Neth. J. agric. Sci. 29 (1981) 49-61

Results of municipal waste compost* research over more than fifty years at the Institute for Soil Fertility at Haren/Groningen, the Netherlands

S. de Haan

Institute for Soil Fertility, P.O. Box 30003, Haren-Gr., the Netherlands

Accepted: 9 December 1980

Key words: municipal waste compost, plant nutrition, macroelements, microelements, soil organic matter

Summary

Results of research on municipal waste compost as an organic fertilizer or soil amendment at the Institute for Soil Fertility since the 1920s are reviewed. Until about 1950, municipal waste compst was used principally on agricultural soils (mainly reclaimed cut-over peat and heath soils). Between 1950 and about 1970, about equal proportions of compost were utilized in agriculture, horticulture, and in amenity areas; since 1970, amenity areas have demanded the largest share.

Since more than 90 % of the compost is now applied in amenity areas, there is little risk for food chain crops from potentially toxic substances which may be present in municipal waste compost in rather high concentrations.

The main producer of municipal waste compost in the Netherlands is the VAM Waste Disposal Company, with a rather constant production level of about 100 000 tonnes per year. In 1980, the VAM put into use the first large-scale domestic refuse recycling plant, yielding about 33 % of organic residues suitable for compost production besides paper (20 %), metals (2 %) and plastics (5 %).

The current tendency in the Netherlands towards large-scale recycling of municipal waste components may lead to an increased compost production. Because the recreational sector can only absorb limited quantities, this compost would largely have to be disposed of on agricultural land. In such a situation limits for maximum permissible concentrations of potentially toxic substances in this compost, and maybe also maximum permissible application rates would have to be set: for sewage sludge such limits already exist.

* The words municipal, town and domestic, and waste and refuse are used as synonyms in this paper. Municipal waste compost is abbreviated to MWC, occasionally.

Introduction

Domestic waste has been used within the memory of man as a fertilizer or soil amendment. Up to this century, town refuse was in fact the only means – from outside agriculture – to raise or maintain soil fertility or to reclaim waste lands. In the province of Groningen, where our institute is situated, since about 1600 large areas of moorland, after peat excavation for heating purposes, have been transformed into fertile land with refuse from the city of Groningen, which up to modern times was able to pay its expenses for education from waste revenues.

Circumstances changed towards the end of the nineteenth century, on the one hand because of the introduction of chemical fertilizers, which made farmers less dependent on organic fertilizers, and on the other hand because of the introduction of the water closet and other conveniences. As a result, the part of the waste richest in plant nutrients was voided into the surface water as sewage, at first without, and now mostly after purification, leaving the sewage sludge behind.

This paper deals with the solid part of household and town waste insofar as it is used, after composting and screening, as an organic fertilizer. Composting and screening is usually done the other way around, but the VAM Waste Disposal Company, by far the biggest compost producer in the Netherlands, produces compost by composting before screening. In any case, it has only done so in this way up to the introduction of new separation techniques in 1980.

The liquid part of the waste is only dealt with in this paper as far as it is, as more or less dewatered sewage sludge, mixed and composted together with the solid part of the waste from which, in this case, the non-compostable part has been removed beforehand. Composting sewage sludge together with solid town refuse is a common practice in some countries, but not in the Netherlands up to now, because of organizing problems. However, research was done in this field at our institute, and results will be reported.

Municipal waste compost as a remedy against 'heath reclamation disease'

In the first decades of this century in the Netherlands and neighbouring northwest Germany, large areas of heath were reclaimed with mineral fertilizers only, but misfortune did not stay away. Especially on formerly wet sites, with incipient peat formation, crops suffered from a disease which later was found to be caused by copper deficiency. Municipal waste compost, or town compost as it was called in those days, proved to be a good remedy against this disease.

Town compost in those days was still built up from solid waste from homes, streets, parks, etc. and human faeces collected separately, but mixed with the solid waste afterwards. The Institute for Soil Fertility, at that time named National Agricultural Research Station, started experiments in 1923 with the single waste components as remedies against heath reclamation disease. Solid domestic waste, notwithstanding its low nutrient content, proved to be the best remedy (Hudig et al., 1926/27).

