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Food and Fertilizer Series: No. 6

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Survey and Analysis of Refuse in Taiwan

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With the steady increase of population in Taiwan, disposal of organic wastes including nightsoil and refuse[2] have become problems more and more annoying to local government agencies and menacing to the sanitation and public health of urban residents. The solution of these problems has been a challenge both to the sanitarians and agriculturists on this island, and, incidentally, considerable improvement has already been attained through the nightsoil disposal improvement projects sponsored by provincial and local agencies in recent years. However, not so much has been done to meet the problems relevant to the effective disposal and utilization of urban and village refuse for agricultural purposes.

There is no doubt that much fertility could be restored to the land if all organic wastes were returned to the soil in a proper way. Recently, a great deal of interest has developed in Taiwan as to the possibilities of composting urban refuse for agricultural use as a source of fertilizer elements since it seems to be an ideal way for dealing most effectively both with the health problems involved and the needs of agriculture. Although in some localities, especially in southern Taiwan, quite a few farmers have long ago come to appreciate the value of urban refuse as a source of organic matter for their land, there are still many places where organic refuse is being squandered in a reckless and unhygienic way.

In view of the lack of basic data on the composition of refuse in Taiwan, the Food & Fertilizer Division of JCRR and the Environmental Sanitation Laboratories of the Institute of Public Health, NTU have been planning a general refuse survey since early in 1955. The project which is the subject of this report was primarily an immediate result of this planning and partly a result of the two-day meetings on nightsoil and refuse sponsored by the Provincial Institute of Environmental Sanitation in March, 1956 in which the In-

1. Agricultural Chemist and Associate Professor of Environmental Sanitation, College of Medicine, NTU, respectively.
2. The term "refuse" is used here to include garbage, ashes, rubbish and dead animals which are commonly present in the mixed community wastes. Nightsoil is not included.

stitute of Public Health, NTU was assigned to undertake an island-wide survey and analysis of refuse with the purpose of supplying basic data for future development of refuse disposal methods.

General Survey

Field surveys were made in twelve major areas, Keelung, Taipei, Yilan, Hsinchu, Taichung, Chiayi, Tainan, Kaohsiung, Pingtung, Taitung, Hualien and Penghu with the cooperation of the local agencies and JCRR field agents during both summer and winter seasons starting from June, 1956 and extending to April, 1957 in order to determine the quantity and quality of the refuse in various localities and also to collect some information on the present situation of refuse collection and disposal. From 24 cities and towns a total of more than 120 samples were collected in the summer season for physical and chemical analysis. This was repeated during the winter season.

I. Quantity

An investigation of the production of refuse by 11 cities and 13 townships showed a variation in mixed refuse of from 0.3 to 0.7 kg per capita per day an with average of 0.5 kg. Table 1 gives the daily output of urban refuse in the major cities and towns with reference to the population involved.

II. Current methods of refuse disposal and their related problems

In Taiwan several methods of refuse disposal are in common use, i.e. open dumping, landfill, composting, dumping at sea or in rivers, and incineration. Each of these methods is accompanied by open dumping except for the case of offshore dumping.

In all the cities and towns surveyed, household wastes are dumped in bins built of cement or wood which are usually situated in front of the houses along the streets and alleys. These are cleared periodically, usually once a day, by the sanitary corps or town scavengers and transported by hand-cart or truck to the dumps around the cities or towns without any further sanitary treatment in most cases. After the waste has decomposed, local farmers dig it up, screen it and take the fine portion to use as fertilizer. This is, however, done in a haphazard way particularly in the off season when farmers use very little fertilizer.

The open dumps always provide an ideal environment for breeding disease-bearing vectors such as flies, mosquitoes and rats, thus giving rise to serious

Table 1. Average daily output of urban refuse in 24 cities and towns

Locality	Daily Output (m/t)	Population involved	Per capita daily output (kg)
Keelung City	120	180,000	0.7
Taipei City	550	750,000	0.7
Yilan City	12	38,000	0.3
Hsinchu City	70	120,000	0.6
Taichung City	110	180,000	0.6
Changhua City	25	55,000	0.5
Chiayi City	40	90,000	0.4
Tainan City	140	220,000	0.6
Kaohsiung City	180	352,000	0.5
Pingtung City	22	60,000	0.4
Hualien City	25	53,000	0.5
Lotung Chen	8	21,000	0.4
Shulin Chen	3	5,000	0.6
Hsinpu Chen	2.5	5,000	0.5
Fengyuan Chen	12	22,000	0.5
Wufeng Hsiang	1.8	5,000	0.4
Yuanlin Chen	10	22,000	0.5
Tounan Chen	7	16,000	0.4
Hsinying Chen	15	30,000	0.5
Anping District	5	11,000	0.5
Fengshan Chen	18	38,000	0.5
Chaochow Chen	5	10,000	0.5
Taitung Chen	20	43,000	0.5
Makung Chen	10	20,000	0.5

public health problems. Although bitter complaints have been made about such nuisance conditions from time to time by nearby residents, no tangible efforts have been made by the concerned agencies to improve this prevailing situation. The reluctance, or inability, of the concerned authorities to take effective measures in refuse disposal in the past may be due to several conditions of which the most important are lack of funds and necessary equipment and facilities together with lack of a well-organized overall plan and regulations.

