DISPOSAL OF TOWNS' WASTES†

Paper No. 6259

The disposal of sewage sludge

by

William Fillingham Brown, B.Sc.(Eng.), M.I.C.E.

Paper No. 6263

The disposal and utilization of refuse

by

John Capie Wylie, B.Sc., M.I.C.E.

Paper No. 6262

The agricultural value of sewage sludge and town refuse

by

Geoffrey Edward Graham Mattingly, B.Sc., Ph.D.

Paper No. 6261

The water-pollution aspect of refuse disposal

by

John Longwell, D.Sc., F.R.I.C., F.R.S.H.

Discussion

The Chairman, in proposing a vote of thanks to the Authors for their Papers and introductory notes, said that perhaps the most interesting possibility was that the sludges from sewage and towns' wastes could be complementary in contents so far as agricultural use was concerned. These were very bulky materials, which had to be disposed of as cheaply as possible, and if they could be complementary and so become an asset, if properly used, it seemed important that that aspect should not be neglected. However, these things had apparently not yet reached the efficiency of the old-fashioned methods, and farmyard manure seemed to be much more capable of giving good results than these somewhat synthetic substances. Of course, that was not unusual on farms!

54. He had been interested in and rather frightened by the references to pollution of ground-water by tipping. He thought that controlled tipping was coming back into favour and that incineration was receding from favour in these days. If this meant that there was going to be increased pollution of ground-water, which in the vast majority of the areas in the country was still the source of drinking-water, it was a

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† Proc. Instn civ. Engrs, vol. 8, p. 409 (Dec. 1957).

subject about which one ought to be careful and which one ought to investigate thoroughly, once the right lines of approach were decided upon. He would say that it probably depended entirely on the conditions of flow of the ground-water, the state of the soil, and many other almost geological features.

Mr W. P. Haldane (City Engineer, Edinburgh), thought that one of the best tributes that could be paid was to say that the Authors had avoided extravagant claims. Such claims, on the subject under review, had done more harm in the past than good, even though the extravagances had come from over-enthusiasm. They had only to remember the correspondence in *The Times* last year under the heading "This Filthy Business" to realize that much should be tackled. He thought that what was holding them back on one large item of the matter, namely, the discharge of sewage effluents into estuarial waters, was uncertainty.

56. In Paper No. 6259, Mr Fillingham Brown had outlined the position up to a point where there was considerable unanimity of opinion, namely, that the grossest crudities could be extracted and that the resultant sludge could be treated by digestion, but after that there seemed to be considerable uncertainty. Mr Fillingham Brown had mentioned various methods that might be followed after the digestion stage, and in doing so he was probably thinking in terms of his own contribution to the committee on which he had sat, namely the Hill Committee.[21] That committee had been encouraging to a number of drainage authorities, but it had qualified its recommendations by the recognition that special circumstances might necessitate various forms of disposal. Mr Haldane thought that many authorities were puzzled about the best method of disposal, and he did not think that any authorities would expect to get a method of disposal which would make money or even one which would break even—but they would like to be assured that the best method was followed. What was the best method?

57. The Zuckerman Report[5] was not, to his mind, encouraging in attempts to get sewage sludges back to the land. The Hill Report was more encouraging. Then, if one turned to the latest edition of Imhoff and Fair on sewage treatment[22] (which presumably could be taken as representative of current American practices), it was even mentioned that, having gone to the cost of digesting sludge, the product could be discharged into receiving waters. That was discouraging to those who hoped that benefit could be derived by the application of sludge to the land.

58. Mr Haldane would like to think that further study of the problem would follow from the present meeting, that the discussion would focus the problem, and that concentration might be given to the best method for treating sludge after it was digested. He would like to think that the very last recommendation of the Hill Committee would be pursued, namely: "... that the larger sewage disposal authorities be encouraged to continue or to initiate research into the practical aspects of new processes of sludge treatment, with the co-operation, where possible, of the Water Pollution Research Board and the University Research Departments."