The VAM Waste Disposal Company as producer of municipal waste compost

As a consequence of the favourable effect of solid town refuse, a composting plant was set up by the VAM Waste Disposal Company in 1929 near Wijster in the north-eastern part of the Netherlands, which at that time still comprised large tracts of heath and moorland. The refuse was, and is still, transported by special trains, in the first years from The Hague, about 200 km away, now from many other cities and municipalities throughout the country.

The refuse to be processed into compost is moistened and deposited in large windrows (Fig. 1), which at regular intervals are turned with cranes. After about eight months the compost is separated from the uncompostable components. Among these are metals, and because they are removed at the end of the process, the heavy-metal content of VAM compost is rather high. Up to some ten years ago attention was only paid to the micronutrients among the heavy metals: Cu, Co, Fe, Mn, Zn.

The VAM compost plant in Wijster now produces about 100 000 tonnes of compost per year from the refuse of about one million people. The uncompostable part (about two thirds now) is removed to an adjoining company-owned dumping site,

Fig. 1. One of the four railway tracks along which the refuse is transported, and the adjoining refuse windrow, at the compost plant of the VAM Waste Disposal Company at Wijster.

together with the waste from another two million people, for wich no composting facilities are present, and which is partly transported by trucks. The situation may change in the near future because of the new Waste Act obliging each province to solve its own waste disposal problems, as far as non-chemical waste is concerned.

Macroelements in municipal waste compost

Contents of the main plant nutrients N, P and K are rather low in municipal waste compost compared with farmyard manure. The Ca content of MWC is rather high, and the same is true for the S content (Table 1).

Not only the percentage, but also the plant availability of nutrients is generally low in MWC compared with mineral fertilizers. Much research in this field was done at our institute during World War II and the first years thereafter when, as a consequence of shortage of fertilizers, even the small contribution of nutrients in MWC was important. According to Rowaan (1949), availability of nitrogen in MWC was 10 % in the first year, with no after-effect in the second year, and of phosphorus 10-15 % in the first as well as in the second year. Roorda van Eysinga (1967), however, found a negative effect of MWC on P uptake by tomatoes and on the content of plant-available (= water-soluble) P in the soil, and the same was found by de Haan (1980a, b) for various crops and various soils treated repeatedly with MWC since 1948.

Potassium is as available in MWC as in normal mineral K fertilizers, and also magnesium is easily available. Calcium is, we know, more a regulator of soil pH than a nutrient. In comparison with an equal amount of Ca in mineral fertilizers, Riem Vis (1969) found a smaller effect of Ca in MWC on soil pH, and de Haan (1955) less scab on potatoes, the development of which is favoured by liming.

Total content of soluble salts in MWC is generally rather low (1-2 % of DM) allowing its use as a soil amendment in rather large quantities.

Table 1. Contents of macro-elements in dry matter of municipal waste compost and in farmyard manure.

	Municipal waste compost			FYM
	Netherlands	FRG[1]	France[2]	
% N	0.96	0.7	0.9	2.50
P_2O_5	0.75	0.6	0.6	1.60
K_2O	0.33	0.5	0.3	1.70
CaO	3.00	5.0	5.6	1.90
MgO	0.28	0.7	0.5	0.80
Na_2O	0.40	–	0.4	0.45
Cl	0.32	–	0.5	0.90
SO_3	0.80	–	1.5	0.55

[1] Kumpf/Maas/Straub (1977).
[2] Pommel & Juste (1977).

Municipal waste compost as a source of soil organic matter

The organic matter content of MWC is about 30 % on a dry-matter basis. Until the introduction of natural gas as a source of energy, organic matter in MWC consisted for about 60 % of non-combusted remnants of household coal (de Haan, 1972). At our institute, Gerretsen developed a method to determine the content of household coal in MWC (Gerretsen & Campen, 1958). The difference between total organic matter – determined by loss-on-ignition, with a correction for content of $CaCO_3$ – and household coal was considered to be active organic matter. The content of active organic matter is now determined at our institute according to the Walkley-Black method, as modified by van Dijk and de Roos (1973).