Another very common problem of refuse disposal either in cities or towns is the difficulty of obtaining suitable land area for the dumping of refuse

within reasonable hauling distance. Obviously the availability of land is a primary consideration for any kind of disposal. Land in urban areas is very expensive. As a consequence, sea or river dumping is becoming quite common throughout the island especially where suitable dumping sites are scarcely available and refuse is not extensively utilized for agricultural purposes.

In Keelung and Makung, all the urban refuse collected are dumped into the sea or on the seashore. Such practice is creating problems in regard to offshore fishing and nearby bathing beaches, and the problems are more critical during the typhoon season which covers about one third of the year. River dumping also has the same drawbacks causing obnoxious downstream conditions.

In some areas, such as in Hsinchu, Taichung, Chiayi and Tainan where there is an acute demand for refuse as a composting material, refuse is sold and transferred directly to farmers or contractors at the dumping sites or re-shipping stations.

One of the best illustration can be found in Tainan city where the demand always exceeds the supply and an allocation system has been operated very successfully for the past nine years. Parts of non-compostable portions, mainly cinders and mud or sludge taken from the street sewers, are separately taken out for landfill purposes. Roughly segregated raw refuse is sold at NT$ 7 per ox-cart load which weighs about 1.2 tons or the equivalent of three ordinary hand-cart loads. Considering other expenses including those for transportation and labor, farmers are actually paying about NT$ 30 for each ox-cart load and their long experience has proved that the increase in crop yield justifies this additional outlay. Owing to the limited supply, farmers can get only four ox-cart loads per hectare a year, an amount apparently far below their requirement.

The localities where there is a constant demand for urban refuse have the common geographical advantage of having on their borders a large acreage of farms under dry land cultivation such as sugarcane plantations or sweet potato farms. In this respect, Taipei, Keelung and Yilan areas are definitely handicapped in finding a market in the neighbourhood for their urban refuse.

Besides active interest of the local farmers, there is the example of the Taiwan Sugar Corporation (TSC) which is now making fairly extensive use of urban refuse, particularly in the Kaohsiung and Pingtung areas. In Kaohsiung city refuse is carried away by trucks to the sugarcane fields in the outskirts, piled up there for a certain period, usually six months or more, and then sold to TSC at about NT$80 per cubic ping weighing about four tons.

Incineration is not a very common practice in Taiwan. Only three incinerators in Taipei city are in operation and about 100 tons of city refuse are incinerated there everyday. From the point of view of sanitation the method is satisfactory. However, it produces no revenue, is costly and a sheer waste.

Sometimes during dry seasons, in Yilan and Lotung refuse is transferred to contractors, who burn it and supply the ash to farmers as fertilizer. The selling price of the ash is from NT$ 4 to NT$ 8 for 100 catties (60 kg).

The first pilot scale composting plant for urban refuse was inaugurated in December, 1956 in Pingtung city under joint operation of the city public office and the IES. The plant can handle 27 tons of raw refuse a day using a windrow process with periodic turning and addition of nightsoil. By this venture, Pingtung city has successfully laid a corner-stone for the future development of refuse disposal in Taiwan. Recently, Taipei city government has started planning a Forced Air Bin type compost plant following the method developed by Pingtung city.

Present disposal methods in various cities and towns are given in Table 2.

Physical Analysis

Physical analyses were performed during the course of the survey to determine the relative quantities of vegetable matter, paper, rags, etc. in the mixed refuse at various localities. Since the characteristics and composition of wastes may vary considerably with the season and in different localities, physical analyses were carried out at the respective cities and towns during both summer and winter seasons.

Special regard was paid to the sampling technique so that representative samples would be obtained. After several trials, the following method was used:

1. With the cooperation of local sanitary corps or other concerned agencies, different types of districts (market, residential, commercial, industrial or public places) were designated for sampling. Batches were collected separately as they came in from the designated districts. The decision as to number of loads and districts to be surveyed was carefully studied so as to obtain more samples from those districts, usually residential and commercial, which produce more refuse.
2. When the designated cart came to the dump, the scavenger was requested to dump his load on the ground and four or five workers under the supervision of our surveyors screened and segregated the refuse by hand

Table 2. Present methods of refuse diposal (%)

Locality	Open dumping or Landfill	Sea/River dumping	Incineration or Burning	Agricultural utilization
Keelung City	—	100	—	—
Taipei City	78	—	18	4
Yilan City	50	—	50	—
Hsinchu City	33	—	19	48
Taichung City	26	—	—	74
Changhua City	80	—	—	20
Chiayi City	—	—	—	100
Tainan City	47	—	—	53
Kaohsiung City	20	—	—	80
Pingtung City	—	—	—	100
Hualien City	60	—	—	40
Lotung Chen	70	—	30	—
Shulin Chen	100	—	—	—
Hsinpu Chen	100	—	—	—
Fengyuan Chen	—	50	—	50
Wufeng Hsiang	100	—	—	—
Yuanlin Chen	20	—	—	80
Tounan Chen	—	—	—	100
Hsinying Chen	100	—	—	—
Anping District	—	—	—	100
Fengshan Chen	—	—	—	100
Chaochow Chen	100	—	—	—
Taitung Chen	—	80	—	20
Makung Chen	—	100	—	—

to determine physical composition. A screen with meshes of 2 cm. square was used to facilitate the analysis and the segregates were weighed. The physical constituents of each load were reported as per cent of total weight of the cart-load.