59. He wondered if progress in this matter had been made since the Committee reported in 1954.

Mr John Griffiths (Chief Chemist, Main Drainage Department, Middlesex County Council), stated that, apart from his professional interest in the subject, he had a further interest in having been associated with Mr Fillingham Brown, as his deputy, for some years before the latter had entered into consulting practice. Having been concerned with sewage purification for more than 30 years, his main concern was obviously with Paper No. 6259 by Mr Fillingham Brown, although that of Mr Mattingly, Paper No. 6262, was of great interest in having a direct bearing on the problem of sludge utilization. From the information given in the latter Paper, it was fairly clear that sewage sludge could be classed as a useful manure, although deficient in potash. Most people engaged in sewage purification had conceded that point for many years. They could not do anything about it; the potash was just washed away. It appeared that the use of sewage sludge in assisting the composting of town refuse had the advantage of improving the town refuse and assisting in the disposal of a waste material which, of itself, was inferior to sewage sludge.

61. There must be agreement with the general picture drawn by the Author in Paper No. 6259, but on reading through the notes and from the Author's remarks when introducing his Paper it became obvious that he had hoped that the discussion would amplify many of his points. One point of interest was that a difference had not been drawn between primary and secondary sludges. The primary sludges produced at a sewage works contained the coarser material and grease which separated from the sewage in the initial stages of treatment. The secondary sludges were the product of biological treatment of the settled sewage. If the primary sludges were produced from tanks which were manually cleaned at intervals of several days (sometimes weeks), they were likely to contain about 90 to 94% moisture, and the dry solids would contain up to 70% of organic matter, 20% of which was grease. More modern treatment plants where manual cleaning methods had been superseded by mechanical cleaning gave figures of 93 to 96% moisture and similar solids composition. Secondary sludge contained the flocculated suspended and colloidal matter removed from the settled sewage, together with associated aerobic organisms, which were the main source of nitrogen. The moisture content of such sludges was from 95 to 98% for humus sludge and 98 to 99·5% for surplus activated sludge. The grease content of these sludges was very low, and the solids differed from those of primary sludge from a manurial point of view. The nitrogen content of activated sludge could be as high as 8%, although it was usually nearer the 6% mark, and the phosphate content was between 4 and 5%.

62. Unhappily, secondary sludges were just as objectionable as primary sludges, even more so if the drying process was prolonged, and since they were much more difficult to dry than primary sludges, the usual method of disposal was to return the secondary sludge to the incoming sewage flow, mix the primary and secondary sludge solids in the initial stages of treatment, and dispose of the whole as primary sludge.

63. On the subject of activated sludge, the question of the extraction of vitamins had been mentioned. This matter had been gone into by one of the big research laboratories, and some time ago Mr Griffiths had had contact with its representatives, who had admitted that the extraction of Vitamin B_{12} did not particularly interest them at the present time. Other sources of B_{12} were more profitable to them by far. To the best of his knowledge, they were still carrying on with research into the question of the extraction of various substances from activated sludge—but he was afraid that he had never been able to extract from them what they would hope to extract!

64. No mention had been made of sludge pressing and vacuum filtration. Pressing, which was considered suitable for special types of sludge—mainly the high-grease-content sludges of the West Riding—was still employed, and had been introduced at one or two works during recent years. There were at least three modern post-war works in the country using vacuum filters as a means of sludge dewatering. As rapid means of initial sludge dewatering, vacuum filters had much to commend them. They were, however, expensive in operation, since the chemical requirement of the sludge and the maintenance costs were high. With primary sludges, the product of pressing might contain as little as 65% moisture, and there was 75% moisture from vacuum filtration. Activated sludge, on the other hand, could give nothing better than 85% moisture. Vacuum-filtered sludge required further drying for economic transport, and the fuel requirements for further drying were considerable.