The effect of organic matter in MWC on the organic-matter content of soils was studied at our institute by Kortleven (1963). To study the effect of MWC on the productivity level of soils, a series of more than 20 field experiments was laid out in 1948 on different soils in different parts of the country. In these days it was thought that the yield level of soils could be raised by increasing the organic-matter content, which for the country as a whole was only possible by utilizing municipal waste compost. Intensification of the livestock industry, leading to a surplus of organic manures in many regions, had not yet started at that time.

The series of experiments showed that on well-cultivated soils maximum yields could hardly be improved by using MWC. The most important positive effect of MWC was due to its lime content, which became apparent especially in the yield of sugar beet on acid soils (Kortleven, 1956; de Haan, 1972). Following frequent applications of MWC the effects may become negative on some soils, whereas on other soils there may be a significant increase in maximum yields (de Haan, 1979).

Microelements in municipal waste compost

Contents of microelements in municipal waste compost in the Netherlands (average values for VAM compost from 1967 to 1978), the Federal Republic of Germany, France and Switzerland are presented in Table 2 and compared with farmyard manure. Compared with FYM, contents of microelements in MWC are high, with large differences among countries, as a result of differences in systems of waste collection (with or without industrial waste), and differences in composting and analytical methods.

Within a few years after the above-mentioned series of experiments had been laid down, especially oats on light sandy soils showed symptoms of manganese deficiency, which were then regarded as a consequence of an increase in soil pH. In 1965, leaves of sugar-beet on plots of a reclaimed peat soil, which had been treated regularly with MWC since 1948, showed chlorotic symptoms. Smilde (1969) found excessive zinc concentrations in these leaves, especially in comparison with leaves from plots treated with lime in amounts equivalent to those in MWC. According to Arnold Bik (1969), MWC could replace up to 5 % (by volume) of the potting soil for flower crops without damage to the crops due to excess zinc.

Of the experiments laid out in 1948, six are continued as a micro-plot field experi-

Table 2. Contents of microelements in dry matter of municipal waste compost and in farmyard manure.

	Municipal waste compost				FYM
	Netherlands	FRG[1]	France[2]	Switzerland[3]	
As	9	7	–	–	1
B	60	32	60	–	18
Cd	6	3.7	7	12	1
Cr	220	–	270	–	20
Cu	630	266	250	780	40
Hg	5	2	4	–	0.1
Mn	400	–	600	–	230
Ni	110	–	190	90	4
Pb	900	230	600	1570	20
Zn	1650	1000	1000	2330	160

[1] Kumpf/Maas/Straub, 1977.
[2] Pommel et Juste, 1977.
[3] Keller, pers. communication, 1979.

ment on the grounds of our institute at Haren since 1965. In this experiment, the main soil types in the Netherlands are represented, namely three sandy soils with a humus content from 3 to 10 %, and three clay soils with a clay content from 10 to 40 %. MWC has been applied in amounts of 0, 10, 20, 30 and 40 tonnes/ha biannually from 1948 to 1971, and annually since 1971.

Fig. 2 gives an impression of the effect of such frequent MWC applications on the chemical composition of the soils and of crops grown on these soils. In Fig. 2 the mean values for macro- and microelements in the soils in 1975 (after 15 applications) and in the edible part of five crops (carrots, red beet, turnips, peas and dwarf beans) grown on the soils in 1974 (after 14 applications) are presented.

Fig. 2 shows that especially the soil microelement concentrations have increased. Effects in crops are, generally, much less pronounced and sometimes opposite to the effects in the soils. In plants, Mo concentration was found to increase strongest. Mn concentrations in the plants usually decreased rather strongly. Both effects may be related to the effects of MWC on soil pH, although excessive pH effects were moderated by application of lime or sulphur at lowest or highest MWC application rates, respectively. Molybdenum as an anion becomes more mobile with increasing pH contrary to manganese and other heavy metals. The decrease in plant Mn may also result from a Zn/Mn antagonism. Plant Zn increased rather sharply. The rather large differences between soils and crops, will not be discussed here.