3. Daily output was estimated from the average daily number of cart or truck loads from each district, and from this, the average per cent output of each district was computed. The mean of the per cent constituents of all districts calculated on a weighted-average basis represents the average physical composition of the refuse of the respective city or town.

The major weakness in this survey method, arising from several restrictions of times, men, financial and other facilities, will be found in the practice of single determinations instead of repeated samplings and analyses; nevertheless, due to the relatively small variation in such a large number of samples, it may be supposed that this method will not lead to findings which are grossly misrepresentative or misleading.

Results of physical analysis are given in Tables 3 and 4.

Table 3. Physical analysis of summer refuse

Locality	Physical Composition (%)								
	Vegetable & plant wastes	Soil & ash	Glass & crock-ery	Stone & brick	Rags	Waste paper	Metals	Wood	Others
Keelung City	52.3	43.7	0.2	0.5	1.2	1.5	0.0	0.5	0.1
Taipei City	41.0	51.6	0.3	3.0	1.5	1.0	0.3	1.1	0.1
Yilan City	52.2	39.5	2.6	0.0	0.5	2.3	0.2	1.5	1.2
Hsinchu City	64.6	32.1	0.2	1.5	0.3	0.7	0.1	0.4	0.0
Taichung City	41.2	56.0	0.1	1.0	0.4	0.9	0.1	0.1	0.2
Changhua City	21.2	75.4	0.1	0.6	0.7	1.7	0.1	0.2	0.2
Tainan City	71.5	25.0	0.2	1.2	0.6	0.7	0.1	0.2	0.5
Kaohsiung City	51.2	42.3	0.2	2.1	0.3	1.6	0.1	0.4	1.8
Pingtung City	40.4	52.0	0.1	4.3	0.6	1.9	0.0	0.2	0.5
Hualien City	59.4	28.4	0.5	6.3	0.7	3.6	0.6	0.3	0.3
Lotung Chen	57.4	24.4	3.0	6.9	2.3	1.4	0.3	1.5	2.8
Shulin Chen	23.6	68.4	1.0	4.8	0.6	1.5	0.0	0.0	0.1
Hsinpu Chen	52.1	45.3	0.0	0.8	0.4	0.5	0.1	0.1	0.8
Fengyuan Chen	61.8	33.3	0.2	1.4	0.7	1.5	0.1	0.5	0.5
Wufeng Hsiang	43.5	53.1	0.1	0.4	0.6	1.8	0.5	0.0	0.1
Yuanlin Chen	49.7	35.9	2.0	0.8	1.3	9.5	0.1	0.5	0.4
Tounan Chen	40.2	56.7	0.1	1.5	0.1	0.7	0.1	0.3	0.3
Hsinying Chen	58.7	37.6	0.1	0.0	0.8	2.2	0.1	0.2	0.2
Anping District	78.0	16.2	0.4	0.8	1.6	1.6	0.2	0.4	0.7
Fengshan Chen	32.4	59.8	0.3	4.5	0.5	0.8	0.0	0.8	1.0
Chaochow Chen	60.3	35.6	0.4	0.8	0.4	1.6	0.1	0.5	0.2
Taitung Chen	65.1	29.6	0.6	1.2	0.4	2.2	0.3	0.0	0.5
Makung Chen	57.9	30.0	0.8	2.2	2.1	5.9	0.3	0.1	0.8
Average	51.1	42.3	0.6	2.0	0.8	2.0	0.2	0.4	0.6

