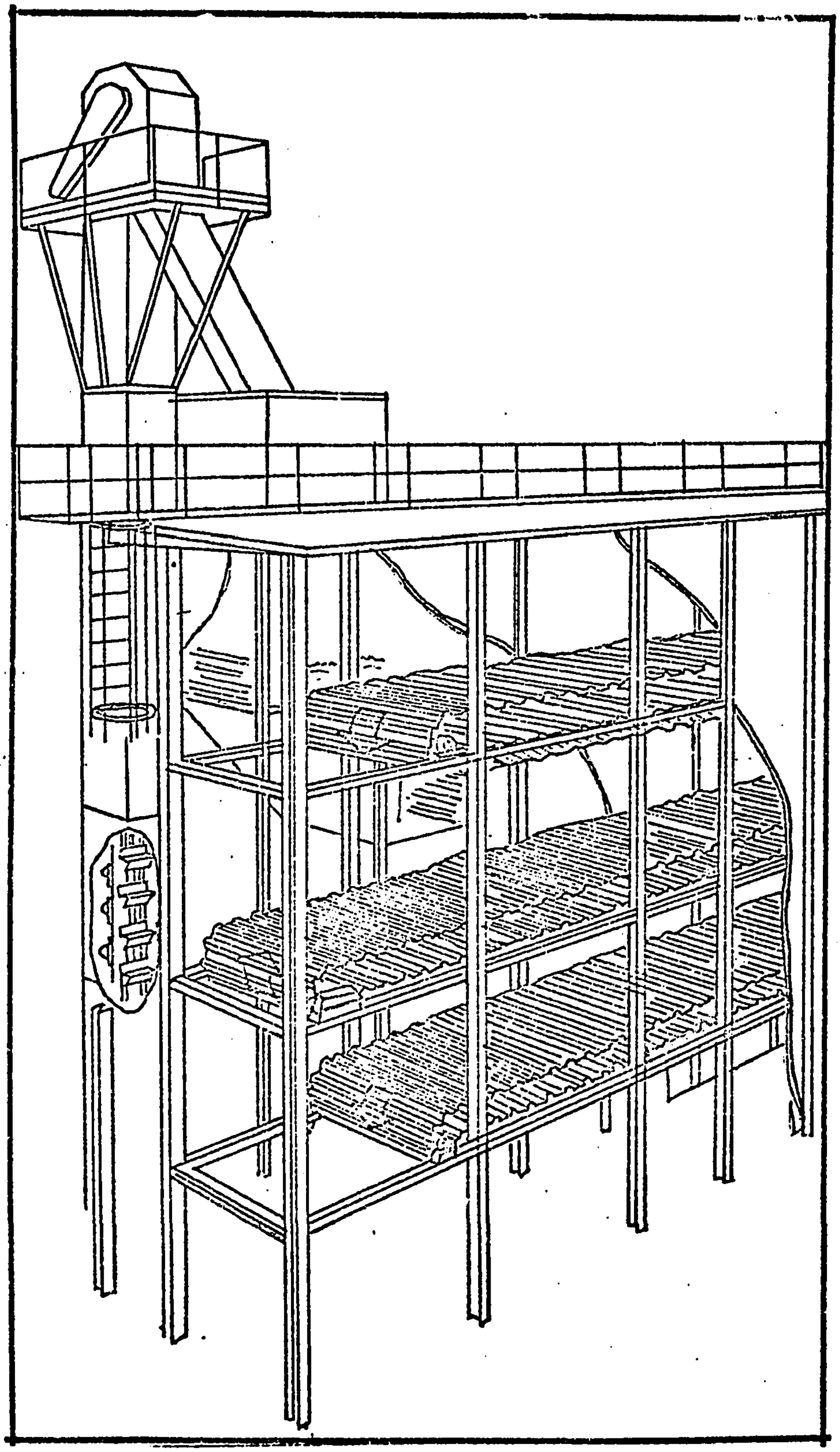

Figure 36

DETAILS OF DIGESTOR IN FIGURE 35

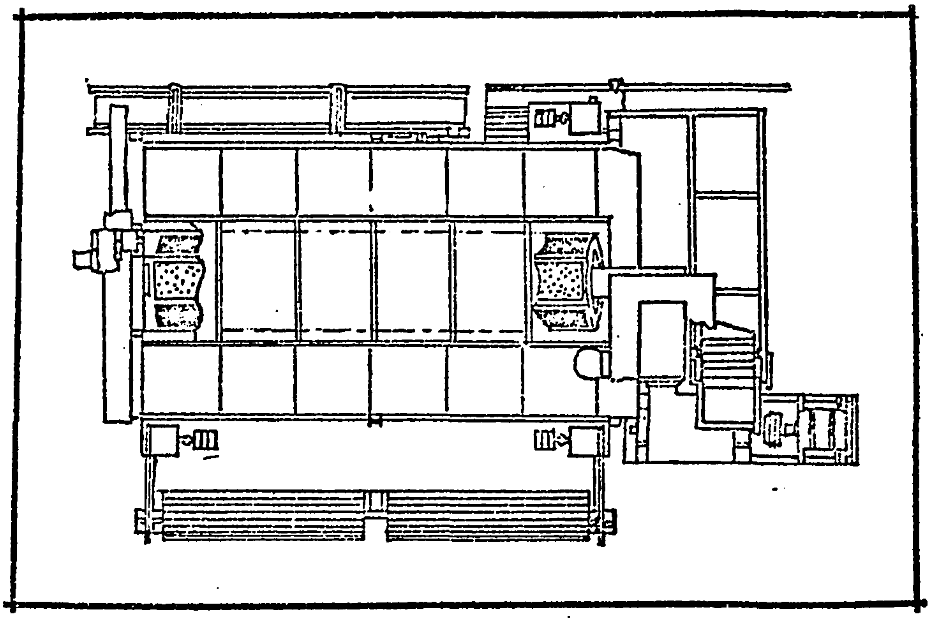

Figure 37

DETAILS OF SCREEN IN FIGURE 35

mechanical forces. The forces are categorized as follows: tension forces, compression forces, and shear forces. In size reduction of solid waste, these forces are inseparable due to the heterogeneity of solid wastes.

2. Theoretical Power Requirement (Drobny, et. al., 1971):

The power requirements for size reduction of solid waste were approximated for 2- and 1-inch pieces of material (Table 35).

a. Example of Computation of Theoretical Power Requirements for Ductile Steel.

