History of municipal solid waste composting in Tokyo (Operational challenges and transitional improvements)

Bureau of Environment
Tokyo Metropolitan Government

Concept ⇒ Composting municipal waste(Composting garbage in urban areas)

Composting raw materials

- **Livestock waste**
- **Agricultural waste**
- **Sewage sludge**

Concept → **Municipal waste (garbage)**

- Food scraps (bread, rice, vegetables, fish, meat, fruit, etc.)
- Cooking scraps (vegetable scraps, fish bones, etc.)
- Tea and coffee grounds

Contents

1. Brief history of municipal waste composting technologies in Japan

First era of composting

○Supply of cheap chemical fertilizer
○Decrease in demand for compost products due to negative changes in garbage

Second era of composting

○Recovery of decline in soil fertility due to heavy use of chemical fertilizers

○Review of organic farming and organic pesticides

Composting regains popularity

1938 Kobe Composting experiments begin

Composting facilities start operation nationwide (30)

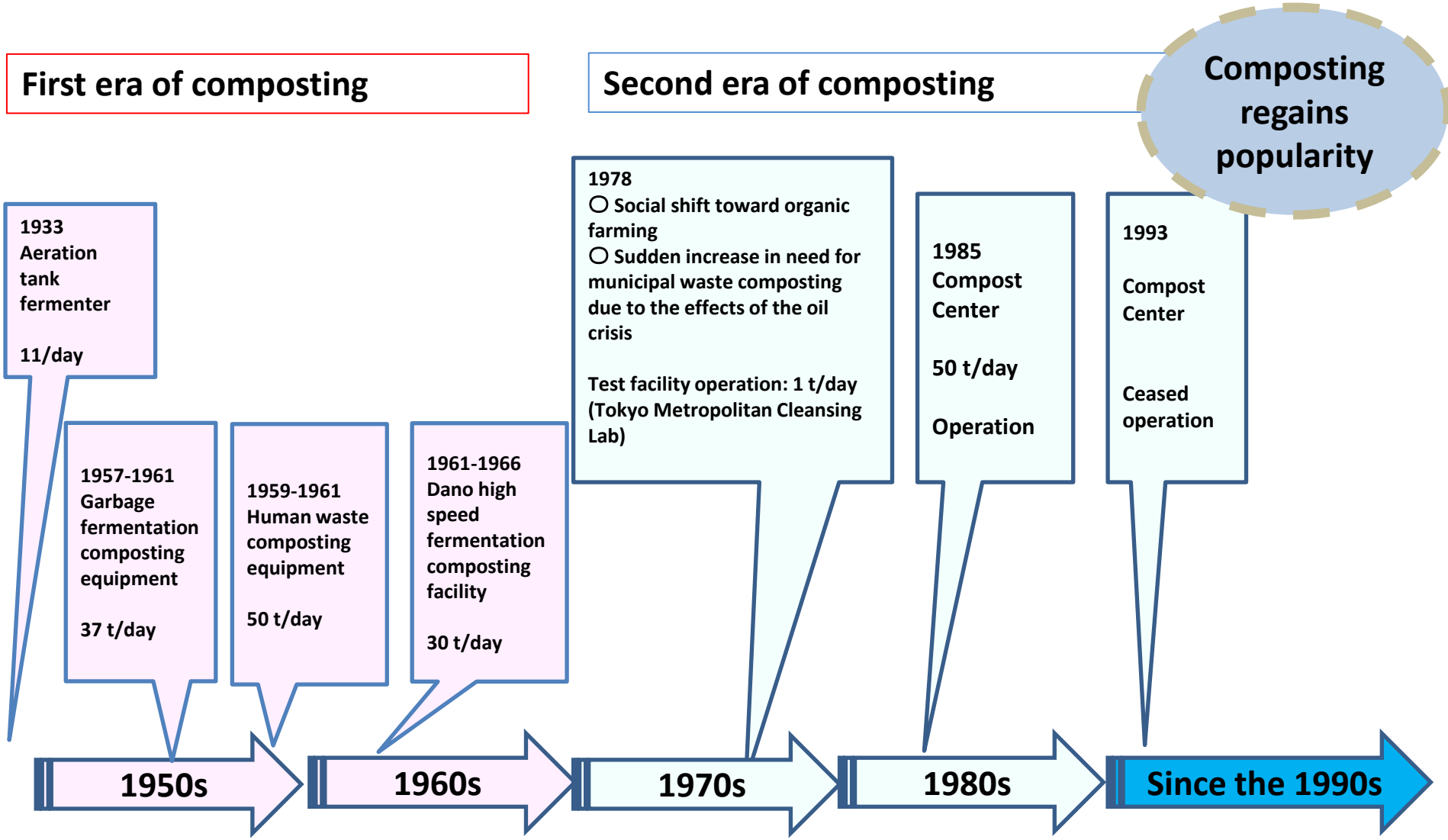
Composting facilities begin closing one after the next nationwide

Value of composting is recognized again

Current of as 2012
76 government-owned facilities

1950s → **1960s** → **1970s** → **1980s** → **Since the 1990s**

2. COMPOSTING RESEARCH AND CHANGES IN PROCESSING FOR MUNICIPAL WASTE IN URBAN TOKYO



First era of composting (Tokyo) (1930-1960)

1. From 1933: Operation of compost business using an aeration tank fermenter (11 t/day) starts.

A) High expectations that this would prove a powerful alternative to manure relying on human waste, which was problematic at the time.