Table 4. Physical analysis of winter refuse

Locality	Physical Composition (%)								
	Vegetable & plant wastes	Soil & ash	Glass & crock-ery	Stone & brick	Rags	Waste paper	Metals	Wood	Others
Keelung City	52.5	38.0	0.1	2.6	1.1	2.8	0.2	2.3	0.5
Taipei City	42.2	51.6	0.6	1.5	2.3	0.7	0.1	0.6	0.4
Yilan City	45.8	51.8	0.1	0.8	0.4	0.8	0.0	0.3	0.2
Hsinchu City	73.2	22.4	0.4	1.5	0.6	0.8	0.1	0.8	0.4
Taichung City	44.9	43.6	3.3	4.4	0.3	1.8	0.1	0.2	1.6
Changhua City	29.9	64.9	0.1	2.5	0.5	1.0	0.1	0.4	0.6
Tainan City	54.9	42.2	0.1	1.0	0.4	0.9	0.1	0.1	0.4
Kaohsiung City	49.8	42.7	1.0	1.6	0.8	3.4	0.0	0.2	0.5
Pingtung City	37.5	58.4	0.3	1.9	0.3	1.3	0.0	0.1	0.2
Hualien City	71.3	22.9	0.4	1.2	0.5	2.3	0.1	0.3	1.1
Lotung Chen	54.8	35.2	0.6	2.4	0.8	2.7	0.2	0.5	2.9
Shulin Chen	60.2	31.7	0.2	5.5	0.4	1.1	0.1	0.2	0.7
Hsinpu Chen	42.6	55.0	0.1	0.7	0.3	0.7	0.1	0.4	0.3
Fengyuan Chen	55.4	33.9	1.5	6.1	0.3	2.1	0.0	0.4	0.3
Wufeng Hsiang	27.0	69.3	0.3	0.6	0.4	1.0	0.1	0.5	0.8
Yuanlin Chen	57.9	34.1	0.3	2.9	0.8	2.9	0.5	0.3	0.4
Tounan Chen	50.3	46.4	0.2	1.5	0.2	1.0	0.2	0.1	0.1
Hsinying Chen	49.5	47.5	0.2	0.5	0.3	1.7	0.0	0.2	0.1
Anping District	55.8	38.7	0.1	3.6	0.5	0.7	0.0	0.1	0.6
Fengshan Chen	39.7	55.3	0.2	2.7	0.3	1.4	0.1	0.2	0.0
Chaochow Chen	51.4	41.8	0.2	2.6	0.6	2.6	0.1	0.2	0.5
Taitung Chen	47.2	45.5	0.3	1.9	0.5	3.7	0.1	0.3	0.6
Makung Chen	31.8	64.8	0.2	1.2	0.5	0.9	0.0	0.0	0.6
Average	48.9	45.1	0.5	2.2	0.6	1.7	0.1	0.4	0.6

Physical data are collectively summarized in Table 5.

Table 5. Average physical composition of urban refuse from 23 cities and towns (%)

Physical Composition	Summer Refuse		Winter Refuse	
	Range	Average±S.D.	Range	Average±S.D.
Vegetable & plant wastes	21.2–78.0	51.1±13.8	27.0–73.2	48.9±11.5
Soil and ash	16.2–75.4	42.3±14.9	22.4–69.3	45.1±12.5
Glass and crockery	0.0– 3.0	0.6± 0.8	0.1– 3.3	0.5± 0.7
Stone and brick	0.0– 6.9	2.0± 2.0	0.5– 5.5	2.2± 1.5
Rags	0.1– 2.3	0.8± 0.6	0.2– 2.3	0.6± 0.4
Waste paper	0.5– 9.5	2.0± 2.0	0.7– 3.7	1.7± 0.9
Metals	0.0– 0.6	0.2± 0.1	0.0– 0.5	0.1± 0.1
Wood	0.0– 1.5	0.4± 0.4	0.0– 2.3	0.4± 0.4
Others	0.0– 2.8	0.6± 0.6	0.0– 2.9	0.6± 0.5

S. D.—Standard deviation.

The analyses show considerable variation from place to place. However, irrespective of seasonal variation, nearly 90 per cent or more of the mixed refuse is made up of vegetable matter and ash in the ratio of about 1 to 1. Other salvable materials such as, rags, waste paper, glass and metals, taken together, in most cases, constitute only 2—3 per cent of the total, showing a marked contrast to the average figures of 20—30 per cent for these components reported in western countries (2, 3). The low percentage of these components might be partly due to the intensive salvage operations of the rag pickers. Rags, metals, tin cans, paper and glass are picked over while in the refuse bins and often picked over again at the dumping ground for anything of the slightest value, such as combustible cinders, and sold to local junk-dealers. Good markets usually exist for metals, rags, glass and paper.

Vegetable matter, which is made up largely of straw, grass weeds, fallen leaves, fruits and kitchen vegetable trimmings, constitutes the major portion of compostable materials. "Soil and ash" is usually a mixture of street sweepings, combustible and non-combustible cinders, and very often, some rice-hull ash from kitchen-stoves. Very little of combustible cinders were found in the mixed refuse.

Fairly high percentages of vegetable and plant wastes in the mixed refuse together with very low contents of those obnoxious substances such as glass

and crockery, metals, stone and bricks offers certain positive advantages as a source of composting materials. The data revealed that in many localities, compostable portions exclusive of ashes and other salvables averaged about half of the total weight.

Seasonal variation in physical composition was not significant as shown in Table 5, which seems to stand to reason since Taiwan is situated in the sub-tropic zone where the change of season is not very clear-cut. However, there was some seasonal variation in the constituents of vegetable matter; more straw and watermelon rinds were found in the summer while more kitchen vegetable wastes and orange-peels were found in the winter.

The density of mixed refuse was estimated for several samples in Taipei city. Under average compactness the mixed refuse weighs 250-350 kg per cubic meter varying with degree of wetness and relative proportion of vegetable matter to soil and ashes of the content.

Chemical Analysis

Chemical analyses were carried out on the compostable portions of raw refuse samples largely made up of vegetable matter. Samples were taken at random, immediately after the physical analysis was made, from several different spots of the segregated piles of vegetable and plant wastes so as to insure a composite sample that will be representative of the total pile of the compostable materials. They were then mixed thoroughly and quartered down until the desired sample size was obtained. Samples were ground in a Wiley mill to ensure homogeneity before being used for chemical analysis.