The force required for two inch pieces = 50,000 psi x 0.05 in. x 2 in. x 2 = 10,000 lbs (with the assumption of reduction of large sheets of 0.05 in. steel to 2 in. squares). The force for one inch pieces = 50,000 psi x 0.05 in. x 1 in. x 2 = 5,000 lb.

With the assumption of 20% elongation (yield factor) and of yield occurring for two inches on each side of the fracture line,

Travel length = 0.2 x 4 = 0.8 in. (assume 0.1 ft.)

Clamping energy = 2200 lb/ton x 1/12 in. = 183 ft/lb (with assumption of 1 ton grip force to produce a one inch deep corrugation)

Breaking energy = 10,000 lb x 0.1 ft = 1000 ft/lb for two inch pieces

Breaking energy = 5,000 lb x 0.1 ft = 500 ft/lb for one inch pieces

Two inch pieces per ton = $\frac{2200 \text{ lb} \times 36 \text{ pieces/ft}^2}{2 \text{ lb/ft}^2}$ = 39,600 pieces/ton

One inch pieces per ton = $\frac{2200 \text{ lb x } 36 \text{ pieces/ft}^2}{2 \text{ lb/ft}^2}$ =

158,400 pieces/ton

where 0.05 in. steel weighing about 2 lbs/ft^2

b. Power requirement per ton.

Two inch pieces = $\frac{39{,}600 \text{ pieces x } (1000 \text{ ft/lb} + 183 \text{ ft/lb})}{(33{,}013.3 \text{ ft-lb x } 60)}$ =

23-66 HP-hr/ton

One inch pieces = $\frac{158{,}400 \text{ pieces/ton x } (500 \text{ ft-lb} + 183 \text{ ft-lb})}{(33{,}013.3 \text{ ft-lb x } 60)}$

= 54.64 HP-hr/ton

Wood for two inch pieces = $23.66 \times \frac{1}{.082} \times .08 \times .5$ =

11.52 HP-hr/ton

Wood for one inch pieces = $54.64 \times \frac{11.52}{23.66}$ = 26.60 HP-hr/ton

c. Equipment for Size Reduction.

Daily solid waste quantity = 500.0 tons

Anticipated operating days = 350 days per year

Total operating day tonnage = 521.4 tons/day

d. Consideration of Use vs Theoretical Design.

Design capacity = 521.4 tons/day

Rated capacity = 521.4 tons/day

Dependable capacity (assuming 80% of the rated capacity) =

27.2 tons/hr

Actual capacity = 27.2 tons/hr

It is assumed that 27.2 tons of solid waste is evenly distributed and fed into five size reduction systems (27.2 tons/hr) = 5.5 tons/hr. Since the size of rubber material in solid waste is too small, it is not necessary to consider

Table 35

THEORETICAL POWER REQUIREMENTS FOR SIZE REDUCTION OF COMMON SOLID WASTE

Component of Solid Waste	Density* (lb/in^3)	Ratio to Steel	Strength* (psi)	Ratio to Steel	Yield* Factor (%)	Major Force	2" Pieces Horse Power	1" Pieces Horse Power
Metal	0.280	1.000	50,000	1.00	20(1.00)	Tension & Shear	23.66	54.64
Wood	0.023	0.082	4,000	.08	10(.50)	Shear & Tension	11.52	26.60
Brick (demolition)	0.065	0.232	45,000	.90	1(.05)	Compression	4.59	10.60
Glass	0.094	0.336	11,500	.23	1(.05)	Compression	.81	1.87
Rubber	0.040	0.143	3,000	.08	750 (37.50)	Tension	496.86	1,145.45
Rag (fiber plant)	0.055	0.196	42,000	.84	7(.35)	Tension	35.41	81.78
Plastic	0.045	.161	8,900	.18	1(.05)	Tension	1.11	2.56
Paper (packing)	.034	.121	6,345	.13	2.5(.13)	Shear	3.29	7.60

* (Drobny, et. al., 1971; Miner and Seatone, 1955; Weast, 1968; Perry and Chilton, 1973)

the power requirement of rubber. Therefore, 35.41 HP-hr/ton for two inch pieces could be used.

B. Principles of Composting

Composting enhances the oxidation of organic matter primarily to

$C_nH_{2n}O_n + O_2 \longrightarrow$

1. Minerals +
2. Humus +
3. CO_2 +
4. H_2O

The empirical molecular formula of initial material is

$C_{28}H_{46}O_{26}N$ (molecular weight = 812.3) (Table 36)

The empirical molecular formula of final material is

$C_{18}H_{26}O_8N$ (molecular weight = 384.2) (Table 36)

1. Theoretical Oxygen Requirement:

$C_aH_bO_cN_d = 0.5\ (ny + 2s + r - c)O_2$

$nC_wH_x\ O_y\ N_z + sCO_2 + r\ H_2O + (d - nz)NH_3$

where $r = 0.5\ (b - nx - 3(d - nz))$

$s = a - nw$

Moles of organics entering the process = 573,170.0 lb*/812.3 mole/lb = 705.6

Moles of organics leaving the process per mole entering the process (assuming 80% reduction of the initial material (Rich, 1963)) = n = 260,000.0 lb (705.5 mole) x 384.2 mole/lb = .96

*Based on 286.6 tons of dry weight per 24 hours

Table 36

THEORETICAL FORMULA OF COMPOSTABLE WASTE

Chemical Species	Weight (%)	Atomic Weight	Atomic Unit	Ratio of Atoms	Atoms in Empirical Moles
INITIAL					
C	44.1	12.01	3.68	56.62	28
H	6.0	1.00	6.00	92.31	46
O	41.8	16.00	2.61	40.15	20
N	1.8	14.00	.13	2.00	1
FINAL*					
C	31.97		2.66	35.46	18
H	3.90		3.90	52.00	26
O	18.55		1.16	15.46	8
N	2.13		0.15	2.00	1

* (Wilson, 1970; Rich, 1963; and An Interim Report of the Gainsville Compost Plant, 1969)

$r = 10.5$

$s = 10.7$

Quantity of oxygen required by the process = 0.5 (ny + 2s + r - c)O_2 = 153,312.7 lb/day

Checking by use of materials balance:

IN

Organic material =	573,170.0 lb
oxygen =	153,312.7 lb
Total =	726,482.7 lb

OUT

Organic material =	260,000.0 lb
carbon dioxide =	332,196.5
water =	133,358.4
ammonia =	479.8
Total =	726,034.7 lb
DIFFERENCE =	448.0 lb

Assume the generation of final material ($C_{18}H_{26}O_8N$) takes 7 days by mechanical operation, daily oxygen requirement = 21,901.8 lb/day.

