COMPOSTING OF CITY REFUSE [1, 2]

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Man's bad social habits are fast catching up with him. The disposal of solid municipal wastes, including sludge, refuse and industrial wastes has only recently been recognized as one of the most serious problems of community development. Not only is it serious from a sanitation standpoint but the volume is so great that man is almost faced with the problem of "wallowing in his own filth." This waste is overburdening antiquated disposal facilities. Whereas man has been progressing in technology, medicine and science, and has improved his standard of living at a fantastic rate, his progress in waste disposal has not been given the serious attention it requires if we are to survive in modern civilization. The problem has reached alarming proportions in recent years and extends beyond national boundaries.

All waste disposal should be integrated in such a manner as to require the participation of multi-disciplined experts. We are at the threshold of an urgent problem that needs study and action lest it suddenly pass from the realm of urgency to desperation. Fortunately, a few have recognized the full impact of this problem on modern civilization and are making slow but sound progress toward a solution. For example, an "International Research Group on Refuse Disposal (IRGR) has made available certain publications of research involving refuse disposals *(12)*. These research reports and articles have served to focus attention on the problem of adequate disposal of community wastes. John S. Wiley, who has been assigned by the U. S. Public Health Service to the position of Research Director of the sanitary section of its Technical Development Laboratories at Savannah, Georgia, has developed a sound research program leading to a better understanding of the process involved in the composting of wastes. The introduction of a new periodical entitled "Compost Science" in the spring of 1960 further serves to center attention on the disposal of wastes. Papers presented in this journal have particularly emphasized scientific methods and procedures of waste disposal and the logic behind such methods as a proper step forward in the advancement of modern society. Such publications also have pointed out the benefits that can accrue to man in the salvaging of community refuse. A book by Dr. Gotaas entitled *Composting: Sanitary Disposal and Reclamation of Organic Wastes*, published by The World Health Organization *(4)* brings together in an excellent manner the more pertinent literature on composting.

Compost is one of the valuable resources available to man as a byproduct of municipal waste disposal. Compost materials have been dissipated along with our natural resources of water, timber and minerals by our modern civilization. Although this waste has been ignored in the United States and certain other countries, a realization of the advantages of composting city refuse is apparent in many foreign countries such as the Netherlands, where today nearly 30% of all city refuse is converted to compost and this quantity is increasing every year *(9)*.

It is not the purpose of this paper to present the technological aspects of city waste disposal, but rather to emphasize the great agricultural value of city compost. In short, this is an open challenge to agriculture, as well as to industry, to quit standing aloof, allowing potential organic fertilizers by millions of tons to be lost for soil building. Will the agricultural scientist continue to stand by and ignore this tremendous source of organic fertility, which is so seriously needed in our soils to maintain the organic matter? Will modern society continue to allow refuse to be dumped into water sources where it can cause pollution, or to be burned where it can cause air pollution, or to be piled unceremoniously in heaps to decay openly and breed flies, rats and other kinds of vermin?

The answer to these questions is obvious to the sanitary engineer and the scientist who has made careful study of the disposal problem.

Man cannot afford to wait until the exploding population has expanded communities to the extent that sanitary and healthful methods of city refuse disposal are no longer possible. *Now* is the time to face this problem while there is still adequate space and resources to provide suitable disposal facilities. *Now* is the time for agricultural scientists to apply scientific experience and knowledge to the practical problem of the use of refuse compost for improving the productivity of soil and establishment of better plant growth such that both the grower and the compost producer can profit. An outlet for the city

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refuse compost must be found or it will accumulate to fantastic quantities. The agricultural industry cannot afford to allow this valuable source of organic matter to be wasted or used in any way except on the soil.

ADVANTAGES OF COMPOSTING

Composting of municipal refuse is generally considered by the researcher in the field of waste disposal as being technically feasible. Some of the advantages of composting municipal refuse are listed as follows:

1. Provides a new and more effective and sanitary method of refuse disposal.

2. Supplies a source of organic matter for maintaining and building seriously depleted supplies of humus in soil.

3. Reclaims certain valuable materials, such as, metals, glass, cardboard and rags.

GENERAL NATURE OF CITY REFUSE

Raw refuse from cities in the United States differs considerably from that in Europe where the practice of composting refuse is fairly well established. For example, there is much more paper, rags, metal and glass in the United States than in European refuse. The city refuse in the United States is highly cellulosic, mostly because of the great amount of paper it contains. Proteinaceous materials are low in proportion to cellulosic materials. Readily available carbohydrates are also proportionately lower in city refuse from the United States as compared with that of Europe. Most city refuse has a surprisingly low moisture content. Because of these basic differences in the raw refuse, the well-established composting processes in Europe, for example, require modification before they can be successfully employed in the United States. Certain modifications, however, can readily be made by competent engineers working together with biological scientists. The adaptation of the Dano Bio-Stabilizer as originally established in Europe to processing of refuse in the United States is a good example of this point *(3)*. It should be pointed out also that successful European methods are not directly applicable to the United States because of differences in psychology of the public health with respect to space, time, engineering, and need and use of composts.

In 1952 the University of California made analyses of a large amount of mixed refuse from Berkeley, California, as a result of compost studies *(11)*. The data in Table 1 show that this material had a large amount of salvageable material and a modest amount of compostable material, about 68% on a weight basis.

TABLE 1—AVERAGE COMPOSITION OF MIXED REFUSE FROM BERKELEY, CALIFORNIA[a]

Physical Composition		Chemical Composition	
Kind	Amount	Kind	Amount
	(%)		(%)
Tin cans	9.8	Moisture (as collected)	49.3
Bottles & broken glass	11.7	Ash (dry basis)	28.5
Rags	1.6	Carbon (dry basis)	35.7
Metals	0.9	Nitrogen (dry basis)	1.07
Non-compostable waste of no value	7.6	Phosphorus as P_2O_5 (dry basis)	1.16
Compostable material	68.4	Potassium as K_2O (dry basis)	0.83

[a]Taken from Univ. of Calif. Tech. Bull. 2. 1952. *(11)*.

MICROBIOLOGICAL ASPECTS OF COMPOSTING

Inoculation of refuse for composting has not proved necessary if the conditions favorable for composting are provided. Organic refuse is teeming with indigenous microorganisms that multiply rapidly when the proper factors are provided. Both mesophilic and thermophilic organisms play important roles. Bacteria, fungi, streptomycetes and algae are active in the compost process. There is some evidence that the fungi are the dominant organism under dry conditions, whereas bacteria dominate under wetter conditions of composting. The saprophytic bacteria and fungi are the most active. These outgrow and aid in the elimination of parasitic organisms. Thus nature has a way of purifying man's refuse. The final compost from most processes may be used without fear of diease organisms.

PHYSICAL ASPECTS OF COMPOSTING

According to Snell *(7)* proper grinding is the key to efficient composting. Grinding vastly increases the surface area exposed for microbial attack. This facilitates penetration and invasion of the organisms. Grinding also breaks down natural barriers such as the effect of lignin, which physically blocks the penetration of organisms to the more readily available carbon sources *(2)*. Oxygen can penetrate the organic wastes more readily when they are ground. Grinding or mechanical pulverizing also facilitates the mixing of different kinds of refuse. Acid or alkaline residues are thus neutralized and made more suitable for rapid attack. Another advantage of grinding is the mixing of organisms indigenous to different kinds of materials and spreading of organisms of greater population to areas of less population. Less heat and moisture are lost during the process of composting as a result of grinding. Perhaps one of the most important advantages of grinding is the insurance of a more uniform product and a product that does not resemble the beginning refuse in an obvious way. Although grinding is very important in the production of a suitable compost, grinding, pulverizing or shredding will not substitute for the microbiological process essential for the production of good compost.

Temperature during composting is vitally important to the production of a suitable compost. Temperatures should be sufficiently high for a sufficient length of time, according to Snell *(8)*, to accomplish three objectives. *(a)* destroy pathogenic organisms, *(b)* destory weed and vegetable seeds, and *(c)* destory fly eggs and larvae. Gotaas *(4)* suggests that a temperature of about 60°C be maintained for about one hour to kill pathogens. Most seeds are killed if a temperature of about 50-55°C is maintained for a few days under moist conditions. Snell *(8)* cautions against prolonged high temperatures of 70-75°C for fear of slowing down some of the beneficial microbial activity and causing nitrogen to be lost.

CHEMICAL ASPECTS OF COMPOSTING

Composting is accomplished best under aerobic conditions. Excess of water can cause anaerobic conditions. Odors accumulate and often the process is slowed if the moisture exceeds about 70%. Fly breeding is held to a minimum by keeping the compost moist but not soggy. Control of a favorable hydrogen ion relationship in the compost also is accomplished better under aerobic than anaerobic conditions.