Samples were analyzed for moisture, organic matter, nitrogen, phosphoric acid and potash. Organic matter was determined by loss on ignition and nitrogen by the Gunning method (1). Phosphoric acid was determined by the Lorenz method after wet digestion of the sample (4). Potash was photometrically determined by Lithium dipicrylaminate method (7). Carbon was estimated by the equation: $c=\frac{100-\%\ \text{ash}}{1.8}$ as suggested in the New Zealand report (5). Moisture content was expressed as a percentage of the total original weight, all other constituents being expressed on an oven-dry basis.

The average chemical composition of the compostable materials are given in Tables 6 and 7, and summarized in Table 8.

Table 6 Chemical analysis of compostable materials in summer refuse

Locality	Chemical Composition (%)						
	Moisture	Organic matter	Carbon	Nitrogen	P_2O_5	K_2O	C/N
Keelung City	40.1	82.6	45.9	1.08	0.44	1.72	42.5
Taipei City	39.1	67.6	37.5	1.06	0.40	1.54	35.4
Yilan City	43.2	80.7	44.8	1.12	0.40	1.63	40.0
Hsinchu City	18.7	68.6	38.1	1.25	0.59	1.66	30.5
Taichung City	59.8	75.7	42.0	1.32	0.56	1.76	31.8
Changhua City	56.9	69.4	38.5	1.18	0.67	1.16	32.6
Tainan City	42.4	38.7	21.5	0.86	0.47	0.58	25.0
Kaohsiung City	49.7	55.6	30.9	1.02	0.51	0.74	30.3
Pingtung City	47.9	62.1	34.5	1.54	0.62	1.20	22.4
Hualien City	48.2	75.4	41.9	1.24	0.48	1.75	33.8
Lotung Chen	28.4	70.6	39.2	1.61	1.36	1.49	24.3
Shulin Chen	27.5	72.4	40.2	0.97	0.32	1.02	41.4
Hsinpu Chen	23.2	69.4	38.5	1.29	0.64	1.76	29.8
Fengyuan Chen	52.5	67.7	37.6	1.05	0.66	1.77	35.8
Wufeng Hsiang	67.6	34.3	19.0	0.66	0.38	0.93	28.8
Yuanlin Chen	51.0	63.9	35.5	1.33	0.43	1.19	26.7
Tounan Chen	71.8	68.7	38.1	1.21	0.45	1.22	31.5
Hsinying Chen	55.3	48.7	27.1	1.22	0.44	0.77	22.2
Anping District	46.0	54.6	30.3	0.95	0.44	0.95	31.9
Fengshan Chen	36.1	57.1	31.7	0.84	0.45	0.81	37.7
Chaochow Chen	52.1	69.0	38.3	1.08	0.44	1.27	35.5
Taitung Chen	40.9	54.9	30.5	1.03	0.59	1.42	29.6
Makung Chen	40.3	77.4	43.0	1.08	0.33	0.87	39.8
Average	45.2	64.6	35.9	1.13	0.52	1.27	32.1

Table 7. Chemical analysis of compostable materials in winter refuse

Locality	Chemical Composition (%)						
	Moisture	Organic matter	Carbon	Nitrogen	P_2O_5	K_2O	C/N
Keelung City	73.9	81.4	45.2	1.43	0.45	1.70	31.6
Taipei City	65.3	82.2	45.6	1.74	0.44	1.35	26.2
Yilan City	74.6	66.8	37.1	1.76	0.63	1.07	21.1
Hsinchu City	65.3	79.1	43.9	1.61	0.60	1.54	27.3
Taichung City	58.2	71.5	39.7	1.16	0.62	1.03	34.2
Changhua City	69.1	81.6	45.3	1.32	0.33	1.01	34.3
Tainan City	60.3	71.6	39.8	1.20	0.52	1.24	33.2
Kaohsiung City	66.0	76.3	42.4	1.34	0.55	1.57	31.6
Pingtung City	64.4	73.4	40.8	1.36	0.46	1.24	30.0
Hualien City	72.1	70.5	39.2	1.47	0.83	2.40	26.7
Lotung Chen	78.0	75.5	41.9	1.63	0.55	1.41	25.7
Shulin Chen	67.1	81.3	45.1	1.12	0.28	1.49	40.2
Hsinpu Chen	63.2	77.8	43.2	1.34	0.46	1.98	32.2
Fengyuan Chen	35.4	60.4	33.5	0.76	0.42	0.76	44.0
Wufeng Hsiang	72.5	70.0	38.9	1.24	0.45	1.13	31.4
Yuanlin Chen	62.7	38.7	21.5	0.93	0.60	1.08	23.1
Tounan Chen	87.0	62.2	34.5	1.54	0.54	1.35	22.4
Hsinying Chen	78.9	74.7	41.5	1.71	0.56	2.41	24.3
Anping District	40.4	75.2	41.8	1.25	0.43	0.96	33.4
Fengshan Chen	66.7	74.8	41.5	1.29	0.35	1.61	32.2
Chaochow Chen	80.3	83.5	46.4	1.06	0.30	1.60	43.8
Taitung Chen	54.2	69.8	38.8	0.98	0.69	1.55	39.6
Makung Chen	55.2	77.5	43.0	1.14	0.48	0.99	37.7
Average	65.7	72.9	40.5	1.32	0.50	1.41	31.1