2. Consideration of Use vs. Theoretical Design:

Daily quantity = 500 tons. Anticipated operating dyas = 350 days per year. Total operating day tonnage = 521.4 tons. Rated capacity = 521.4 tons. Dependable capacity (assuming 80% of rated capacity) = 651.7 tons. Moisture content = 55.91% (from Table 33 by weighted average).

3. Design of Digester:

Dimension of Size:

Total quantity = 651.0 ton/day (dependable capacity)

Width = 8 ft (assumed value)[1]

Height = 8 ft (assumed value)[1]

Length = 646.5 ft (assume 850 lb/yd^3 of compostable material)

If we consider 25% initial shrinkage after moisture adding and grinding, length will be 484.9 feet with the same previous conditions.

If the composting material is less than 65% by weight moisture, it has been found advantageous to introduce wet sewage sludge. Since wet sewage sludge is available from the ChungGae Channel Treatment Plant, a sewage holding system is desired.

4. Sewage Holding System:

The model of this system was selected from the Gainsville Plant.

Moisture desired: 64% of the total = 651.3 ton/day

Present moisture content: 55.91%

Moisture required: 8.1% = 52.8 tons/day

Assuming 56.23 tons of moisture is required because of the significant amount of briquette ash entering this process,

Dimension of holding tank:

---

[1] Personal communications with Mr. Pierson, 1975.

Assuming 2430 lb/yd^3 of sewage sludge, 10.8 ft x 10.8 ft x 10.8 ft = 1259.71 ft^3 with outer walls of one foot thick concrete.

5. Pumping System:

   The pumping system is necessary to transfer wet sludge from the plant to the holding tank where it is moved to the mixing screws without dewatering. There, solid materials are mixed with the sludge.

   Experience at the Gainsville Compost Plant shows a 3-HP with 50 gallon per minute at 420 rpm will satisfy this purpose.

6. Sludge Aerating System:

   The sewage sludge should be kept aerobic by continuous aeration with air supplied by a pressure blower.

IV. RECEIVING AND SEPARATING SYSTEM

A. Dimensions of Tipping Area

Width: The tipping area should be greater than the turning radai of any truck (usually 50 to 70 feet).

Length: The total length of the tipping area should extend the length of the storage pit (420 feet).

For economy of plant operation, it is recommended to build a semi-enclosed structure. The ceiling of an enclosed tipping area must be high enough to provide the necessary clearance for the dump trucks (generally a minimum of 24 feet). The entrance and exit should provide a minimum of 18 feet vertical clearance.

Special considerations of the tipping area: a) The tipping area should provide an area of reinforced concrete at an angle of 8^o to 10^o from the backing bumper for cleaning and safety purposes. b) The height of the backing bumper is recommended to be about one foot high to prevent damage to the truck while backing. c) Dust, odor, rodents, fire and noise hazards should be considered for employee safety.

B. Storage Pit

The storage pit is usually designed to contain 1.5 times the 24 hour capacity. Assume the solid waste generation is 500 tons per day, (1.5)(500 tons/day) = 750 tons/day (density 850 lb/yd^3) = 47,647 ft^3.

A rectangular open-cell is recommended for easy construction and for usage of a hoist. Cell length is a function of the number of dumping spaces (assume nine feet for each dumping space + .5 feet of walking space between dumping spaces): 10 feet.

Width = assume 15 feet.

Depth = assume 6.5 feet.

Cell capacity = 975 ft^3, or 15.35 tons of refuse.

Net cell weight = 4.86 tons (assume 20.40 lb/sq.ft. in 1/2 in.)

Total cell weight = 20.21 tons.

Total length of pit required = 490 feet.

Number of cells required = approximately 49 cells.

Charging system: for economical design, it is recommended that an automatic or manual hoist be used to continue the flow of refuse into the sorting system.

Lifting height = approximately six feet with an average coefficient of friction (u = 0.5).

Charging adaptor: to control the flow of refuse from the pit cell into the sorting belt for hand picking.

C. Dimensions of Adaptor

Width = assume 12 feet at the front and 3.5 feet at one end, depending on the width of the sorting belt.

Length = assume 9.0 feet (7 feet for the front and 3 feet for the end), depending on the distance from the cell to the sorting belt.

Depth = assume 10 feet, depending on the flow rate of the sorting belt.

D. Special Considerations of the Adaptor

1. Easy handling and moving capabilities from one receiving cell to another with some type of railroad or hard-rubber roller.
2. The adaptor should be tightly fixed in the stationary position.
3. The angle of the adaptor should not exceed 45° during operation because of dust generation and rapid flow of refuse from the cell.
4. Preparation of a ventilation system above the adaptor.
5. The adaptor should be large enough to that at least two workers can freely work each side.

E. Conveyor Belt for Separation

The salvage of recyclable material is extremely important in Korea in order to conserve the natural resources and increase the efficiency of incinerating or composting refuse.

F. Size of Conveyor Belt

Width = approximately four feet, within hand reach, depending on the elevation of the belt.

Length = assume 20 feet, depending on the plant space availability.

Side wall height = 1/2.5 feet above the belt to prevent runover of refuse from the sorting belt.

G. Consideration of Undercover of the Conveyor Belt

If a screening type of belt is used, particles of refuse less than screen opening size will fall onto the floor, causing dust generation, especially powdered briquette ash which can endanger the workers. Therefore, it is necessary to build a wall to prevent the dust generation under the belt. It is recommended that a dust suction collection system be used.

One cycle capacity = 32 ft^3, or 0.5 tons

Number of sorting conveyor belts required = 25

Number of cycles required for sorting the daily generation:

(500 ton)/(25)(.5/cycle) = 40 cycles/8 hours

Actual working hour = 6.5 hour

Rate of cycles = 49/6.5 hour, or 7.6 cycles/hr, or 3.8 tons

Required labor = 5.2 persons per belt when assuming 0.5 tons handled per person per hour

Total labor required = 130 persons

25 persons (general helper-one person per belt)

25 persons (2 persons per adaptor, with one adaptor handling four of the pit cells)

TOTAL = 180 persons (not including personnel required in receiving or supervision in sorting system)

Total required area:

Length: (10 feet for distance between the sorting belt and pit cell) + (65 feet for the length of sorting belt) + (65 feet for employee facility, scaling, and bailing system) = 140 feet total length.