65. No mention had been made by the Authors of the quantity of sludge solids to be handled. There was evidence that the weight of solids present in sewage was higher now than in pre-war days. Although the figure of 0·15 to 0·16 lb/head/day was accepted as a normal figure, there were several works which were at present receiving solids in excess of 0·2 lb/head/day, an increase of about 20 to 30%. Some of that increase must undoubtedly stem from the improved standard of living generally, but a proportion must be ascribed to the increased quantity of industrial wastes which were now

discharged into sewerage systems after the passing of the Public Health Act, 1937, and the Rivers (Prevention of Pollution) Act, 1951. If it was assumed that the primary sludge resulted from the removal of 70% of the sewage solids, then the quantity of primary sludge was equal to 0·14 lb/head/day and this would give rise to about 0·09 lb/head/day of digested sludge. The quantity of secondary sludge was about 0·06 lb/head/day, and the total quantity of disposable solids to be expected was of the order of 0·15 lb/head/day, which was equivalent to the quantity usually accepted as being received at a works.

66. Concerning the conclusions contained at the end of Mr Fillingham Brown's Paper, Mr Griffiths would perhaps sum up rather differently on points (*c*), (*d*), and (*e*). The method of disposal (and he thought this partly answered Mr Haldane) must depend on the local circumstances. Sewage sludge was not a readily marketable commodity. If a market could be found, then the return was unlikely to be such as to show a profit. Hence, the problem was really one of disposal. Where dumping areas existed, then the most economical method of disposal was to transport in the liquid form, having dewatered as far as possible by settlement and storage to reduce bulk. If this was not possible, then air drying was least costly. He rather differed on the point that it was a primitive and untidy method. The trouble with bed drying was the difficulty of lifting sludge; this would perhaps be mechanized in the not-too-distant future. Mechanical watering and heat drying were practicable, but the cost was very high. In a nutshell, the more money spent in treatment, the more one would lose. Wherever possible, the minimum amount should be spent, and thereby money be saved.

Mr R. M. Finch (City Engineer, Nottingham) hoped that they would not miss their objective. Their primary objective was the disposal of towns' wastes. In order of efficiency, so far as research was concerned, he would put sewage disposal first. He thought that up to now they had done a good job of work at the Institute of Sewage Purification; sewage works had produced methane gas, of which a good deal more would be heard in the future, and digested sludge. As a layman, he might be wrong in assuming that this was the best form of sludge from a handling point of view that had been produced up to the present time.

68. There was also the problem of refuse disposal; the objective here seemed to be to marry sewage and refuse disposal, but there were other waste materials that a local authority had to deal with. For example, there was the ash from power-station plants, and there were pit-dirt heaps in different parts of Britain. In sewage sludge there was an excess of liquid and a lack of nitrogen. In power-station ash there was a product without any moisture at all, and in other waste products from power stations, he understood, there was a quantity of sulphates. It seemed to him that it was possible to combine the two, or other materials, for composting.

69. To do this it was necessary to have some employing authority to carry out the work and take an interest in it, and he did not think that there was one in Britain that would take an active interest in all the forms of waste available nowadays. He would make it an obligation on a local authority or any other developer to replace the land that they took away from agriculture. In this connexion, the argument was cost. He supposed that agricultural land, in round figures, was worth about £100 an acre; developable land near a big city cost £1,000 or £1,500 an acre. Therefore, there was a big difference in value which accrued to some extent to the local authority, more particularly as housing land. If a city wanted 1,000 acres for such development, he would ask that city to replace that land somewhere. With that incentive, they might do something, say by refuse disposal, and Mr Finch agreed that it should not be burned. It should be collected at suitable spots in any urban area, as much salvage taken out of it as economically as possible, and the rest tipped at a suitable spot. Such areas could only be ascertained by a national survey. They would have to be located where tipping would not interfere with water supplies. For the first 15 or 20 years it would be in waste land, probably within the near vicinity of the city or urban area concerned. If a city was not satisfied to deal with the matter in this way, then it should make a contribu-

tion to the authority that would do these things. Such provisions would, he felt, give the necessary incentives.