Table 8. Average chemical composition of compostable refuse from 23 cities and towns (%)

Chemical Composition	Summer Refuse		Winter Refuse	
	Range	Average ± S.D.	Range	Average ± S.D.
Moisture	18.7 – 71.8	45.2±13.2	35.4 – 87.0	65.7±11.9
Organic matter	34.3 – 82.6	64.6±12.4	38.7 – 83.5	72.9± 9.6
Carbon	19.0 – 45.9	35.9± 6.8	21.5 – 46.4	40.5± 5.3
Nitrogen	0.66 – 1.61	1.13±0.21	0.93 – 1.76	1.32±0.26
P_2O_5	0.32 – 1.36	0.52±0.20	0.28 – 0.83	0.50±0.13
K_2O	0.58 – 1.77	1.27±0.38	0.76 – 2.41	1.41±0.42
C/N	22.2 – 42.5	32.1±5.8	21.1 – 43.8	31.1±6.5

S. D.—Standard deviation.

In spite of wide variability in physical composition of the mixed refuse, the chemical composition of the compostable materials remains fairly constant irrespective of season and locality. Winter refuse, in general, contains more juicy vegetable wastes, which undoubtedly have some bearing upon its high moisture content. The variability of organic matter content seems to be largely due to the variable amount of soil adhering to the sample rather than anything inherent in the materials. Soil was always found mixed with refuse sample.

For the purpose of rough evaluation, an average compostable refuse could be considered from Table 8 as containing 1 per cent nitrogen, 0.5 per cent phosphoric acid, and 1 per cent of potash on the dry basis. Assuming that the average daily per capita output of the mixed refuse weighs 0.5 kg, and about 50 per cent of this is compostable and contains an average of 50 per cent moisture on the fresh basis, the daily per capita production of nitrogen from refuse would be 1.2 gm. This would give an annual per capita production of 450 gm of nitrogen. On the same assumptions, the annual per capita production of P_2O_5 in the refuse would be 220 gm and of K_2O would be 450 gm. Taking the current prices, the annual per capita production of nitrogen, phosphoric acid and potash in the refuse would total approximately NT$ 6. Thus the annual refuse output in Taiwan would be worth some NT$ 54,000,000 in terms of fertilizer value which is equivalent to 40,000 metric tons of chemical fertilizers. Probably about half of the nitrogen and potash would be lost before the compost reaches the soil. All these figures are very rough approximates,

but they will give some idea of the economic importance of organic wastes to the people on this island.

Along with compostable materials, dozens of samples of refuse compost and of some other miscellaneous materials relative to organic wastes were collected from various localities in order to determine their chemical characteristics. Most of these refuse composts had been buried in the dumps for several months and were well-rotted. Some of them are being utilized by local farmers or sold to sugar mills while some are not utilized and just squandered. Analyses are given in the following tables.

Since buried refuse usually contains an appreciable amount of non-compostable materials such as crockery, stone and brick, these were removed by screening and sorted prior to making an analysis. Taking the average figures given in Table 9 as the basis of calculation, 1 ton of screened refuse compost contains approximately 3 kg of nitrogen, 3 kg of P_2O_5, and 4 kg of K_2O which is worth about NT$ 60 in fertilizer value. In most localities, non-segregated refuse piled up for more than six months is sold at NT$ 20-30 per ton. Complaints have been made by the consumers about the large amount of foreign matter and better segregation is requested.

Table 9. Chemical analysis of buried refuse

Locality	Moisture %	Organic matter %	Nitrogen %	P_2O_5 %	K_2O %	C/N	pH
Taipei [1/]	19.2	12.6	0.34	0.14	0.53	20	7.3
Taipei [2/]	42.0	23.5	0.65	0.40	0.49	20	7.1
Shulin [3/]	20.6	12.3	0.43	0.25	0.28	16	6.8
Hsinchu	22.8	13.5	0.32	0.32	0.53	23	7.3
Changhua	21.1	11.3	0.26	0.30	0.35	24	7.3
Yuanlin	17.8	15.1	0.34	0.35	0.40	25	7.8
Tounan [4/]	26.4	9.5	0.23	0.38	0.50	23	7.4
Tounan [5/]	26.3	8.0	0.23	0.27	0.51	19	7.3
Tounan [6/]	31.7	10.4	0.33	0.37	0.45	17	7.2
Hsinying	46.5	10.7	0.73	0.65	0.52	8	7.8
Hsinying	14.2	10.5	0.32	0.43	0.54	18	7.1
Tainan [7/]	7.8	5.9	0.18	0.21	0.48	18	7.7
Kaohsiung [8/]	14.5	14.4	0.49	0.43	0.50	16	7.5
Kaohsiung [9/]	31.3	13.1	0.42	0.40	0.60	17	7.3
Fengshan [10/]	27.4	19.1	0.58	0.54	0.62	18	7.9
Pingtung	23.4	16.6	0.57	0.55	0.51	16	7.0
Chaochow	22.5	11.1	0.39	0.60	0.49	16	7.4
Taitung	32.8	19.0	0.47	0.43	0.73	22	8.2
Hualien [11/]	12.5	17.9	0.65	0.66	0.52	15	7.2
Hualien [12/]	29.2	15.4	0.40	0.45	0.62	21	8.4
Yilan	40.3	16.1	0.39	0.56	0.41	23	7.5
Makung [13/]	20.6	18.2	0.30	0.39	0.63	24	7.3
Average	25.0	13.8	0.41	0.41	0.51	20	
Standard deviation	9.7	4.2	0.15	0.14	0.10	5	

Note: All percentages, except per cent moisture, based on oven-dry weight.