Width: (15 feet for each side of sorting belt, for walking and transporting) + (4 feet for width of the belt) + (4 feet between belts) = 214 total feet for the width of the belt. Total width is 490 feet.

Availability of storage area for salvageable materials and coal ash = 38,640 ft^2.

Total area required = 68,600 ft^2

H. Control Tower

To regulate the speed of the sorting belt and to protect the worker's safety, the control tower platform is located at a high elevation.

APPENDIX E

CHARD GROWTH 25 DAYS AFTER SEEDING

Treatment (Ton/Acre) / Observation	6 (A)	12 (B)	24 (C)	48 (D)	85 (E)	85 (F)	Control (G)	Control (H)
	1.87*	0.95	3.00	1.00	0.80	1.65	1.40*	0.55
	2.95	3.02*	2.89*	1.75*	3.87*	2.00*	2.00	1.00*
	2.26*	3.50	2.35	1.45	1.00	1.20	0.20*	2.80
	2.12	0.81*	3.00	2.13*	0.70	1.60*	0.20	1.50*
	1.75	1.53*	2.64*	1.85*	4.60	2.25	1.45*	2.50
	3.23*	2.00	4.05*	1.25*	1.10	0.20	0.70	2.25*
	1.50*	1.32*	2.50*	2.50*	3.20*	1.26	0.80*	5.25
	1.40*	0.15*	2.42*	1.20	1.10	4.04	2.00*	1.70
	2.35*	2.26*	2.55	2.60*	1.50*	2.57	0.70	0.93
	1.60	4.00	1.00	3.15	2.35	2.27	1.30	1.60*
	1.50*	0.70*	3.70*	2.55*	2.70*	1.98	1.25*	1.10
	3.25	2.45*	4.25	2.05	3.50	2.00*	1.87	0.70*
	1.60*	1.80*	1.30*	3.00	3.25	0.75	1.60	1.90*
	0.40*	1.00	2.45	1.50*	4.50	2.15	2.00*	0.50
	1.60*	0.85	2.86*	3.35	2.80	2.90*	1.20	1.35*
	3.00*	1.70*	2.25	2.70*	0.90	3.25	0.17	1.65*
	0.90*	3.35	3.50*	4.00	2.50	2.10*		1.55*
	1.00	4.30*	1.84*	2.35	0.30	1.07		
	0.45	4.25	1.80	2.25	2.40	2.50		
	2.34*	2.15	1.15*	0.25*	3.60*	2.89		
	1.10*	2.50*	2.00	0.85	3.00	0.80*		

APPENDIX E

(Continued)

Treatment (Ton/Acre) / Observation	6 (A)	12 (B)	24 (C)	48 (D)	85 (E)	85 (F)	Control (G)	Control (H)
	2.80	3.25	1.20*	1.00*	2.80	1.83		
	1.70*	2.80*	2.85	2.50	1.60	1.85		
	0.90	2.50	0.85*	2.25*	1.70	1.53		
	1.35	4.50*	4.50*	5.58*	1.83*	1.75*		
	2.40*	4.25*	2.15	5.45*	2.26	1.85		
		1.50	0.95	3.54	2.27*	1.00		
		3.25*	1.50*	2.00*	3.80	0.80		
			4.25	3.55*	4.83	4.40		
			3.85*		3.00	4.60		
					0.95	0.95		
						2.96*		
						3.00		
						2.40*		

* denotes randomly selected observation

APPENDIX F

SIX RANDOM OBSERVATIONS OF SWISS CHARD DRAWN FROM APPENDIX (From Appendix E)

Observation Number \ Treatment	6-Ton Acre	12-Ton Acre	24-Ton Acre	48-Ton Acre	85-Ton Acre	Control (No Compost)
1	1.87	3.02	2.89	1.75	3.87	1.40
2	2.26	0.81	2.64	2.13	3.20	0.20
3	3.23	1.53	4.05	1.85	1.50	1.45
4	1.50	1.32	2.50	1.25	2.70	0.80
5	1.40	0.15	2.42	2.50	3.60	2.00
6	2.35	2.26	3.70	2.60	1.83	1.25
7	1.50	0.70	1.30	2.55	2.27	2.00
8	1.60	2.45	2.86	1.50	2.40	1.00
9	0.40	1.80	3.50	2.70	2.00	1.50
10	1.60	1.70	1.84	0.25	1.60	2.25
11	3.00	4.30	1.15	1.00	2.00	1.60
12	0.90	2.50	1.20	2.25	2.90	0.70
13	2.34	2.80	0.85	5.58	2.10	1.90
14	1.10	4.50	4.50	5.45	0.80	1.35
15	1.70	4.25	1.50	2.00	1.75	1.65
16	2.40	3.25	3.85	3.55	2.96	1.55
MEAN	1.82	2.33	2.55	2.43	2.34	1.41

APPENDIX G

GROWTH OF SWISS CHARD UNDER FOUR DIFFERENT TREATMENT CONDITIONS

Treatment / Observation Number	Compost Only (A) 1 2	3	Compost & Fertilizer (B) 1 2	3	Soil Only (C) 1 2	3	Fertilizer Only (D) 1 2	3
1	18.85-3.87	14.98	32.00-2.89	29.11	13.15-2.00	11.15	27.00-0.55	26.45
2	11.95-0.70	11.25	35.15-3.25	31.90	10.00-1.40	8.60	26.15-1.00	25.15
3	12.50-1.00	11.50	26.20-1.53	24.67	13.55-1.45	12.10	30.55-1.50	29.05
4	15.85-1.10	14.75	29.45-1.26	28.19	12.00-0.80	11.20	36.14-2.25	33.89
5	11.35-0.90	12.45	32.50-2.50	30.0	13.00-2.00	11.0	35.00-2.50	32.50
6	14.45-2.35	12.10	24.00-2.00	22.0	11.15-0.70	10.45	21.00-0.93	20.07
7	12.20-1.10	11.10	30.15-3.00	27.15	6.00-0.20	5.8	22.15-1.70	20.45
8	18.75-1.70	17.05	32.50-2.27	30.23	5.00-0.20	4.8	32.95-1.90	31.05
9	16.00-2.26	13.74	17.85-0.80	17.05	11.55-0.70	10.85	23.55-1.60	21.95
10	16.38-3.00	13.38	29.15-1.98	27.17	11.25-1.30	9.95	22.40-2.80	19.60

APPENDIX G

(Continued)