According to Toth *(10)* the average composition of some fertilizing constituants of garbage is as follows: ash 29%; nitrogen (N) 1.0%; phosphorus (P_2O_5) 1,2%; and potassium (K_20) 0.8%. Composting would tend to increase these values due to the net loss in weight by CO_2 evolution as a result of microbial activity. There is a wide varation in the N, P_2O_2, and K_2O contents of city refuse. Some cities include home trash, trees, yard prunings, etc., in their garbage collections.

Generally, nitrogen content of refuse determines its rate of decomposition and subsequent compost production. Unless the nitrogen content is between 1.25 and 1.50% on a dry weight basis the lack of this element prohibits compost formation at a maximum rate. Moreover, compost of less than this level of nitrogen will cause nitrogen starvation in plants if applied to soils low in native nitrogen *(10)*.

For the most part, phosphorus and potash content of city refuse is sufficient to support maximum compost production if other factors are favorable.

GENERAL CHARACTERISTICS OF MUNICIPAL WASTE COMPOST

The chemical characteristics of city refuse compost varies widely depending upon the kind of material composted and the specific process employed. If the beginning material is high in protein or nitrogenous substances such as excreta, slaughterhouse wastes, sludge, etc., it will be higher in nitrogen than composts made from refuse containing home prunings, trees, shrubs, dirt and ash. According to Gotaas *(4, 5)* a wide range in composition has been reported by various authors for municipal compost, see Table 2.

TABLE 2—CHEMICAL COMPOSITION OF SOME REPRESENTATIVE MUNICIPAL COMPOSTS[a]

Substance	Percentage by Weight
Organic matter	25 -50
Carbon (as C)	8 -50
Nitrogen (as N)	0.4- 3.5
Phosphorus (as P_20_5)	0.3- 3.5
Potassium (as K_20)	0.5- 1.8
Ash	20 -65
Calcium (as Ca0)	1.5- 7

[a]Taken from Gotaas *(4)*

McGauhey and Gottas *(6)* reported the characteristics of municipal garbage and refuse which contained considerable quantity of paper as having the following values: N about 1.4%; P_20_5 about 1.1%; K_20 about 0.8%; carbon about 28%; and ash about 37%. Fuller, *et al.* *(1)* report that refuse high in paper processed by the Dano process had a composition of about 0.92% N; 0.57% P_20_5 and a pH value of 7.1. Other samples taken from this same process, though not previously reported by our laboratory had nitrogen values ranging from 0.9 to 1.3% N and phosphate values ranging from 0.5 to 0.9% P_20_5.

The pH of municipal compost prepared by aerobic process finally ends up at a value near neutral or slightly alkaline even though the initial pH value of the compostable material may range from 5.0 to 7.0.

The physical condition of the compost is greatly controlled by the initial grinding, shredding or pulverizing employed. Refuse composted in mechanical digesters can be ground finer than that composted in windrows. Thus, in general the final products will differ considerably in appearance depending on the process used. Fine grinding usually results in a product that less closely resembles the beginning refuse than coarse grinding or no grinding. Some processes grind after composting as well as before. This tends to make a more uniform product which is more readily accepted by the public.

The color of compost varies from a dark gray to a deep brown or deep gray-brown.

Most city compost contains some bits of metal, glass and hard materials that are not altered by the microbiological process involved in composting. These materials will appear in the final product, depending on the extent of removal by screening and other means, upon the termination of composting. Their importance is determined by their nuisance and aesthetic value as assessed by the user rather than their harmful effects in the soil.

AIMS FOR A GOOD COMPOST

Fertility value

Compost should contain at least 1.5 nitrogen on a dry weight basis to insure against the possibility of causing nitrogen starvation to plants when incorporated into soil. When the nitrogen content is below 1.5% the material decomposes slowly and nitrogen starvation may appear in plants grown on soil where the compost is applied. The use of commercial nitrogen either as an additive to the compost or to the soil will improve the effectiveness of the compost. Usually compost is sufficiently supplied with phosphorus, potash and micronutrients so these elements are not apt to be a factor in its use for plant production. Only if the phosphorus content of the compost falls below about 0.2% P will it be a factor in limiting plant growth. It should be kept in mind, however, that as decomposition proceeds all the plant nutrient elements are released gradually for use by plants. Only during the initial stages of decomposition may the microflora offer a problem of competition with the plant for nutrient elements.