B) Technical challenges included transitioning from natural fermentation to high speed composting

2. From 1957: Garbage fermentation composting equipment (37 t/day)

A) Manual sorting and separation process becomes necessary due to glass and plastics in garbage.

B) Operations ceased in 1961 due deterioration of the working environment and increases in storage costs due to fluctuations in seasonal demand and expiration dates of products.

3. From 1959: Human waste composting equipment (50 t/day)

Quality compost could be achieved due to the fermentation inhibition caused by adding human waste ultimately resulting in ceasing of operations in 1961.

4. From 1961: Dano high speed fermentation composting facility (30 t/day)

A) Various problems surfaces including fluctuations in product demand and increased storage costs.

B) The change in collection method from garbage to mixed waste led to significant decreases in operation efficiency and the plant ceasing operations in 1966.

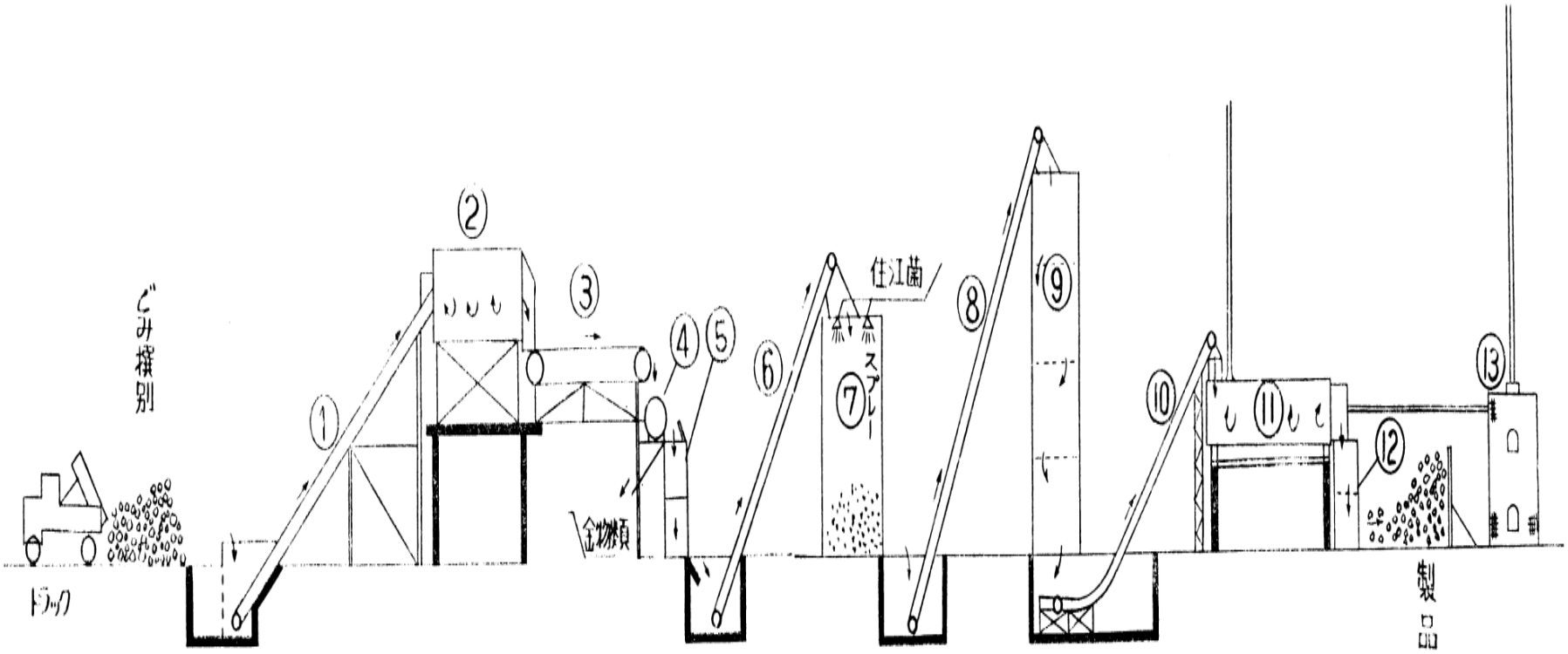
*Part of the reason farmers chose not to use compost was due to the foreign matter content in the compost.