Observation Number \ Treatment	Compost Only (A) 1 2	3	Compost & Fertilizer (B) 1 2	3	Soil Only (C) 1 2	3	Fertilizer Only (D) 1 2	3
11	17.50-2.50	15.0	25.00-1.07	23.93	6.50-1.25	5.25	26.10-0.70	25.40
12	14.90-1.60	13.3	28.14-1.83	26.31	11.85-1.87	9.98	25.50-1.10	24.40
13	14.55-2.40	12.15	16.50-0.70	15.80	9.00-1.60	7.40	25.00-0.50	24.50
14	13.95-1.50	12.45	21.00-0.95	20.05	13.55-2.00	11.55	22.95-1.35	21.60
15	11.75- .95	10.80	35.00-4.40	30.6	12.15-1.20	10.95	24:00-1.65	22.35
16	16.80-3.00	13.80	29.15-1.00	28.15	9.00-0.17	8.83	21.00-1.55	19.45
MEAN		13.11		25.77		9.37		24.87

1 denotes growth height (cm) for 61 days

2 denotes growth height (cm) for 25 days

3 denotes growth after applying fertilizer

APPENDIX H

KOREAN FOREST SOIL SURVEY

Yr. of Survey / Soil Type	1968-1969 acres	1970	1971	1972	1973	TOTAL
Favorable	10,727.95	144,285.05	111,326.60	27,651.16	18,557.11	312,547.87
(Humid Brown Soil)	3.89%	51.71%	33.02%	8.27%	7.47%	21.19%
Acceptable	33,798.49	2,531.75	316.16	105,042.43	82,747.47	224,436.30
Wet Brown Soil (Dry Subhumid)	12.26%	0.91%	0.09%	31.42%	33.29%	15.22%
Unfavorable	231,123.08	132,226.51	225,524.58	201,670.31	147,246.58	937,791.06
Arid: Brown Soil Semi-arid: Brown Soil Arid: Red Soil Semi-arid: Red Soil Gully / Rill / Sheet erosion soil	83.85%	47.38%	66.89%	60.31%	59.24%	63.59%
	275,649.52	279,043.31	3,371,167.34	334,363.90	248,551.16	1,474,775.20

APPENDIX I

MINIMUM CONTENT OF ESSENTIAL NUTRIENT NECESSARY FOR A SATISFACTORY GROWTH OF REPRESENTATIVE TREE SPECIES AT PLANTING SITE REQUIREMENTS OF REFORESTATION[1]

Item / Tree Classification	Available P_2O_5 (lbs/acre)	K_2O	Exchangeable Ca (lbs/acre)	Mg	Min. Depth to Ground Water (ft.)
Microtrophs	Tr.	30	200	50	2.0 - 3.0
Mesotrophs	20	50	500	120	2.0 - 2.5
Megatrophs	50	125	1200	300	1.0 - 3.5

[1] Wilde, 1958.

APPENDIX I

(Continued)

	PH Range of Optimum Re-action	Minimum Content of Silt and Clay Particles (%)	Minimum Content of Organic Matter in 6" Layer (%)
Microtrophs[1]	4.5 - 7.0	5 - 10	0.7
Mesotrophs[2]	4.7 - 7.5	15 - 25	1.8 - 2.5
Megatrophs[3]	4.7 - 8.0	25 - 40	1.8 - 4.0

Example 1. Jack pine, long leaf pine, scotch pine, etc.

Example 2. Longtooth aspen, yellow birch, douglas fir, north red oad, eastern white pine, white spruce, etc.

Example 3. White ash, basswood, white cedar, black locust, hard maple, white oak, tulip poplar, black walnut, etc.

APPENDIX J

CHARACTERISTICS OF CULTIVATED SOIL, KOREA (UPLAND)

Province (DO)	Range of pH				Range of Organic Matter (%)				Available P_2O_5 (PPM)			
Gyong-Gi	4.5 - 6.8				0.9 - 3.5				8 - 2-8			
Chung-Buk	4.8 - 6.8				0.8 - 3.7				8 - 206			
Chung-Nam	4.6 - 7.1				0.7 - 3.6				5 - 178			
Kyung-Buk	4.9 - 6.7				0.8 - 3.2				7 - 185			
Kang-Won	4.9 - 6.9				0.9 - 2.4				13 - 198			
Je-Ju	4.1 - 7.2				0.8 - 6.1				9 - 184			
Kyung-Nam	4.5 - 6.7				0.9 - 3.8				4 - 198			
No. of Sample	4	1325	2065	267	371	1928	871	481	216	751	915	1750
Average Range	<4.5	4.6-5.5	5.6-6.5	> 6.6	<1.0	1.1-2.0	2.1-3.0	>3.1	<40	41-120	121-200	> 200
Percent*	0.1	37	55.9	7.0	10	53	24	13	6	20	25	49

* Percent as a whole country.

APPENDIX J

(Continued)

Exchangeable K(meq./100gm)	C.E.C. (meq/100 gm)	Exchangeable CA (meq/100 gm)	Exchangeable Mg (mg/100 mg)
0.12 - 0.72	4.7 - 15.3	= 6.8	1.0 - 6.8
0.13 - 0.86	4.0 - 17.3	3.42 - 5.32	0.9 - 7.8
0.11 - 0.70	0.5 - 16.7	0.22 - 8.40	0.6 - 7.9
0.12 - 1.00	3.0 - 13.2	2.80 - 4.14	1.2 - 8.6
0.12 - 0.78	5.0 - 16.7	1.45 - 6.29	1.8 - 7.9
0.11 - 1.03	7.5 - 15.2	= 6.85	0.7 - 6.8
0.11 - 0.90	4.6 - 19.9	0.10 - 7.94	1.6 - 10.1

338	1570	1378	352	45	218	675	258	15	16	106	185	20	136	427	411
<109.2	109.3-218.4	218.5-436.8	>436.8	<5.0	5.1-7.5	7.6-12.5	>12.6	<800	801-1600	1601-3200	>3200	<480	481-960	961-1920	>1920
9	43	38	10	3.8	18.2	56.5	21.5	4.7	5.0	32.9	57.4	2	14	43	41

= Data shows single range.