70. It was necessary to deal with not only sludge, which might with suitable treatment form a top dressing for the land, but also with power-station ash, pit dirt, and all the other things that must be brought together. He was quite satisfied, on the basis of practical experience, that by these means a useful job of work could be done.

71. Without any serious effort on his part Nottingham had brought down their refuse-disposal costs to nothing. The credit to the balance sheet last year had been 6*d*/ton. That was something that could be achieved reasonably easily by any other authority that took the trouble, and was achieved without taking into credit the value of the land that had been recovered as waste land, and filling up of areas that had been lowered by colliery subsidence. He was sure that, given a national survey of all the places on which waste could be disposed, useful work could be done for the nation. He believed that in Holland they recovered land at the rate of £400 or £500 an acre. That would not be considered economic in Britain, but the state might be reached here where waste or marginal lands would have to be salvaged. Instead of putting a compost of doubtful value in farmers' hands, he would rather put it on some waste land to at least bring the land up to some reasonable standard. From his own experience, he could say that they had in Britain grown fairly good crops on land that had been recovered in this manner.

Dr Joseph Tinsley (Department of Agricultural Chemistry, Reading University), commented on the Papers from an "outside" standpoint, and said that although he had no knowledge of civil engineering, he had been concerned with the chemical aspects of preparing organic manures from a basis of straw with various kinds of nitrogen sources, and he might perhaps give a few figures to illustrate the subject which Dr Mattingly had briefly touched upon—the relative quantities of the major plant nutrients which were involved in the question of disposal of town refuse.

73. From the mean composition of the 800,000 tons of sewage-sludge dry matter which could be expected to be of use in agriculture, one could work out that there might be present something of the order of 20,000 tons of nitrogen, about the same quantity of phosphate, and a very small quantity of potassium—about 4,000 tons. If one set alongside that the quantities of these elements excreted by the human population of Britain, reckoned in round figures of 50 million people, the quantity of nitrogen in the excreta was about 360,000 tons; phosphate, about 200,000 tons, and potassium, 160,000 tons. It could be seen that in the sewage sludge recovered the potassium was a very small quantity of that which went into the sewage effluent. The proportions were, roughly, nitrogen, one-eighteenth, phosphate, one-tenth, and potassium, one-fortieth of the material excreted which was trapped, as it were, in the sewage sludge. The remainder escaped in the effluent from the sewage plants into the rivers and the various other places where it was deposited. A lot of the nitrogen escaped into the atmosphere by de-nitrification.

74. The question arose if, from a national point of view and from the aspect of producing crops, it might not be better to look at what was escaping in solution rather than at that small quantity which was caught in the sewage sludge; and even if it was possible to make use of the liquid (the water from the filter beds) for irrigational purposes in the summer months, use could be made agriculturally of several times as much plant nutrient as one could ever hope to get by treating sewage sludge.

75. So far as Dr Tinsley's own work was concerned, the quantity of nutrients in the droppings from the poultry population of Britain—there was about one hen in this country for every person—was such that more nitrogen was obtained from the hens' droppings than from the sewage sludge. There was about the same quantity of phosphate, and about three to four times as much potassium. Therefore from the farmer's point of view, if he conserved his poultry droppings on the farm, he had a more valuable material than sewage sludge.

76. He was not decrying the value of sewage sludge in any way. As he had said, he

had no connexions with civil engineering, but it so happened that in a recent edition of his professional paper,[23] there was a brief account of a modern composting plant which was to be built in Bangkok by a British engineering firm. This plant was to handle mechanically the town refuse and to mix it with sewage sludge, doing this in a large six-storey building. The stuff would come up to the top and apparently would be mechanically dropped into trays, and after mixing these trays would be inverted, so that their contents would fall into the next layer below, thus going down the six floors in turn and coming out at the bottom of the building. He did not know whether any similar sort of plant could be aimed at in Britain.