1/ Open dump around the incinerator house at Talungtung.
2/ Open dump at Tamsui River bank.
3/ Landfill site.
4/ Open dump, taken in summer.
5/ Open dump, sampled in winter.
6/ Open dump with occasional addition of animal excreta.
7/ Landfill site, largely of non-compostable materials.
8/ Refuse compost sold to Chaotou Sugar Mill.
9/ Refuse compost sold to Shaukang Sugar Mill.
10/ Sold to sugar mill.
11/ Summer sample.
12/ Winter sample.
13/ Open dump on the seashore, not utilized by local farmers.

Table 10. Chemical analysis of artificial refuse compost

Locality	Moisture %	Organic matter %	Nitrogen %	P_2O_5 %	K_2O %	C/N	pH
Keelung 1/	24.8	22.1	1.18	4.26	0.52	10	6.8
Taichung 2/	53.8	33.9	1.15	0.64	0.75	16	6.7
Fengshan 3/	57.7	34.4	0.99	1.01	0.80	19	8.1
Pingtung 4/	34.7	24.9	0.75	0.56	0.56	18	7.4
	41.2	17.6	0.51	0.37	0.57	19	7.6

Note: Expressed on oven-dry basis excepting per cent moisture.

1/ Produced by a private-owned compost plant. Enriched by several kinds of organic wastes including nightsoil, rice-hull, fish scrap, bean-cake, animal excreta, etc. Because of the high cost of production coupled with its geographical handicaps, the plant has been closed down. NT$1,200/ton.

2/ Produced by private compost dealer. Vegetable and plant wastes picked out from refuse dump were treated with nightsoil and animal wastes. NT$ 70 per ton.

3/ Composted from cane-stalks, leaves, and straw with animal excreta.

4/ Finished compost (20 day-process) from Pingtung Composting Experimental Station. Cost of production is estimated about NT$35 per ton.

Table 11. Miscellaneous analysis

Materials	Moisture %	Organic matter %	Nitrogen %	P_2O_5 %	K_2O %	C/N	pH
Refuse ash	5.3	7.9	0.16	0.79	1.80	27	8.5
Sewer sludge	63.1	8.3	0.26	0.19	0.42	18	6.6
Soil & ash, screened	15.3	12.5	0.20	0.18	0.46	35	7.7
	19.2	14.8	0.33	0.28	0.57	25	7.9
Rice-hull ash	33.4	7.6	0.13	0.27	0.63	32	8.2
	32.4	13.0	0.64	0.29	0.64	11	7.3
Briquette cinders	—	—	—	0.02	0.34	—	7.9

Since compost is a slow acting fertilizer, the actual value should be computed on the basis of increases of crop yield produced over a period of several rotations. Long-time records indicate that the continuous application of compost results in increase of nitrogen and organic content and the water-holding capacity of the soil. Although short-term results are not truly indicative of trends, still the few short-term records (6) which are available do show good crop response to refuse compost. Field trials on the application of refuse compost for sugarcane on TSC farms at various rates ranging from 12 to 56 tons per hectare have shown an increase of cane yield of from 10 to 25 per cent as compared with

that of those farms not receiving the compost. The increase in value of sugarcane as a result of the use of an average of 30 tons of refuse compost is estimated at as much as NT$2,000 per hectare. The value thus attributed to the refuse compost is calculated at about NT$66 per ton, which is quite impressive.

Examination of the compost data with those afore-shown physical and chemical data for raw refuse reveals that much of the nitrogen and potash were lost during the decomposition process in the open dumps, while the phosphorus content remained fairly constant in spite of dilution through large amounts of soil and cinders.

In general, the resulting compost is neutral or slightly alkaline in reaction, a fact which might have some bearing upon the nitrogen loss. Loss of potash must have largely resulted from rain leaching.

As noted in Table 10, much improvement can be effected if sorted raw refuse is enriched with a certain amount of other waste materials such as nightsoil, stable manure, slaughterhouse refuse and some such other rich materials.

The quality of refuse compost being, to a large measure, determined by the proportional amount of briquette cinders, their efficient and effective separation has been one of the major concerns of the scavenging agencies in various cities and towns. Fine illustrations of successful separate collection can be found in Nantou chen and Lukang chen where dumping of ashes and briquette cinders into refuse bins is prohibited. The raw refuse thus obtained is sold to farmers at NT$20 per ox-cart load in Lukang as compared to NT$ 6 per ox-cart common in places where separation is not practiced. The income realized through the sale of refuse has been of great help in reducing the annual expenditures connected with refuse disposal.