APPENDIX J

(Continued)

BOTTOM LAND

Province (DO)	Range of PH				Range of Organic Matter (%)				Available P_2O_5 (PPM)			
Gyong-Gi	4.0 - 7.1				0.9 - 3.6				7 - 146			
Chung-Buk	4.5 - 6.3				0.8 - 4.0				7 - 173			
Chung-Nam	4.9 - 7.0				0.6 - 4.3				4 - 183			
Kyung-Buk	4.4 - 6.7				0.7 - 3.7				7 - 169			
Kyung-Nam	4.4 - 6.8				0.8 - 4.3				3 - 180			
Kang-Won	4.8 - 6.7				0.7 - 4.0				7 - 175			
Je-Ju	5.0 - 6.6				1.8 - 5.0				17 - 146			
No. of Sample	22	3192	1801	74	109	1329	1752	4515	1088	2271	852	849
Average Range	4.5	4.6-5.5	5.6-6.5	6.5	1.0	1.1-2.0	2.1-3.0	3.0	40	41-120	121-200	200
Percentage	0.4	62.6	36	1.0	3	29	39	29	22	56	18	4

APPENDIX J

(Continued)

BOTTOM LAND

Exchangeable K(meq./100gm)				C.E.C				Ca				Mg			
0.11 - 0.91				6.9 - 16.5				1.6 - 6.5				0.4 - 5.1			
0.11 - 0.88				4.3 - 22.6				1.9 - 13.5				0.3 - 5.1			
0.1 - 0.87				4.4 - 16.6				1.5 - 7.6				0.4 - 5.6			
0.10 - 0.85				6.9 - 20.2				1.0 - 7.4				0.4 - 5.2			
0.11 - 0.84				4.2 - 16.2				1.8 - 7.5				0.4 - 4.0			
0.11 - 1.76				4.9 - 17.0				1.6 - 6.9				0.3 - 4.8			
0.12 - 0.67				11.9 - 14.5				4.6 - 9.2				1.3 - 2.8			
1142	2869	876	225	16	216	1869	656	66	713	617	258	145	397	633	479
109.2 (lb/acre)	109.3-436.8	218.5-436.8	436.8	5.0	5.1-7.5	7.6-12.5	12.6	1600	1601-3200	3201-4800	4800	480	481-960	961-1920	1921
22	18	18	4	1	8	68	23	4	43	37	16				

APPENDIX K

NUTRIENT REQUIREMENTS FOR UPLAND CROPS[1]

Corn (Grain)		Cotton		Small Grain	
Yield Goal Bu/A	N lbs/A	Yield Goal lbs/A	N lbs/A	Yield Goal Bu/A	N lbs/A
50	60	200	30	10	20
60	80	500	70	20	40
80	105	700	90	30	60
100	140	900	110	45	90
140	200	1100	130	56	115
180	260	1300	150	60	145
200	300	1500	175		

[1] Baker and Tucker, 1974.

APPENDIX K

(Continued)

PHOSPHORUS REQUIREMENTS
(UPLAND)

Soil Test (lbs/acre)	Soybeans Percent Sufficiency	Soybeans P_2O_5 lbs/A	Cotton Percent Sufficiency	Cotton P_2O_5 lbs/A	Small Grain Percent Sufficiency	Small Grain P_2O_5 lbs/A
0 - 10	40	50 - 70	55	60 - 75	25	60 - 80
11 - 20	60	30 - 50	70	45 - 60	45	40 - 60
21 - 40	80	20 - 30	85	30 - 40	80	20 - 40
41 - 65	95	starter	95	20 - 30	90	starter
65+	100	none	100	none	100	none

APPENDIX K

(Continued)

POTASSIUM REQUIREMENT
(UPLAND)

Soil Test lbs/A	Soybeans		Cotton		Small Grain	
	Percent Sufficiency	K_2O lbs/A	Percent Sufficiency	K_2O lbs/A	Percent Sufficiency	K_2O lbs/A
0 - 75	40	70-80	40	80-110	50	50-60
76 - 125	60	60-70	60	60-80	70	40-50
126 - 200	75	40-60	75	40-60	80	20-40
201 - 250	90	20-40	90	20-40	95	15-20
250+	100	none	100	0-20	100	none

SECONDARY MICRONUTRIENTS

Zinc (PPM)	Iron (PPM)	Manganese (PPM)	Boron (PPM)
0 - 0.5(L)	0 - 2.0(L)	0 - 1.0(L)	0 - .25(L)
.51 - 1.0(M)	2.1 - 4.5(M)	1.0+ (A)	.26 - .50(M)
1.0+ (A)	4.5+ (A)	20+ (T)	.50+ (A)

Magnesium soil should contain at least 100 pounds per acre soil test magnesium.

L = low
M = marginal
A = adequate

ADDENDUM

SOLID WASTE MANAGEMENT - POLICY DECISION

The purpose of this section is to seek an effective management system which will appropriately achieve solutions to the problems of solid wastes. Management practices should be directed toward allocating more of our resources to maintaining and improving the quality of the environment.

A. Solid Waste Management Techniques

A number of techniques are available in the field of solid waste management. All the methods require a basic statistical methodology which is appropriate for analysis and forecasting of solid waste generation rates, population, economic conditions, agricultural conditions, and future land uses. This information also is essential in developing planning, programming, and budgeting systems (PPBS) (Nigro, 1973; Davis, Jr., 1969; Lyden, et. al., 1969), a major subject in this section. The PPB system for weapon system analysis had its roots in industry and was initiated by the Rand Corporation, who put into large scale use in the Department of Defense in 1963. It is now being implemented throughout the executive branch of the United States government. This system is one tool of management that provides a method of rational decision making on the waste (disposal) problem.

The basic elements of PPBS are based on the following conditions:

1. Recognition and accurate diagnosis of the Korean solid waste problem.
2. Determination of all possible alternatives, such as incinerators, composting, and sanitary landfill.
3. Investigation and analysis of facts relating to each alternative.
4. Comparison of the consequences of each alternative.
5. Selection of the best possible solution for the solid waste problem.

However, the decision-making effort has a definite range due to the limited amount of time, small fractions of total information necessary for any decisions, and involvement of unskilled personnel. Furthermore, common errors in decision-making involve (1) cognitive nearsightedness: the decision maker has to emphasize the decisions that satisfy the immediate needs rather than long-range goals. (2) Oversimplification of causes: another tendency of decision makers involves dealing with the symptoms of the problem rather than the causes. That is, as long as the symptom does not bring about large scale public pressure, then the decision maker does not devote his full attention to the causes. (3) Unwillingness to experiment: some decision makers are unimaginative, neither innovative nor likely to encourage a creative experiment for solving a problem. (4) Reluctance to make a decision: the choice of the best possible alternative with removal of those errors requires professional skill, depending on the magnitude and importance of the problem. In Seoul, Korea, installing the PPBS for solving solid waste problems should involve relating to a specific characteristic of Korean problems on a national basis, rather than as a municipal solid waste problem for a limited community. To organize the problems involving solid waste disposal, as an example, it is necessary to formulate a committee for close work with decision makers. The committee should achieve planned objectives, have authority and responsibility appropriate to the task, and have adequate numbers of qualified personnel.