First era of composting

Garbage fermentation composting equipment (1957-1961)

First era of composting

System diagram of garbage fermentation composting equipment (rotary fermentation tank) (1957-1961)



1. Transport conveyor 2. Sieve turning 3. Manual sorting conveyor 4. Magnetic sorting machine
5. First crusher 6. First conveyor 7. Storage tank 8. Second conveyor 9. Digester 10. Third Conveyor
11. Rotary dryer 12. Second crusher 13. Combustion furnace

First era of composting

Human waste composting equipment Image of garbage sorting (1959-1961)

First era of composting

Dano high speed fermentation composting facility

The Dano system includes a rotary kiln functioning as a fermentation tank with blades installed on the inside walls. The drum rotates between 0.1 to 1.0 rpm and is suitable for waste with low pigment and moisture content.

First era of composting (Tokyo)

Transitions in municipal waste composting operations in Tokyo due to changes in garbage collection systems

1. 1930s: Smoke pollution emitted from incineration plants. Waste is separated into kitchen waste and trash.

2. 1940s: A policy was developed to incinerate trash while converting kitchen waste into feed and fertilizer.
All kitchen waste could not be converted into feed and fertilizer and so this portion was disposed of in landfills.

3. Composting became more complex due to the mixed waste collections and kitchen waste containing plastic containers resulting in a need to develop sorting technologies.

First era of composting (Decline in 1965)

Key factors and circumstances behind the decline of the first era of composting

- Advancements in the petrochemical industry led to the supply of inexpensive chemical fertilizer.
- The quality of compost products declined due to deterioration in the quality of raw materials as plastics were developed and produced in large quantities becoming mixed with garbage.
- The decline in product quality led to a decline in demand, which created a vicious cycle and decreased production.

Second era of composting (from 1970)

Composting regains popularity

Factors and circumstances behind the resurgence of composting research and operation

① Soaring oil prices caused anewed awareness in effective use of resources and the need to promote recycling.

② The effect of organic fertilizer was reviewed in light of allegedly harmful pesticides.

③ Decreases in soil fertility as a result of using chemical fertilizers resulted in renewed appreciation of and increased interest in organic fertilizers.

④ Development of fermentation tanks and secondary equipment (crushing and sorting equipment) as well as development of various operational processes was advancing.

*** 1981: Tokyo established the "Basic Policy for Municipal Waste Composting Facilities".**

Second era of composting (Tokyo)

Tokyo Metropolitan Cleansing Lab
Composting Experimentation and Research (from 1977)

- **1977-1978: Indoor experimentation and research**
  - **Municipal waste fermentation experiment;**

  Primary fermentation, aerobic fermentation, initial temperature of 35 ° C, 5-6 days

  Secondary fermentation Fermented for approximately 30 days

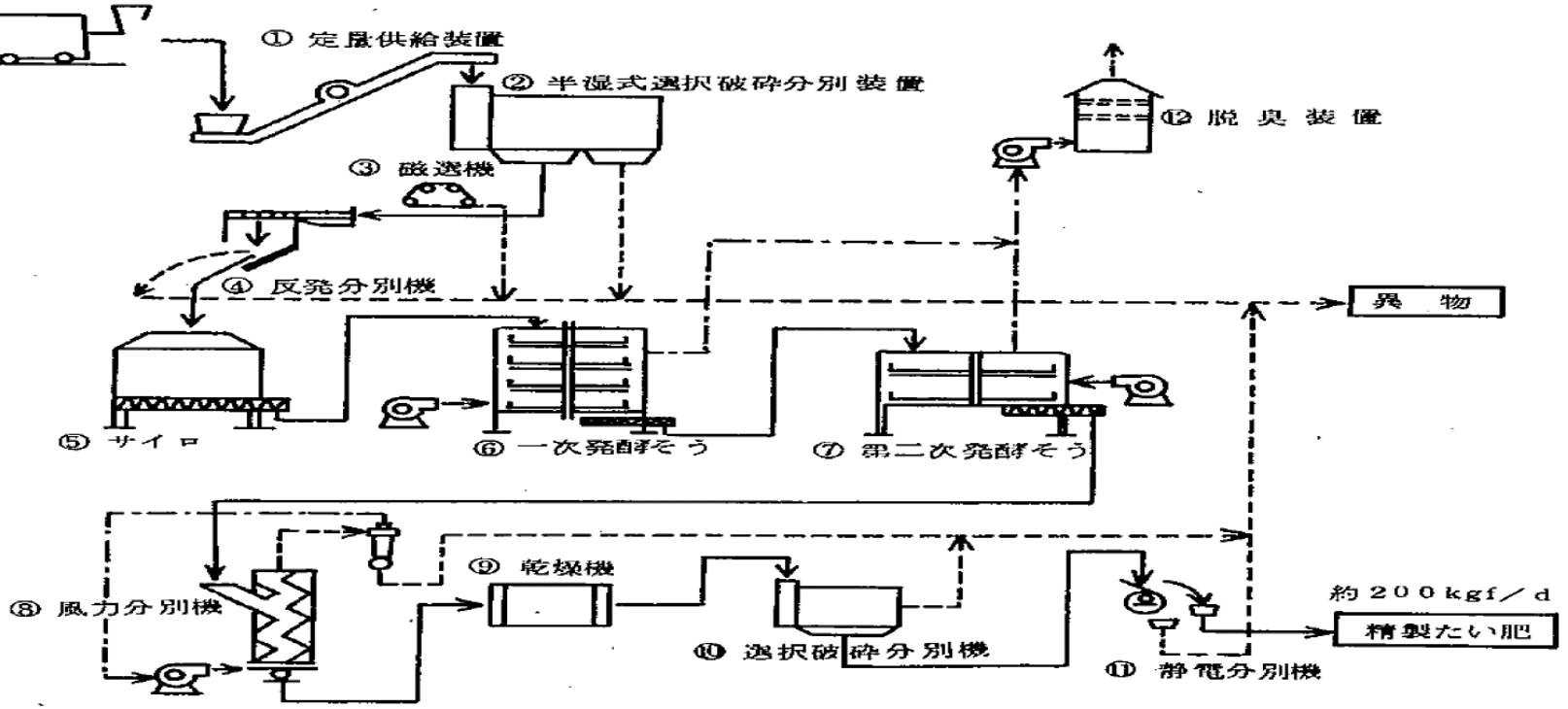
- **From 1978: Construction of compost laboratory research center (1 t/day)**
  - **Conditions study on stable aerobic fermentation, municipal waste, moisture content from 40-60%**
  - **Research into bag-tearing equipment**
  - **Soil improvement effects**
  - **Deodorization experiment performed on compost**
  - **Study on compost demand and marketability assuming efficient and economical composting facilities were in place.**