Polycyclic aromatic hydrocarbons (PAHs)

Besides heavy metals, other substances may be present in MWC in undesirable concentrations. PAHs may occur in MWC in much higher concentrations than in soils. They originate from incomplete combustion of wood, coal, etc. Some PAHs, for

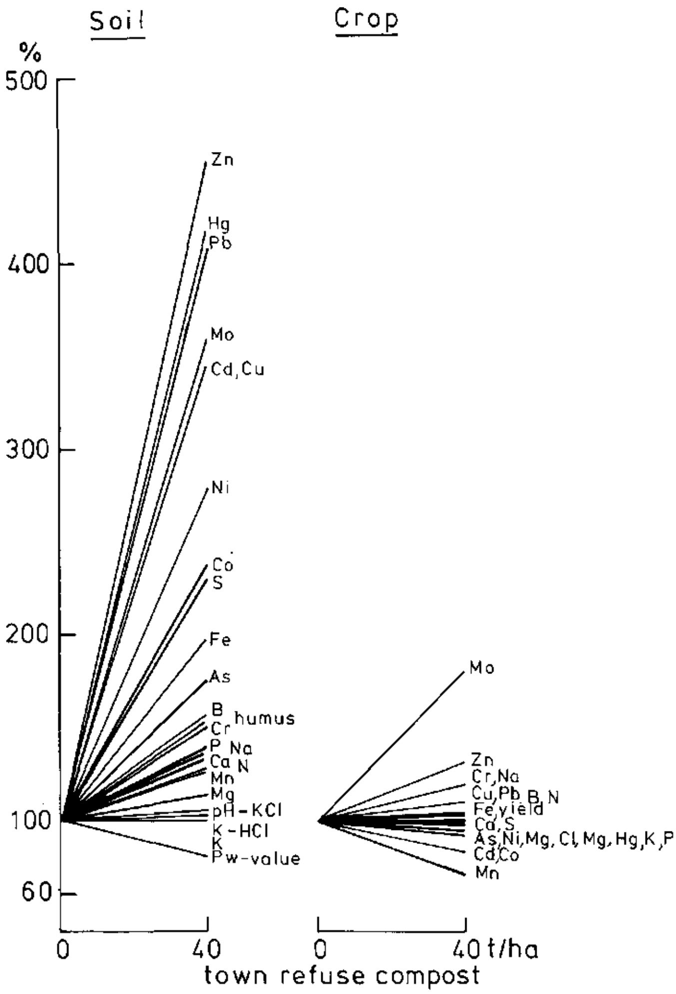

Fig. 2. Effects of municipal waste compost application, continued since 1948, on the chemical composition of soil (in 1975) and crop (in 1974; control = 100 %).

example benzo(a)pyrene, are said to be carcinogenic. Much attention has been paid to this aspect in the German Federal Republic in recent years (Ellwardt, 1977; Harms, 1977; Martens, 1977). In the Netherlands, up to now, PAHs have not been considered problematic in relation to MWC.

Soil/MWC mixtures with up to 100 % MWC as substrates for crop growth

In 1951, a micro-plot field experiment was started at our institute to study effects on crop growth and the formation of humus from MWC without and with bentonite (5 %). Bentonite was expected to favour humus formation. One of the treatments in this trial was 100 % MWC, without and with bentonite, on which normal crop growth was found to be impossible because of heavy-metal damage (Mn deficiency?). Even on the substrate with 5 % bentonite normal crop growth was impossible; results with bentonite were better, however, than without (Kortleven, 1970; de Haan, 1972).

The results of this experiment gave cause for another experiment in 1972, this time in 150-litre vessels equipped to catch drainage water, to investigate the extent to which soils could be replaced by MWC without damage to the crop. For this purpose a light sandy soil and a heavy clay soil were mixed with MWC in the following ratios (bij volume): 100/0, 90/10, 80/20, 50/50 and 0/100. In this trial yields have so far been highest on 100 % MWC. Especially zinc contents in the crops increased with increasing MWC ratio. In the drainage water Zn contents increased only slightly. Fig. 3 shows cumulative Zn amounts over the period 1972-1977 in crops and drainage water.