1. National Advisory Committee (NRC):

The committee has good potential for guiding and supporting an environmental management, analyzing, planning, and implementation program at the national level and could also provide technical expertise and advice to the decision makers. An NRC with broad responsibilities might have the following functions:

a. Provide technical insight into environmental problems.
b. Assure adequate coordination with decision makers.
c. Offer national policy decision information on regulation, planning, and technical assistance, such as air, water, solid waste, radioactive waste, and noise planning, etc.
d. Direct the subcommittees with close cooperative coordination.

2. Subcommittee for Solid Waste Management (Sub-NRC):

The subcommittee on solid waste management should be given four crucial authoritative duties: (a) Design a program to achieve planned objectives. (b) Acquire adequate operating funds for research and grant purposes to promote the demonstration, construction, and application of solid waste management and resource recovery systems which preserve and enhance the quality of land, air, and water resources. (c) Cooperate with NRC and decision makers to coordinate research efforts for advancement of solid waste management, to obtain maximum efficiency in order to solve the given problem. (d) Provide technical services or assistance in solid waste management. The subcommittee should also study the scope and level of public criticism or complaints on the environmental problem and search for effective means to communicate and solve the complaints based on an acceptable level of service. Part of this responsibility can be accomplished by the fact sheets and guidelines related to solid waste problems.

3. Committee's Working Phase:

The aim of the committee is to find new ways to do the given program quickly, less expensively, and more thoroughly, to insure sound judgment through more accurate information. Figure 38 depicts the major phases in the committee's life cycle and sets forth types of decision-making relevant to each committee. The first phase, establishing and legitimatizing the committee's mandate, or mission, is accomplished in the policy process by decisions about the creation and

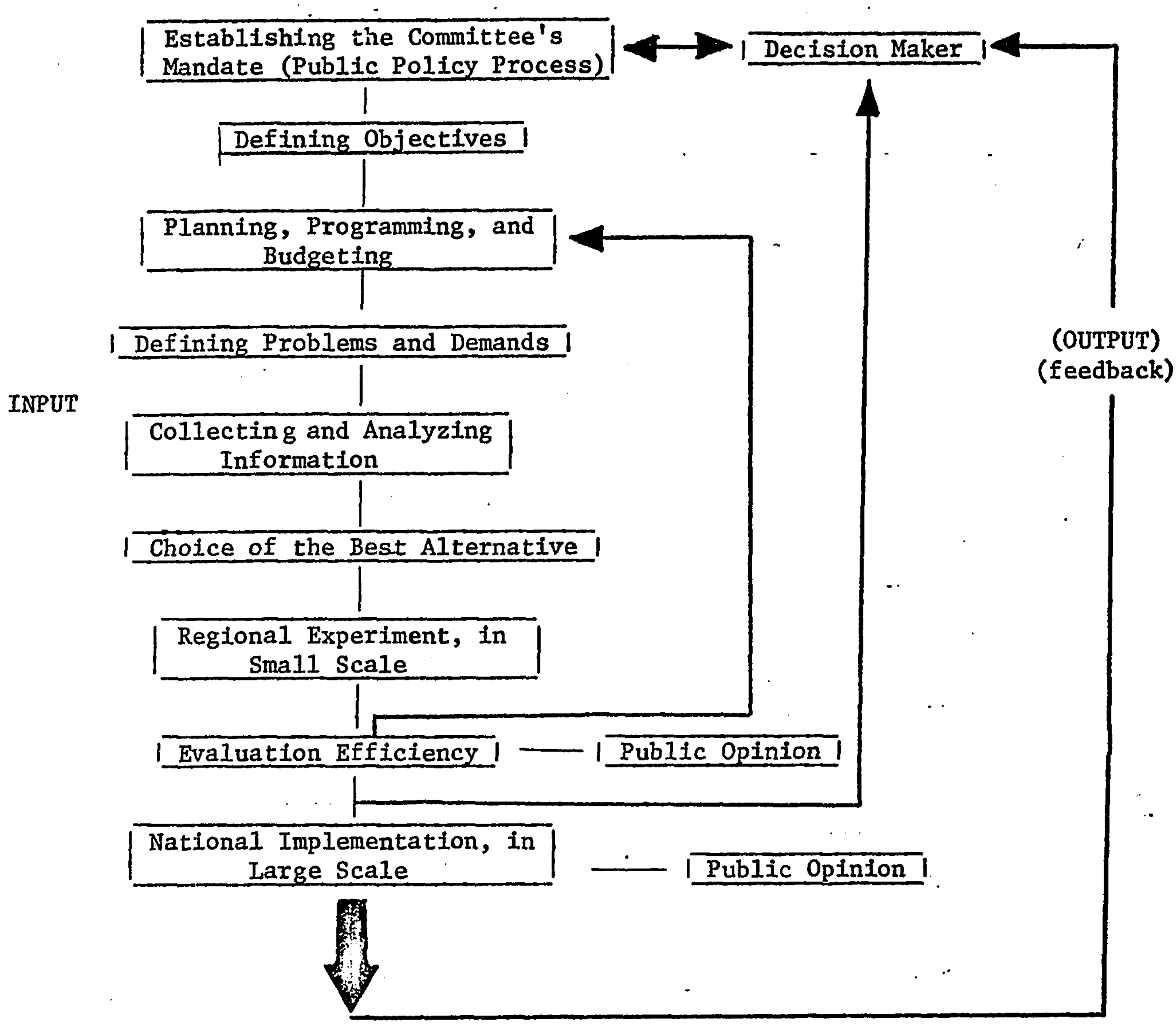

Figure 38

PHASES OF COMMITTEE'S WORKING CYCLE

maintenance of the organization. In the second phase, defining objectives, the organizations make decisions about how to translate the mandate into operational terms. In the third phase, the PPB system is associated with decisions on how to combine limited resources to accomplish those operational objectives suitable to national and regional demands.

The next phases are to concentrate on solving the specific problems which are confronted in the present or future through the collection and analyzing of data, and through the choosing of the best alternative.

The result of the best choice applied to the regional small scale is then put into use on a national scale, with subsequent evaluation of public opinion. The unique characteristics of this model are to design the organizations, national committee and subcommittee to operate in close relationship with the public and the decision-makers as a trinity.