- **From 1985: Support for the constructed compost center (50 t/day)**
  - **Empirical studies on deodorization technologies using bark compost**

Second era of composting (Tokyo)

Tokyo Metropolitan Cleansing Lab
Composting Experimentation and Research (from 1977)

System diagram of research laboratory producing 1 t/day



処理フロー説明

①：日量１ｔｆのごみを投入し，定量供給する。②③④：たい肥化物と非たい肥化物とに選別する。⑤：たい肥化物を貯留する。⑥：たい肥化物を投入し，約１週間滞留させ，一次発酵させる。⑦：一次発酵物を投入し，約二週間滞留させ，二次発酵させる。⑧⑨⑩⑪：二次発酵物中のきょう雑物（微細なガラス，プラスチック等）を精選別し，粒度約５㎜以下のコンポスト約２００ｋｇｆを得る。⑫：発酵そうの臭気を脱臭する。

Second era of composting (Tokyo)

1985: Construction of Tokyo Compost Center

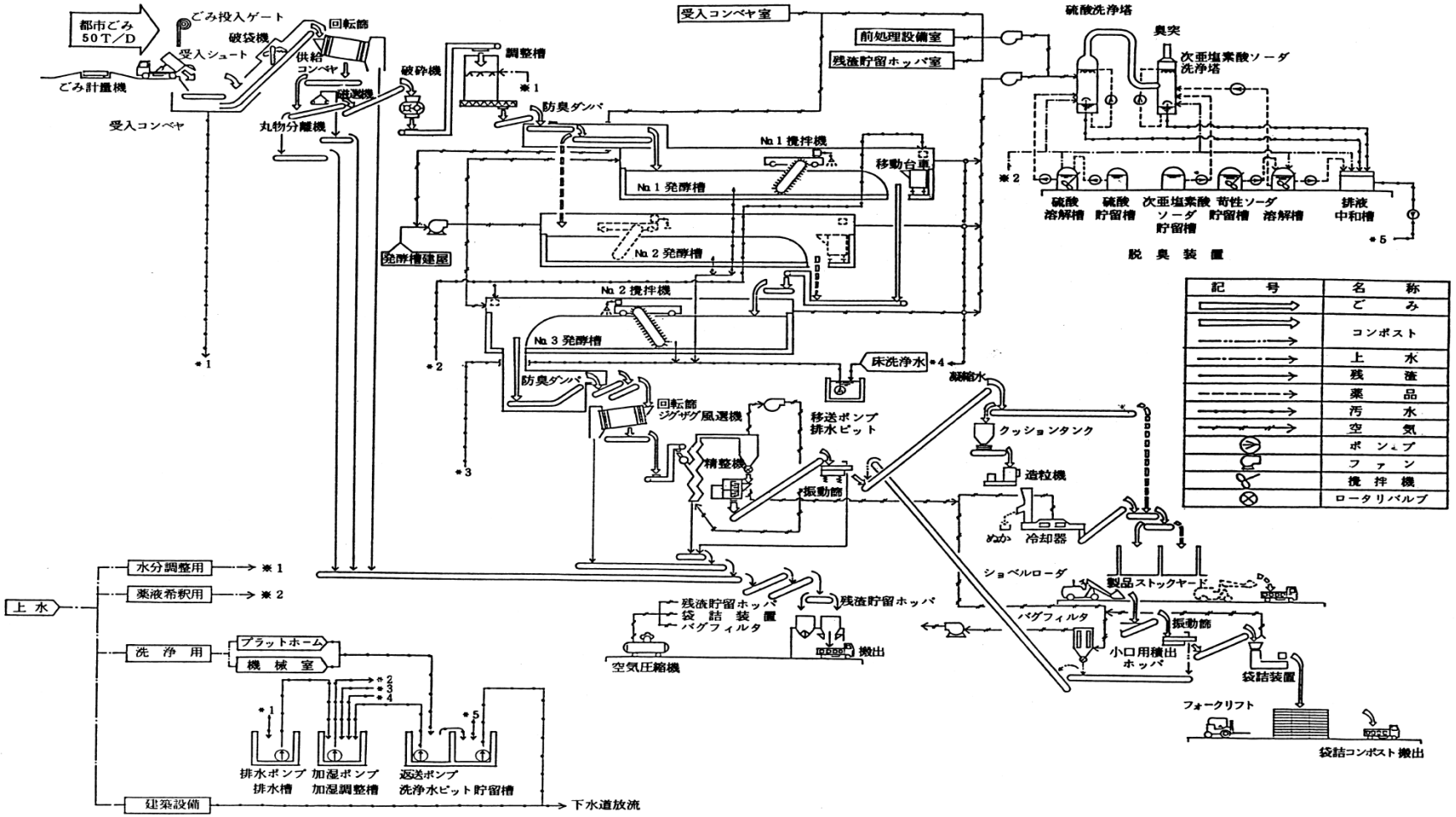
- Facility scale (processing capacity): 50 t/day
- Compost production capacity: 5 t/day
- Process method: High speed composting method
- Bag-tearing equipment: 1 hydraulic scissors type machine (10 t/h)
- Fermentation tank: 3 rectangular box tanks
- Deodorization equipment: Acid/alkaline washing and activated carbon filtering
- Construction cost: Approximately 730 million yen