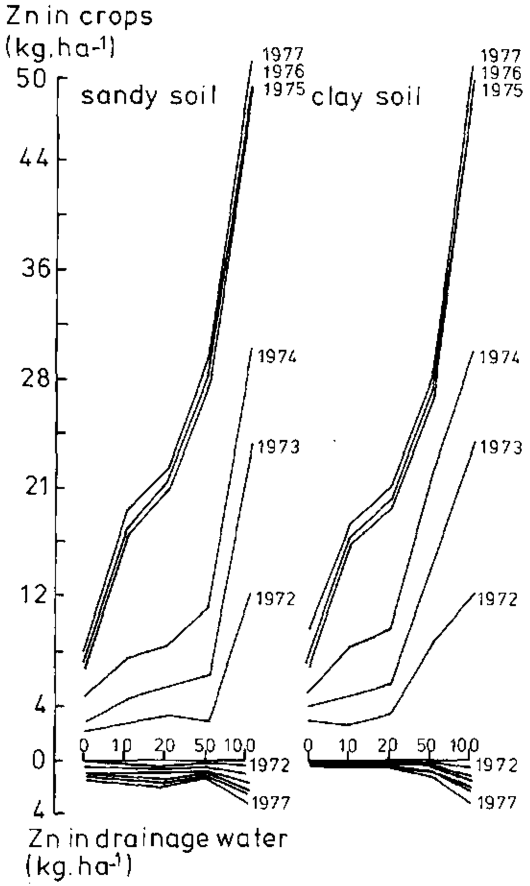

Fig. 3. Cumulative (1972-1977) amounts of zinc in crops and drainage water as affected by increasing MWC ratios.

Fresh (Dano, 'Rasp') compost compared with mature (VAM) compost

As a result of the composting process the VAM Waste Disposal Company produces mature compost. Between 1950 and 1970 sixteen new compost plants were constructed in the Netherlands, eleven working after the Dutch 'Rasp' system and five after the Danish Dano system. In the first system the raw refuse is reduced to smaller particles by means of a rasp; the product can be used immediately, a.o. as hotbed packing, or after a composting (= fermentation) process. In the Dano system, the raw refuse is disintegrated during prefermentation during one or two days in a rotating drum. In both systems, the largest components, including metals, are removed beforehand, resulting in a lower heavy-metal content in the compost compared with VAM compost.

At that time several field experiments were carried out at our institute to compare the effect of fresh and mature compost on crop growth. It was found that after spring application results were better with mature compost in the first year, but with a better after-effect for fresh compost in the second year. After autumn application results with fresh compost were already better in the first year following application (Kortleven, 1956).

Gerretsen et al. (1956) found a negative nitrogen balance for fresh compost during the first two months of fermentation; after two months the nitrogen balance turned positive.

Of the sixteen new compost plants mentioned above, only two are still operational. Lack of appropriate sites for dumping the ever increasing proportion of non-compostable components forced the other plants to close down.

Special compost

The VAM Waste Disposal Company produces a variety of special composts. The most important of these are an extra fine grade compost, used as topdressing for lawns, sports grounds, etc. and peat compost, used especially in the construction of recreational areas adn horticulture. Experiments conducted at our institute showed that a mixture of 60/40 (v/v) peat and compost, respectively, was the optimum ratio for peat compost to be used in horticulture (Riem Vis, 1968).

Combination of municipal waste compost and sewage sludge

In 1955 our institute was concerned for the first time with a combination of solid and liquid municipal waste in an experiment in which the possibility was studied whether liquid sewage sludge could be used to give solid waste the moisture content necessary for fermentation. For this purpose, rasped solid waste was mixed with liquid sewage sludge (5 % DM) in amounts varying from 0-200 % of the weight of the solid waste. It is self-evident that for such a procedure under practical circumstances proximity of the compost and sewage purification plants is a prerequisite.

The experiment showed that rasped solid waste could be mixed with liquid sludge up to one third of its weight without measures being necessary to prevent moisture flowing from the heaps. Effects of sewage sludge addition on compost quality, measured as yields of experimental crops, were not significant (Kortleven, 1960; 1969).

More recently, experiments were carried out with combinations of peat compost and air-dried sewage sludge from drying beds. These experiments showed a better N and P effect of the combinations with sewage sludge compared with compost only (Kortleven, 1969; de Haan, 1977). Heavy metal contents of crops were somewhat lower with peat compost compared with an equivalent addition of sewage sludge. The reason for this may be a more positive effect on soil pH of peat compost compared with sewage sludge.