Prerequisites for the committee are:

a. Identify national goals with greater precision.

b. Determine which of those goals are the most urgent.

c. Identify alternative means of reaching those goals.

d. Select the best representative of public opinion.

e. Determine the necessary cost of the alternatives in preliminary testing, and later in final national application.

Final decisions ideally should rest with the responsible solid waste management agency; for example, the national government, city government, local administrators, and/or representatives of the public, and NRC.

If the best choice of the alternatives in solid waste management is found to be composting, the further detailed decisions, such as distribution, funding, and education, could be decided with close cooperation between the Department of Agriculture and Transportation, city and local administrators, or farmers' groups, with NRC (and/or sub-NRC) (Figure 39).

B. Administrative and Legislative Consideration of Solid Waste Management

Here, a message by the President of the United States of America, J. F. Kennedy, and an act passed by the U.S. Congress on solid waste problems, are recorded:

> Concerning conservation programs, a message from the President of the United States (March 1, 1962) stated: "As our population expands, as our industrial output increases, and as rising productivity makes possible increased enjoyment of leisure time, the obligation to make the most efficient and beneficial use of natural resources becomes correspondingly greater. The standard of living we enjoy,...is attributable in large measure to the wide variety and rich abundance of this country's physical resources. But these resources are not inexhaustible - nor do they automatically replenish themselves. We depend on our natural resources to sustain us - but in turn their continued availability must depend on our using them prudently, improving them wisely, and, where possible, restoring them promptly. We must reaffirm our dedication to the sound practices of conservation which can be defined as the wise use of our natural environment; it is, in the final analysis, the highest form of national thrift - the prevention of waste and despoilment while preserving, improving, and renewing the quality and usefulness of all our resources. Our deep spiritual confidence that this Nation will survive the perils of today - which may well be with us for decades to come - compels us to invest in our Nation's future,

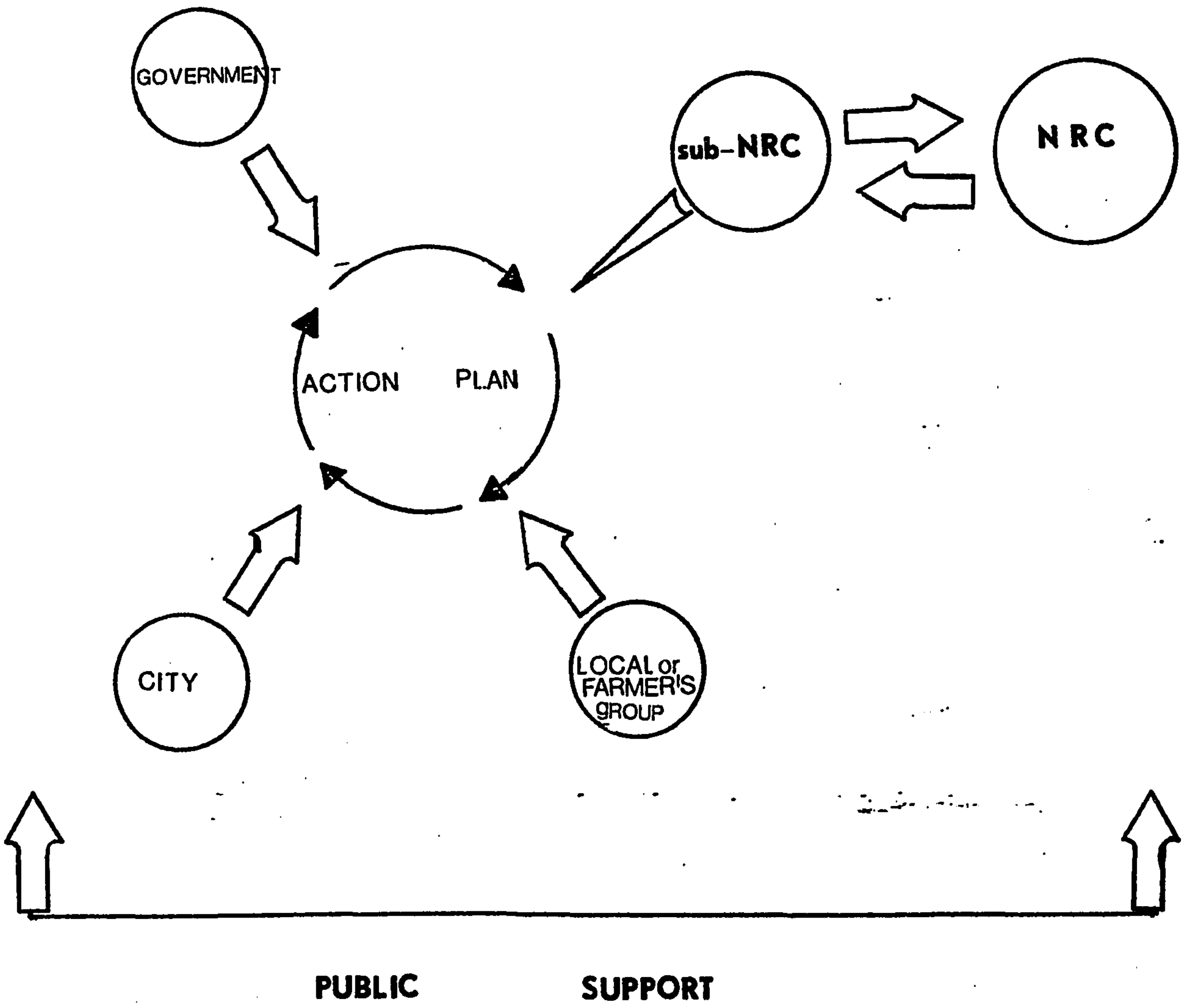

Figure 39

ACTIVE PLAN OF SOLID WASTE MANAGEMENT - COMPOST to consider and meet our obligations to our children and numberless generations that will follow. Our national conservation effort must include the complete spectrum of resources: air, water, and land; energy and minerals; soils, forest, and forage; fish and wildlife."

The Solid Waste Disposal Act (Public Law 89-272), Sec. 202 a-(4), Title II, Solid Waste Disposal, finds that:

"Inefficient and improper methods of disposal of solid wastes result in scenic blights, create serious hazards to the public health, including pollution of air and water resources, accident hazards, and increases in rodent and insect vectors of disease, have an adverse effect on land values, create public nuisances, otherwise interfere with community life and development."

Sec. 202 a-(5) further states:

"That the failure or inability to salvage and reuse such materials economically results in the unnecessary waste and depletion of our natural resources."