Site features: Adjacent to an incineration plant which enabled use of power generated by the incineration plant and easy offloading of remaining waste after sorting processes.

This center ceased operations in 1994 to make room for the construction of a new incineration plant.

Second era of composting (Tokyo)

System diagram of the Tokyo Compost Center (50 t/day)



Second era of composting (Tokyo)

Tokyo Compost Center Performance Statistics 1985-1994

Performance Statistics

➢ **Characteristics of received garbage in 1989**

1. Flammable materials 88.8%
   - Paper 36.5%
   - Kitchen waste 33%
   - Textiles 4.4%
   - Lumber, grass, etc. 14.9%

2. Plastics 8.5%
   - Plastic 8.4%
   - Rubber & leather 0.1%

3. Non-flammable materials 2.7%
   - Metals 0.8%
   - Glass 1.7%
   - Soil and pottery 0.1%
   - Other 0.1%

➢ **Compost production in 1989**

1. Received garbage 13,801 t/year
2. Amount converted into compost 3060 t/year
3. Compost conversion ratio 22.2%

4. Residual amount 10,741 t/year
5. Residual ratio 77.8%

6. Compost production 288 t/year
7. Compost production ratio 2.1%

➢ **Compost product characteristics in 1989**

1. Foreign substances: 0.4-0.8% (specifications are 1% or less)
2. Moisture content: 27.7-29.4% (specifications are 30% or less)

3. Fertilizer components
C/N ratio: 11.0
Nitrogen (T-N) 3.5%
Phosphate (T-P305) 1.6%
Potassium (K20) 0.9%

➢**Material balance: Receives 50 t/day of municipal waste, produces 2 t/day of compost**
➢**Average product cost: 300 yen/kg (maintenance and management costs of 140 million yen/year)**

Tokyo Compost Center Issues 1985-1994

Issues 1/2

➢ **Decreased compost production**

- The compost center requires 30 days of fermentation to produce compost after sorting received municipal waste to extract kitchen waste.
- The facility was designed to produce 5 tons of compost for every 50 tons of waste received daily.
- However, actual compost production was less than design goals at 2-3 tons.
- Key factors include single-person and elderly households switching from container collection to disposing waste in bags, increases in hard paper products such as cardboard as well as non-flammable materials, and decreases in operation efficiency due to blockages and malfunctions in machinery.
- To counter these issues, attempts were made to use waste from restaurants in busy sections of the city to more easily extract kitchen waste, but waste from these sources also included a significantly high proportion of bottles, cans, styrofoam, and so on. Using kitchen waste from hotels, however, resulted in an improvement to 3 tons.
- Collecting waste suitable for compost was an ongoing problem.

➢ **Insufficient facility performance**

- Mechanical sorting equipment was not able to sufficiently remove unsuitable materials such as plastics which resulted in unsuitable materials being included in the fermentation tank inhibiting the fermentation process.
- There was no equipment for adjusting moisture content. Waste with high moisture content had to be drained in the fermentation tank. (Suitable moisture content is 30%)

Issues 1/2

- **Root rot in compost product**

  Initial compost product was produced in the shape of a rose. This resulted in being one of the causes of root rot, and so the product was changed into pellets resulting in slower-acting material and eliminating root rot.