Mr A. S. Knolles (Borough Engineer and Surveyor, Twickenham), thought that it could be generally accepted that the two wastes that had been described, used either individually or perhaps in combination, were not really high-grade fertilizers, but nevertheless they did supply a considerable amount of humus and trace elements, and if, as in Paper No. 6262 Dr Mattingly had suggested, the proper inorganic materials were added, it seemed to him that there was no reason why they should not have some value to the farmer. Could Dr Mattingly say something about the value if any of the trace elements in household refuse?

78. In putting this across to the farmers, there was obviously the difficulty that there was much literature pointing out that household refuse and, to a certain extent, sludge, had certain drawbacks. He thought that what was necessary was to show the farmer how those drawbacks could be overcome and that they could be overcome at a reasonable cost.

79. Household refuse could be very valuable in another direction, namely, in the reclamation of land. He could not agree with Mr Wylie's statements in §§ 12 and 13 of Paper No. 6263, because, if one used his figures, in 50 years, if all refuse was tipped to a depth of 6 ft, 200,000 acres would be reclaimed. Even if half that amount was used for reclamation, surely it would be a worth-while contribution, especially since the reclamation would usually be near towns, where land was expensive. They had heard Mr Finch refer to land at £1,000 or £1,500 an acre. In the London area and in certain areas in the suburbs, £6,000 was the price for an acre of land, and it was just in those areas that useful tipping could reclaim land. On the one side of London there were pits caused by the removal of chalk, and on the other side there were extensive gravel pits, unfortunately in some cases water-bearing gravel pits, but nevertheless they could be filled. He referred to plant at Charlton, where they had 60 acres of land which they were at present reclaiming.

80. He knew that this was not the place to mention the findings of the Technical Committee on the Disposal of Refuse in Wet and Dry Pits, to which findings they looked forward in due course; but he would refer to one of the difficulties, namely, the aerial nuisance caused when one tipped into wet pits. That nuisance was chiefly the result of sulphates being turned into sulphides by sulphate-reducing bacteria. Those bacteria were anaerobic, so that they must have anaerobic conditions and certain optimum-temperature conditions as well. Those difficulties could be overcome. In his case, the difficulties were overcome by reducing the large water-area into small lagoons which were filled under certain temperature conditions and within a period of time which prevented aerial nuisance. They had also produced conditions where they had deliberately obtained aerial nuisance with a view to seeing what remedies they could adopt. One method of getting over the difficulty was to use sulphuric acid—an expensive and not an easy method if one wanted to use ordinary labour. Another method was to aerate the water. Various methods had been tried, either pumping air into the body of the water or pumping the water into the air so that it took up air as it fell in droplets. The method which he had found most satisfactory was the use of chromic-acid waste; this was a cheap material, fairly easy to use, and in the experiments where they had deliberately obtained aerial nuisance, they had found that it worked satisfactorily. Therefore the method that he was using was to divide into lagoons, and although

he did not expect any difficulties, he had in store chromic-acid waste which he could use if anything went wrong.

81. Mr Knolles said that in one of a number of photographs that he had with him, screenings being pushed by a bulldozer were shown. There was considerable steam from the pile; obviously this was because of the heat generated within the tip, and temperatures of as high as 174°F had been obtained.

82. It must be borne in mind that the type of refuse had a bearing on the matter. In areas where separate kitchen waste was collected, if the material was going to be turned into humus there would be a different type of refuse to deal with from that of areas where kitchen waste was not removed. Also, the paper content of refuse varied very considerably between one area and another. At certain coastal holiday resorts in the summer the paper content was very high, which also showed that the time of the year was an important matter as well. Refuse itself was changing considerably and the cinder content was falling. During the past few years, the ⅜-in. screenings had increased from 34 to 37% in the refuse that he had been dealing with, whereas the 1½-in. screenings had dropped from 18 to 15%. At one time he had easily been able to sell the 1½-in. screenings at £1/ton; he could not sell them at that figure at present, although he was continually getting requests for screenings of the type that he had originally sold.