Physical conditions

A good compost is relatively finely divided but also possesses certain granulation that occurs during the latter stages of formation. Compost that has been initially finely divided has less characteristics of the original refuse. Certain amount of granulation of the product is desirable to eliminate the unpleasantness of a dust product.

Moisture content

The final moisture content of compost is important for three main reasons: *(a)* ease of handling and transport to ultimate destination, *(b)* transportation costs, and *(c)* sound public acceptance. One of the most variable characteristics of compost is its moisture content. The moisture content of certain composts from bio-stabilizing or rotating drum processes, however, is surprisingly uniform. The final moisture content of windrowed compost will depend upon the local climatic condition, time of the year and public demand for the compost as well as the procedures employed. Perhaps a good figure at which to aim is 25% or lower. Establishment of this value for the final product, however, does not imply that maintenance of a favorable moisture content between 50-70% during the composting process need be jeopardized but that some means should be employed to get rid of the excess moisture before marketing.

Freedom from appearances of raw refuse

Regardless of who uses the compost, sales appeal is greatly affected by appearances of the original refuse. Identifiable pieces of metal, advertising labels, plastic or glass is not desirable. Even fine glass may present resistance to acceptance of city refuse compost.

Freedom from unpleasant odors

It is important to avoid sales resistance as a result of a product having unpleasant odors. Certain composting processes are not concerned with unpleasant odors because of their strict maintenance of aerobic conditions.

Agricultural value of compost from city refuse

The agricultural value of certain composts has been well established. On the European continent, for example, composts derived from rotted crop residues have been used for centuries. In Japan and China, composts of animal excreta are highly valued for use in food crop production. More recently, composts from municipal refuse have been in demand for soil building in Western Europe. Research on agricultural use of composts made from city refuse in the United States has received limited attention. This is due in part to the limited supply available since composting of city refuse in the United States is a relatively new industry and in part to the lack of awareness the agricultural scientist has for conservation of this natural resource.

The lack of formal research on compost from city refuse from the United States would not be serious except that there is no other compost material with which it can be compared. Certain chemical and physical properties of the final product differentiate it from that of the European continent. For this reason, Fuller, *et al.* *(1)* at the University of Arizona conducted crop tests on the efficient use of municipal compost made by the Dano Process of Sacramento, California.

Municipal refuse compost made by the Dano Process was applied to two Arizona soils of agricultural importance and planted to two test crops, tomato and cotton, to study its effect on plant growth and nutrient uptake under greenhouse conditions. Comparisons were made with and without supplemental soluble nitrogen and phosphorus, alone and together.

The results showed that the compost stimulated growth of both crops whether added alone or together with supplemental nitrogen and/or phosphorus. There was an effective residual influence of the compost on a succeeding crop of cotton. Both crops, however, obtained nutrients directly from the compost. The value of this city refuse compost for enhancing plant growth and for supplying certain nutrients was well demonstrated.

There is a definite advantage in supplying additional soluble commercial nitrogen and phosphorus either to the compost directly or to the soil where composts from city refuse are used for growing crops. A wise combination of commercial fertilizer and compost application for obtaining maximum crop production is suggested.

Compost plays another important part in agricultural production in addition to enhancing plant growth and providing plant nutrients. This is related to the physical condition of the soil. Soil organic matter has long been advocated as playing a key role in the physical condition of the soil and thereby functions in the favorable control of water and air movements. Compost provides the necessary beginning point for maintenance of soil organic matter. Soil organic matter is formed during compost decomposition. Only by decomposition of the compost in soil can it benefit plants. Only by decomposition can biological products be formed to improve soil tilth and can nutrients such as nitrogen and phosphorus and micronutrients be released for use of higher plants. Maintenance of even small amounts of organic matter in soils is critical to a favorable agricultural economy.

Composting of city refuse must become a part of our social structure not only as a means of correcting a serious waste of one of our most valuable resources but to meet the coming demand for sanitary and pollution-free living in a period of high development of modern civilization.

Research at all levels of compost production as well as marketing is seriously needed to solve this refuse disposal problem if civilization is to avoid being blindly backed down the dead-end street of antiquated disposal methods.

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