- **Insufficient deodorizing equipment to deal with the many types of odors produced**
  - Deodorizing improvements were made such as removing moisture from post-fermentation air containing a high odor concentration level and reusing this moisture for fermentation of more compost.
  - The facility was equipped with chemical cleaning deodorizing machinery using acid and alkaline substances. These chemical agents were successful in eliminating odors produced by compounds but were not effective in dealing with complex odors from the fermentation of many different types of waste. Active carbon deodorization equipment was added to the facility, but the capacity of this equipment was not enough to meet demands.

- **Concern over heavy metal content**

  Initially there was concern over cadmium, mercury in batteries, and other harmful substances, but fertilizer product was produced in compliance with the Fertilizers Regulation Act and always better than the standards.

3. Examples of odor problems caused by private compost processing facilities in urban areas

➢Private composting facilities

- Processing capacity of 80 tons/day
- Facilities composting garbage from food factories, restaurants, school cafeterias, etc.

➢Odor problems arose in the areas surrounding the processing facilities. Local governments continue to provide guidance and instruction on improving this situation.

Causes and solutions to odor problems

➢ Main causes of odor

- Moisture content management is not properly conducted before the fermentation process.
- Aeration and other air supply capacity is not sufficient resulting in anaerobic fermentation.
- Deodorizing equipment capacity is not in line with processing capacity.
- There is no expert in fermentation and resulting odors on staff.

➢Improvements and mitigations

- Improvements in moisture content management to maintain proper balance between secondary materials (sawdust and such) and raw materials.
- Improvements in air supply and stirrer equipment. Research into and improvements of deodorizing methods and equipment.
- Review of processing capacity and amount of raw materials received. Improvements in process flow.

4. Problem resolutions needed to further municipal waste compost processing (Example)

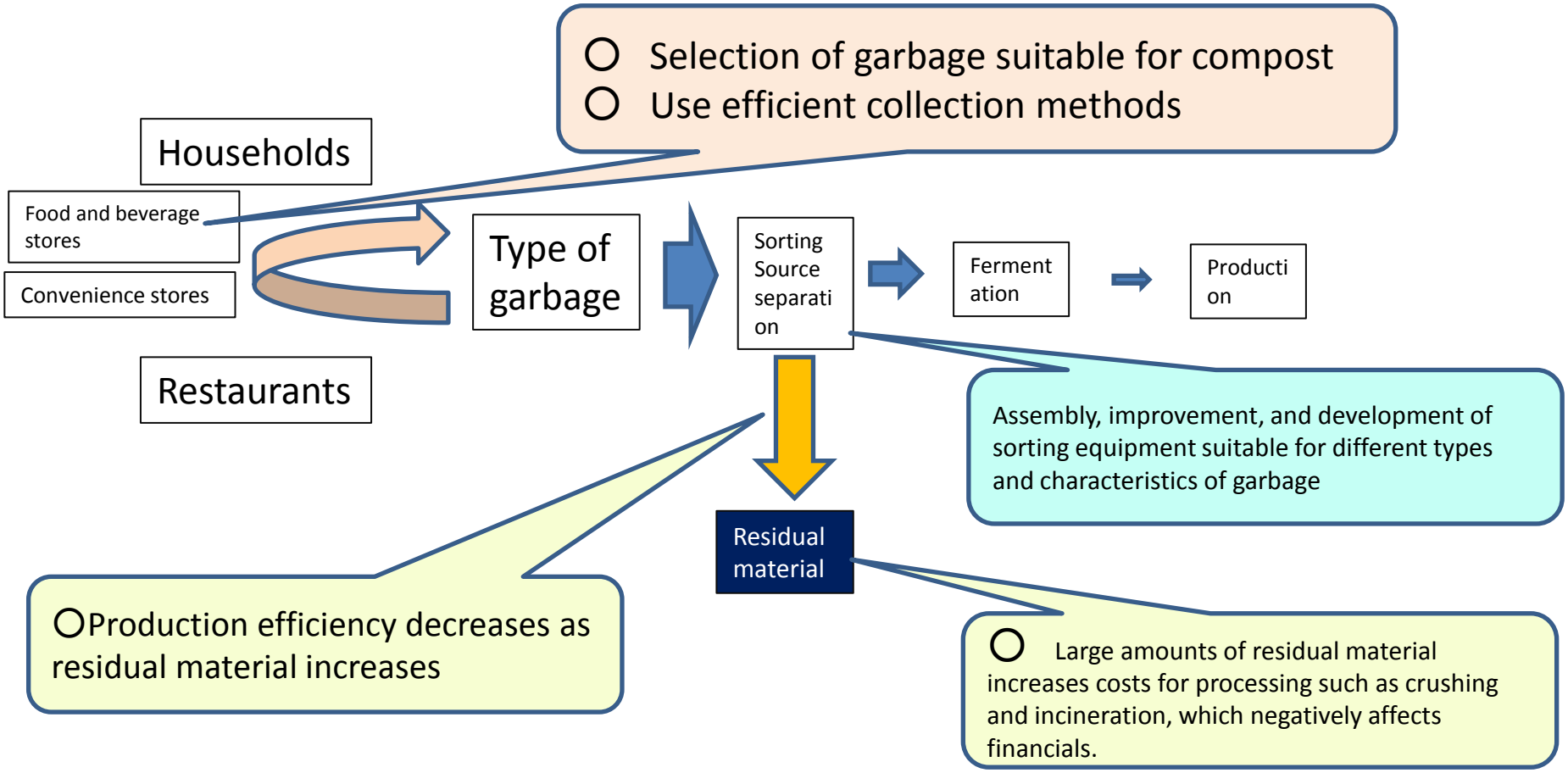
1. Selection of municipal waste, which typically contains unsuitable materials