Conclusion

This brief survey has served to throw some light on the composition of urban refuse and the island-wide extent of the problems involved in the disposal of refuse in Taiwan. The primary consideration of the problem should be sanitation—protection of community health. The secondary consideration is making the best use with a minimum expenditure.

To attain both of these aims, several methods may be considered, i.e. sanitary landfill, incineration, composting, etc. The decision to adopt any of these method requires close study of local conditions. Most of the existing disposal methods such as open dumping, sea or river dumping, incineration or burning

come far from offering a satisfactory solution of the problem. The sanitary landfill and incineration methods seem to be inviting from a hygienic point of view. Landfill, however, calls for a great deal of land within reasonable hauling distance, something which is scarcely available for this purpose in Taiwan. The incineration method is more satisfactory since it is a quick and easy way to get rid of the combustible materials in the refuse. This method, however, is not a source of revenue but is a source of added expense. Furthermore, ordinary refuse contains quantities of non-combustibles and these have to be removed.

The authors would not be so bold as to say that composting is the only and best way to tackle the problems; however, there is sufficient evidence leading them to believe that the method of composting could meet the problems most satisfactorily both from the health and agricultural points of view. Rapid increase of population with its consequent intensive land use, the critical shortage of local commercial fertilizers and the enormous foreign exchange used annually to buy commercial fertilizers from abroad (US$ 27 million in 1956) are the reasons urging the use of organic wastes in Taiwan rather than the utter waste of them by burning or by filling in low lands. The extensive utilization of refuse compost in various areas, especially in southern Taiwan, has shown how seriously farmers have attempted to conserve the plant nutrients in such waste products for the improvement of their crops.

There are, however, still many places where town refuse is not being utilized but is just disposed of in a careless and unhygienic way. It is very wasteful to throw away such potential plant foods if they could be utilized in a proper way. In view of the fact that more than two-thirds of the present annual consumption of chemical fertilizers are imported from foreign countries and that the amount of allocated fertilizers is still far from the desired level for most crops, such a wasteful disposal practice as dumping into river or sea is something Taiwan cannot afford to accept especially where there is such a desperate need of organic manures to compensate for the overwhelming shortage of chemical fertilizers.

The problem set before us is therefore to find a system of waste disposal which would be of greater benefit to the people on this island by conserving a greater production of plant foods for increased crop yield and at the same time eliminating the public health hazards associated with organic waste disposal. The composting method gives promise of being able to solve both these problems at one stroke. As disclosed in this survey, more than 50 per cent of

what goes into the refuse dump is suitable for use as compost, and the refuse contains very little obnoxious materials such as glass or metals. If the refuse be composted with the addition of nightsoil, a better quality of compost could be obtained while, at the same time, helping to solve the nightsoil disposal problem of the communities. The high temperature (about 60°C) attained during the composting process can destroy all of the pathogens as well as weed seeds in a short period.

The benefits to be derived through efficient and effective disposal of organic wastes are so enormous that they should deserve the whole-hearted attention of administrative authorities.

The question will eventually arise of deciding between relative merits of private and public management of composting. Private composting enterprise has often been abandoned due to high cost of processing especially in those countries where chemical fertilizers are available at low cost and abundantly. However, in Taiwan profit-making is not the question; the question is one of making the best use of organic wastes with the minimum of expenditure. To expect profit from refuse disposal would be over-optimistic. The income realized through sale of the product might not be sufficient to cover the cost of processing. The municipalities must therefore pay the difference, which, however, will be no more than the cost of disposing of refuse by other methods.

The time seems ripe now for much larger and more coordinated attack on the problems of organic waste disposal and utilization.

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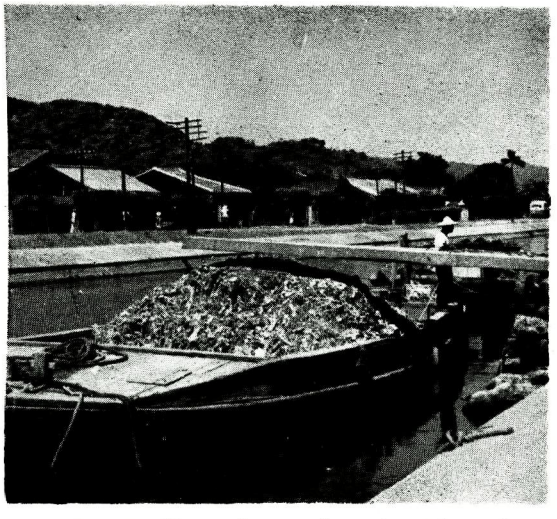
The equipment used in the field survey included screen with large holes of 2 cm square, basket and scale.

Hand sorting of the segregates.



In Keeling city, refuse is shipped offshore and dumped at sea every day except when the sea is rough.

In Hsinchu city, refuse is sold at NT$8 per ox-cart load for composting material. During some seasons the demand is greater than the local supply.

A rag-picker is searching salvable materials in a garbage bin.

Refuse is dumped into the stream. (Chaochow Chen)

Refuse is dumped on the shore. (Makung)