Municipal waste compost as a mulch in orchards and as a protectant against soil erosion by wind and water

The effect of a mulch of normal compost (3 cm) and of peat compost (3 and 6 cm) on bitter pit in apples (Cox's Orange Pippin) was studied in the orchard of the VAM Waste Disposal Company in Wijster. Bitter pit is connected with calcium deficiency, and the rather high calcium content of VAM compost might have a favourable effect. This could not be ascertained in this experiment, however (van der Boon & Das, 1969).

In a wind tunnel, the effect of MWC as a protectant against wind erosion on dune sands used for flower-bulb growing was studied. Normal compost proved to be a better protectant than extra fine grade compost, but the amount needed was rather high (70 t/ha). Subsequent sprinkling improved the effect (Knottnerus, 1965).

In another experiment Dano and Rasp compost showed a still better effect than normal VAM compost. However, the best results were obtained with liquid VAM compost (one part compost to two parts water; Knottnerus, 1969).

Liquid compost is used also to protect newly constructed road banks against wind and water erosion. A grass-seed mixture is added to the liquid compost then and this mixture is spread by a special machine ('hydroseeder'). For this purpose, extra fine grade compost proved to be better than normal compost because there is less risk of spray nozzles blocking up. Twenty-five tonnes compost/ha proved to be sufficient. Under favourable circumstances, the protective function of the compost mulch is taken over by a grass cover after 2-3 months (Knottnerus, 1976).

Municipal waste compost and recycling

As in other developed countries, in the Netherlands attempts are made to solve the waste disposal problem by relating it to the existing or foreseeable shortage of energy and raw materials. Against this background, the VAM Waste Disposal Company in Wijster had a domestic refuse separator built (Fig. 4) in which paper (20 %), metals (2 %), plastics (5 %), organic residues as raw material for compost production (33 %), and in a subsequent phase also glass (10 %) will be recovered from the refuse.

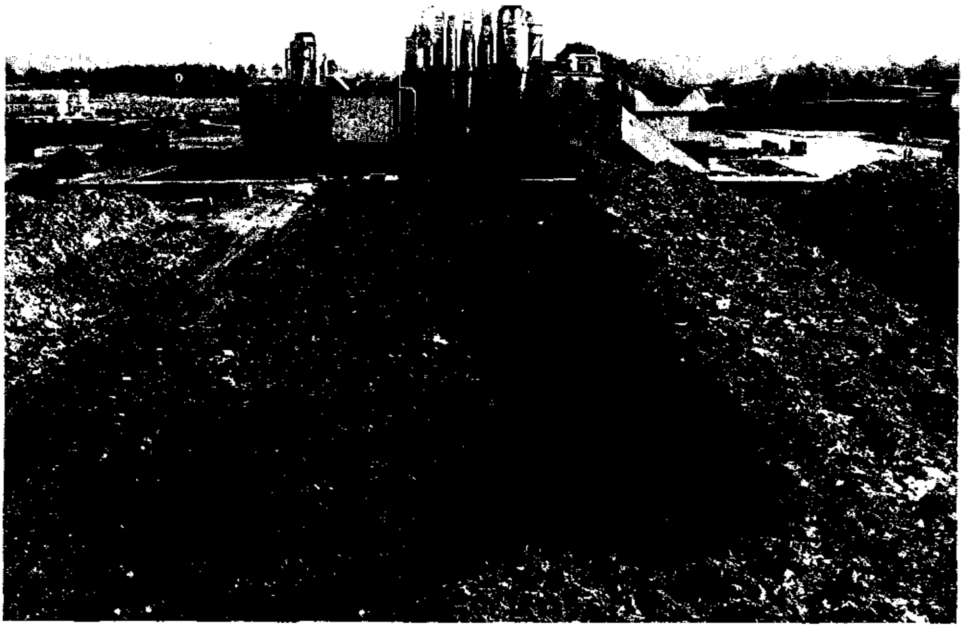

Fig. 4. Domestic-Refuse Separator of the VAM Waste Disposal Company in Wijster.