- **Characteristics of municipal waste (garbage)**
  - **Moisture content is too high.**
  - **Requires grinding, dehydration, and moisture adjustment (additives).**
  - **Additives used as needed include rice straw, grain, and sawdust.**
  - **Purchasing additives raises costs and sometimes negatively impacts financials.**

- **Possibility to contain unsuitable materials**
  - **Garbage raw material may contain heavy metals such as copper, lead, zinc, and mercury.**
  - **May contain small pieces of plastic and glass.**
  - **Garbage could contain salt used in cooking.**

2. Reduction of residual material and the associated improvement in production

The amount of residual material varies depending on the collection method and type of waste discarded. This significantly affects the compost production ratio.



3. Quality control of the product

- **Municipal waste compost characteristics**
  1. Degree of maturity 2. Fertilizer components 3. Hazardous components
  4. Residue (glass, plastics, etc.)

- **Degree of safety when using municipal waste compost for soil and crops**
  1. Does not rapidly decompose after use.
  2. Does not cause nitrogen starvation.
  3. Does not contain growth inhibitors over defined standards.
  4. Does not contain hazardous substances over defined standards.
  5. Does not contain plant pathogens and weed seeds.

- **Municipal waste compost ⇒ Special fertilizer (Fertilizers Regulation Act)**
  - Product quality labeling (certificate of component analysis)
  - Concentration levels of nitrogen, phosphate, and potassium
  - Carbon-nitrogen ratio (C/N ratio)
  - Moisture content and others
  - Hazardous substance regulations
  - Arsenic, cadmium, mercury, lead, hexavalent chromium, organic phosphorous, cyan, and PCB
  - Registration with government agencies
  - Registration as a special fertilizer

4. Ensuring demand and demanded amounts

- **Two aspects of processing facilities**
  - The facility is both a waste processing facility and a facility producing a commercial product.
  - If it were purely a production facility, actual production would be based on demand. As a waste processing facility, however, it is expected to constantly accept waste.

- **Ensuring stable demand**
  - Contracting with farmers capable of sustained use.
  - Setting of prices that promote stable demand and development of suitable supply systems.
  - Disclosure of components and effect on soil improvement. Provide guidance on proper use.

- **Balanced demand ⇒ Compost granulation ⇒ Primary storage**
  - Farmer demand of compost changes in accordance with the season (much higher in fall and spring).
  - Develop demand with other types customers besides farmers such as golf courses and other grounds.
  - Temporary storage locations and equipment needed for periods of decreased demand.
  - Granulating rose-shaped compost improves both usability and storability

- **Ensuring usability in farms and avoiding nitrogen starvation**
  - Granulating compost improves its slow-acting properties, improves usability, and avoids nitrogen starvation.

5. Deodorizing Efforts

- **Odor produced from composting facilities**
  - Hot multi-component gas that includes carbon dioxide as wells as sulfur compounds such as ammonia, ethanol, methanol, acetone, and methyl sulfide.
  - Insufficient fermentation causes organic acids producing odor.

- **Deodorizing systems**
  - Combination of methods including water washing, chemical cleaning using acids and alkalines, activated carbon adsorption, soil adsorption, and compost adsorption.
  - Water washing and chemical washing using acids and alkalines is particularly effective with large amounts that have low concentration levels of odor.
  - Soil adsorption and compost adsorption is a low-cost method, but blockages may be a concern.
  - Direct combustion method decomposes odor at high temperatures and thus is effective, but the cost is high.
  - Activated carbon adsorption is not effective on ammonia. The adsorption effect is reduced by the adhesion of water.

- **Reducing highly concentrated odors**
  - Removing moisture from post-fermentation air in a mist separator and reusing air in the fermentation tank improves the deodorizing effect.
  - Air at the top of the fermentation tank with low odor concentrations is sent to the deodorizing equipment.

- **Aerobic fermentation**
  - Improve air supply capacity of aeration and other equipment to prevent anaerobic fermentation and maintain aerobic fermentation capability.

Reference 1/2

Performance of Municipal Waste Compost Product

Application testing continually conducted at the Tokyo Metropolitan Agricultural Research Center (1985-1994)

- Includes 1-3% each of nitrogen, phosphoric acid, and potassium
- Organic fertilizer with soil improving effect (special fertilizer in compliance with the Fertilizers Regulation Act)
- Compost testing areas showed a yield increase of 255 over areas treated with chemical fertilizer and a yield increase of over 10% over areas treated with cow manure.
- Largely used for Chinese cabbage, cabbage, and fruits.