83. To sum up, he thought that to deal with refuse properly, it was evident that a number of local authorities must amalgamate so as to have available the size of plant and the technical staff to direct the work in a satisfactory manner.

Mr L. P. Brunt (Chief Engineer, Compost Engineers Limited) agreed with Mr Wylie's remarks, in introducing Paper No. 6263, that composting treatment was such an important and interesting subject that it deserved a meeting entirely devoted to it; however, since it was one of the threads which ran through the first three Papers and which also had relevance to the fourth Paper (composting could be a preliminary stage to the tipping of refuse into wet pits, in order to kill the bacteria which might pollute the water supplies), he thought that it would be useful to spend a few minutes in enlarging on composting treatment. Incidentally, he would like to assure Dr Tinsley that it was only because he was out of touch with civil engineering matters that he was not aware of developments in composting treatment that had taken place and were now taking place in Britain. For instance, since 1935 or thereabouts there had been a small municipal composting plant in Leatherhead, working by crude and simple methods. In recent years, there had been considerable developments in composting treatment in Scotland, and there had come into operation in Jersey last year a composting plant to deal with all the refuse from the island and with the sewage sludge from a sewage-treatment plant, which was not yet complete but was under construction.

85. To illustrate his remarks Mr Brunt showed three lantern slides, the first of which was of a flow diagram of composting procedure in relation to the treatment of refuse and sewage.

86. The second slide showed diagrams of examples of typical methods of composting treatment, the first being the heap method. This was used on a large scale in Holland, but would not be suitable in warmer wet climates. It was applicable only in circumstances where the site could be remote from populated areas. In what he had called the "shallow-compartment method" the material was moved two or three times (in the course of composting treatment) from one bed to another of a series by overhead grab or a mobile shovel working at the floor level. This was a method which was employed in Central America, at Kirkonnel in Scotland, and in a few other installations throughout the world. A third type of composting method used special chambers, the purpose of which was to contain the mixture of wastes and provide the right conditions for the active fermentation stage to ensure that the material was exposed to temperatures which would destroy harmful organisms and that the process was properly established, so that subsequently when the compost went to storage for maturing its decomposition proceeded on the right lines. In the static variety the mixture went into a large chamber

and was not disturbed, aeration being through inlets at the bottom. This method did not give a good product; it was liable to be troublesome in operation and was generally obsolescent, but there were quite large installations still working. The next type of special chamber provided "intermittent disturbance". In this method the compost was disturbed once daily or a few times a day, the purposes of disturbing it being to loosen it, re-aerate it, and rub the materials together, thus exposing new surfaces to the attention of the bacteria which did the work of decomposition. The example shown in the slide was the kind to which Dr Tinsley had referred—it had roll-over floor units on which a bed of the raw compost was formed, the units being normally turned once a day, thus dropping the material to a lower level. The third type of special chamber provided more or less continuous disturbance for long periods or all the time, and it could maintain the compost in its most active condition—more thoroughly than other methods—but one had to bear in mind the power requirements in deciding between these last two types of special chamber. The particular example shown had a series of floors, normally eight, with a bed of material on each about 18 in. or 2 ft deep, which was stirred constantly and passed slowly down from one floor to the other.

87. The third slide showed an artist's impression of a plant (to which Dr Tinsley had also referred) to be constructed at Bangkok. It was the largest special chamber installation in the world and was to come into operation in the second half of 1958.

Mr H. E. Bywater (Veterinary Surgeon) said that as a veterinary surgeon whose interests included agriculture, human public health, and the meat industry, but whose knowledge of sewage disposal and treatment was practically nil, he was grateful for the opportunity to express concern regarding the dangers which might threaten agriculture, the public health, and the meat industry. In § 4 of Paper No. 6259 mention was made of the potential danger which might arise from pathogenic organisms and parasitic eggs present in products of the sewage works, and Mr Bywater went on to elaborate on this.