In a pot experiment at our institute the value of compost, produced by this system from Dutch domestic refuse in a pilot plant in Sweden, has already been tested. Especially with regard to its nitrogen effect the new compost seems not essentially different from the traditional compost (Riem Vis, 1968). Heavy metal contents in the new compost are much lower, and this may enlarge its applicability.

Concluding remarks

Times change and man changes with them. This is especially true for man as a producer of waste. In recent times the amount of waste produced has increased strongly, while its composition has changed. Not more than about a third can nowadays be used as a raw material for compost production and it is difficult to separate this part from the rest in such a way that it is free from undesirable elements not originating from the food chain.

It is true that soils are, dependent on their characteristics (pH, clay and humus content), a good sink for potentially toxic organic and inorganic substances because of processes of decomposition and immobilization taking place in the soil, but the capacity of soil as a sink is not unlimited. Excessive concentrations of toxic substances must, therefore, be avoided, not only to maintain existing productivity levels, but also to protect consumers against excessive concentrations of toxic substances in their food. Crop growth may be normal, while concentrations of toxic substances with regard to human and animal health may be already too high.

Standards for maximum permissible concentrations of toxic substances in soils and food crops, as well as in fertilizers and soil amendments, now exist or are being prepared in many countries. In the Netherlands agreement has been reached on maximum permissible concentrations of heavy metals in sewage sludge, but for municipal waste compost an agreement does not yet exist.

The use of municipal waste compost in the Netherlands has moved from agriculture via horticulture to the recreational sector long before its heavy-metal content had been established as a limiting factor. The reason was that compost prices for agricultural use became too high. In horticulture more and more peat is used as a soil amendment and in recent years soilless culture is becoming increasingly common. About 90 % of municipal waste compost is now applied to soils used for recreational purposes.

There seems to be no reason for this situation to change in the future, unless the concept of recycling as much of the municipal waste as possible would become more generally accepted. This could lead to a considerable increase in compost production, which largely would have to be disposed of on agricultural land. Then agreement would to have be reached on maximum permissible concentrations of potentially toxic substances in the compost. Moreover, the price of the compost would have to be low, because short-term (fertilizer) effects are generally small and long-term effects (increase in soil productivity) can not be guaranteed beforehand.

References

Arnold Bik, R., 1969. Onderzoek naar de schadelijkheid van zink in stadsvuilcompost. Jaarversl. Proefstn Bloemisterij, Aalsmeer: 150-152.

Boon, J. van der & A. Das, 1972. Invloed van compostmulch op het optreden van stip in appels. Rapport Instituut voor Bodemvruchtbaarheid, 22 pp.

Dijk, H. van & H. P. de Roos, 1973. Zur bestimmung der 'Abbaubaren Organischen Substanz' und des Rottegrades bei Müllkomposten. Instituut voor Bodemvruchtbaarheid, 9 pp. + appendix 0 183 (unpublished).

Ellwardt, P-Chr., 1977. Variation in content of polycyclic aromatic hydrocarbons in soils and plants by using municipal waste compost in agriculture. *Soil Organic Matter Studies* 2: 291-298. International Atomic Energy Agency, Vienna.

Gerretsen, F. C. & W. A. C. Campen, 1958. Die Bestimmung der Haushaltkohle im Müllkompost. *Inform. Blatt. Int. Arbeitsgem. Müllforschung* 5: 10-12.

Gerretsen, F. C., G. J. Kolenbrander & T. P. Melman, 1956. Vergistingsduur en stikstofwerking van Schiedammer stadsvuilcompost. *Versl. landbouwk. Onderz.* 62.6, 24 pp. (with English summary).

Haan, S. de, 1955. Compost en aardappelschurft. *Maandbl. landb. voorl.* 12(7) 315-320.

Haan, S. de, 1972. Ergebnisse aus Versuchen mit Müllkompost. *Landw. Forsch.*, Sonderheft 27/I: 86-92 (with an English summary).

Haan, S. de, 1977. Zuiveringsslib, veencompost en combinaties van deze produkten als organische meststof of grondverbeteringsmiddel voor tuinbouwgewassen. *H_2O* 10(19) 445-447 (with an English summary).