Reference 2/2

Municipal Waste Composting Technologies

- **Fermentation tank**
  - Rotary kiln fermentation tank
  - Multi-stage fermentation tank
  - Sorting and crushing machine
  - Silo fermentation tank
  - Bottle fermentation tank

- **Sorting equipment**
  - Vibrating sieve machine
  - Trommel
  - Sorting and crushing machine
  - Zigzag wind sorting machine
  - Screen sorting machine
  - Rotary spike sorting machine
  - Inclined belt conveyor sorting machine
  - Specific gravity difference sorter

- **Deodorizing equipment**
  - Chemical cleansing equipment
  - Soil deodorizing equipment
  - Compost deodorizing equipment
  - Activated carbon deodorizing equipment
  - Combustion deodorizing equipment

5. Considerations in planning municipal waste compost processing facilities

To proceed with the planning of compost processing facilities:

Goal: Formation of a recycling-oriented society, efforts to recycle resources and contribute to global warming initiatives.

- Governmental factors in reducing or abolishing the municipal waste (garbage) composting business
  - Difficulty in continually producing high-quality compost due to improper sorting of raw materials and garbage.
  - Necessity and related cost of additives (sawdust and such) to adjust moisture content of garbage with high moisture content.
  - Difficulty in ensuring long-term and stable customers due to fluctuations in compost marketability that peaks in the spring and fall.
  - Significantly high operation costs in comparison with incineration and other processing facilities.
  - Difficulty in maintaining operations in dense residential areas due to insufficient deodorizing systems.

Improve
Overcome

Key resolution factors

- **Ensure high quality raw materials necessary to manufacture compost**

Requires guidance on sorting garbage, a sorting system/process, and promotion and public awareness/education initiatives.

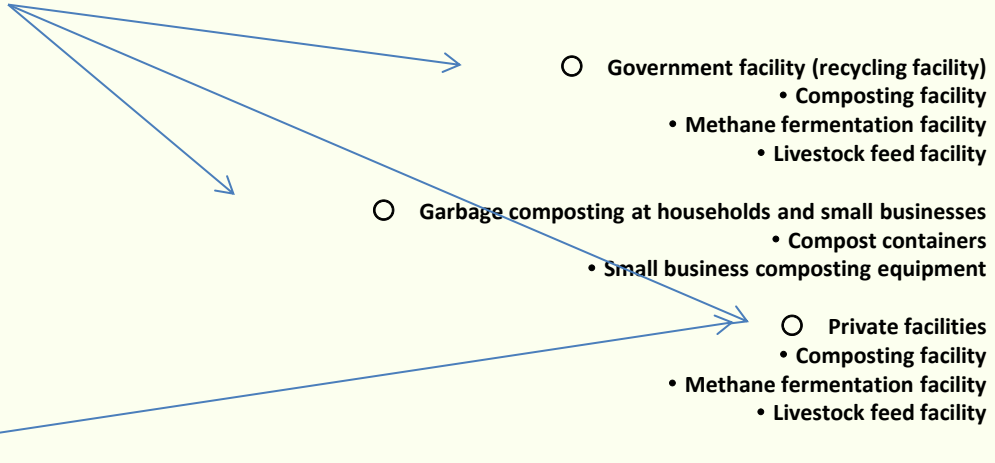
  - **Improved collection devices (biodegradable plastic bags, specialized containers, etc.)**
  - **Management of collection locations (door-to-door collection, station collection, etc.)**
  - **Economic motivation such as making the disposal of garbage free and the disposal of combustible waste requiring a fee.**

- **Ensuring long-term compost users, verification of the effect of usage on farms, widespread publicity**
- **Ensuring aerobic fermentation via sufficient air supply to fermentation tanks, suitable selection/combination of sorting equipment depending on type of waste**
- **Selection and combination of deodorizing equipment suitable for the types of odors present and the regional environment**

Direct combustion equipment often times cannot be installed, which requires proper maintenance and management of a combination of equipment such as cleansing equipment and soil deodorizing equipment.

Summarizing the recycling of municipal waste (garbage)

- **Municipal household waste (garbage)**



- **Restaurants, cafeterias, food and beverage stores, etc. Commercial waste (garbage)**

Initiatives to promote garbage composting in households and small business

Local government initiatives

- **Compost containers for household use**
  - Local governments provide subsidies
  - Many local governments in the Tama region, which has many natural areas
  - Used mainly to ferment and provide fertilizer for ones own land.

- **Commercial garbage processing machines (compact and motorized)**
  - Some local governments provide subsidies
  - Compact, electric devices capable of around 1 t/day

* This initiative is not actively promoted in the 23 Wards of Tokyo.

6. Conclusion

- Composting technologies are already established.
- Operating a stable composting business requires the collection and selection of raw materials appropriate with the scale of the facility and ensuring long-term and stable customers.
- The key to success in composting is the securement of suitable and quality raw materials, crushing and sorting equipment appropriate for the types of garbage collected, improvement and development of aerobic fermentation technologies, and sufficient deodorizing measures.