Haan, S. de, 1980a. Einfluss von organischer Düngung auf das maximal erreichbare Ertragsniveau in langjährigen niederländischen Feldversuchen. *Landw. Forsch.*, Sonderheft 36: 389-404 (with an English summary).
Haan, S. de, 1980b. De fosfaatwerking van zuiveringsslib en stadsvuilcompost. *Bedrijfsontwikkeling* 11: 195-202.
Hudig, J., C. Meyer & J. Goodijk, 1926/27. Über die sogenannte 'Urbarmachungskrankheit' als dritte Bodenkrankheit. *Z. PflErnähr. Düng. Bodenkd., Wiss. Teil* 8: 14-52.
Harms, H., 1977. Metabolism of soil-related phenolic compounds in plants and cell suspension cultures. *Soil Organic Matter Studies* 2: 301-305. International Atomic Energy Agency, Vienna.
Juste, C., & B. Pommel, 1977. Le compost urbain. Ministère de la Culture et de l'Environment, Ministère de l'Agriculture, 75 pp.
Knottnerus, D. J. C., 1965. Huisvuilcompost VAM gebruikt als mulch tegen het verstuiven van 'bollenzand'. Instituut voor Bodemvruchtbaarheid, Rapport 4, 10 pp. + appendix.
Knottnerus, D. J. C., 1969. Bruikbaarheid van enkele soorten huisvuilcompost op verschillende wijzen toegediend als bodembedekkingen tegen winderosie. Instituut voor Bodemvruchtbaarheid, 8 pp. + appendix (unpublished).
Knottnerus, D. J. C., 1976. Stabilisation of a wind erodible surface by hydroseeding (town refuse compost). *Meded. Fac. Landbouwwet., Rijksuniv. Gent* 41: 69-71.
Kortleven, J., 1956 Proeven met stadsvuilcompost. I. Invloed op het gewas. *Versl. landbouwk. Onderz.* 62.12, 245 pp. (with English summary).
Kortleven, J., 1960. Een onderzoek naar de landbouwkundige waarde van huisvuil- rioolslib-compost. Instituut voor Bodemvruchtbaarheid, Rapport 50, 16 pp.
Kortleven, J., 1963. Qualitatieve aspecten van humusopbouw en humusafbraak. *Versl. landbouwk. Onderz.* 69.1, 109 pp. (with English summary).
Kortleven, J., 1969. Een proef inzake de menging van compost en rioolslib. Instituut voor Bodemvruchtbaarheid, C-7238, 22 pp. (unpublished).
Kortleven, J., 1970. Proeven met stadsvuilcompost. II. Instituut voor Bodemvruchtbaarheid, Rapport 11, 121 pp. + figures.
Kumpf/Maas/Straub (Ed.), 1973. Vorlaüfige Qualitätsmerkmale und Anwendungsempfehlungen für Siedlungsabfallkomposte. *Müll- und Abfallbeseitigung* 3(6856) 1-26.
Martens, R., 1977. Vorkommen und mikrobiologischer Abbau von polycyclischen aromatischen Kohlenwasserstoffen in Müllkompost. *Mitt. Dt. bodenk. Ges.* 25: 301-304.
Riem Vis, F., 1968. Wat is de gewenste verhouding in stadsvuilcompost-veenmengsels? *Meded. Dir. Tuinbouw* 31(12) 484-487 (with English summary).
Riem Vis, F., 1969. De invloed van VAM-compost op de pH-KCl van zand- en veenkoloniale grond. Instituut voor Bodemvruchtbaarheid, Rapport 8, 16 pp.
Riem Vis, F., 1978. Verslag van een onderzoek naar de stikstofwerking van verkleind, gesorteerd en gecomposteerd huisvuil. Instituut voor Bodemvruchtbaarheid 5 pp. + appendix (unpublished)
Roorda van Eysinga, J. P. N. L., 1967. Proeven met een mengsel van stadsvuil en zwartveen. Proefstation voor Groenten- en Fruitteelt onder Glas, Naaldwijk, 26 pp.
Rowaan, P. A., 1949. Stadsvuilcompost als meststof. *Maandbl. landb. Voorl.* 6(5) 190-194.
Smilde, K. W., 1969. Veroorzaakt compost metaalovermaat in gewassen? Instituut voor Bodemvruchtbaarheid, C-6628, 5 pp. (unpublished).