89. He well remembered the small spate of legal actions which had occurred about 20 years ago as a result of the alleged poisoning of grazing cattle owing to contamination with sewage effluent of their drinking-water. Many eminent authorities had been called upon to give evidence in those cases but, by and large, it was held that the sewage effluent was harmless to cattle and indeed, in one case, it had even been suggested that the ammoniacal and ferruginous content of the effluent might prove beneficial to animals! Few farmers had since had the temerity to embark upon such litigation, which was likely to prove costly, and in which the chances of success were in doubt.

90. His own opinion was that sewage effluent was capable of causing illness and even death of cattle whose only source of drinking-water was that which was contaminated by sewage or its effluent. This was not so much from the poisonous or infective nature of the sewage as such, but from the fact that it was distasteful to animals, who would therefore not drink sufficient of the contaminated water to meet their minimum physiological needs for liquid and so suffer from dehydration of the tissues.

91. There were more serious aspects of this matter which required attention, for he was not satisfied that effluent and sludge did not infrequently contain organisms pathogenic to both animals and man, when such materials were applied to land which would subsequently be used for the raising of crops and the grazing of animals. It would be an arduous task to demonstrate that pathogenic bacteria generally present in the products of the sewage works survived sufficiently long enough on land, or in the contaminated drinking-water of animals, and in such numbers, as to constitute a menace to live-stock and, through crops or animals, to man. He believed, however, that some micro-organisms might act in this way. What were the views of others present?

92. Mr Bywater thought that he was on much safer ground in stating that it appeared to be unquestionable that the eggs of certain helminths pathogenic to animals and man were spread by sewage sludge and effluent. He would like to elaborate this theory by saying something about the tape worm of man (Taenia saginata) which was transmitted to cattle through the medium of human excreta and from cattle to man who might consume the affected meat in an insufficiently cooked state.

93. Human beings who were infested with this tape worm passed out large numbers of eggs in their stools. The tape worm might attain a length of 20 ft or more, most of which was composed of small segments a few millimetres in width and length. The gravid segments were nothing more or less than bags full of eggs, each bag containing about 100,000 eggs.

94. A tape worm might live for more than 20 years in the intestines of its host, during which time it was constantly casting off segments containing eggs. Mr Bywater left it to the imagination to compute the millions of eggs which a single human carrier might liberate to contaminate the sewage. If a single egg found its way on to the food or into the drinking-water of a bovine animal, then it could establish itself in the muscular tissue (i.e. meat) and there form a cyst about the size of a small pea. This cyst contained the embryo of a tape worm, which could develop and grow to maturity, and egg production, in the intestines of a person who had consumed meat in the substance of which there was a viable cyst.

95. Before the second world war the incidence of "measly beef", as it was called by the butcher, was considered to be practically non-existent in Britain. However, in recent years, owing to the discovery of this condition (cysticercosis) in the Belfast Corporation Abattoir, increasing attention had been paid during routine meat inspection to the detection of this parasite by attention to those parts most commonly affected. It was now established that the condition was wide-spread throughout the United Kingdom, but definite evidence as to the precise number of cattle so affected was not available. It appeared,* however, that the overall incidence was in the region of 2%. The recorded incidence of cysticercosis appeared to be not unrelated to the regularity of inspection, which differed from district to district, although doubtless there were localities where the incidence was more common than in others. The condition was literally rife in the U.S.S.R. and certain parts of Africa and Asia, and was related there to direct contamination of the pastures by infested human faeces. Under such conditions, the grazing animal ingested large numbers of eggs and suffered from massive infestation of the body. It had been stated in such cases, that for every cyst discovered during routine meat inspection, probably a hundred additional cysts escaped detection. Such massive infestations did not occur in Britain. Cases recorded appeared to be of very low numbers of cysts per animal. It was therefore logical to assume that direct contamination of the pastures by human excreta was not the normal means of spread in Britain, and that dilution of eggs took place during distribution and that the means of distribution appeared to be normally through sewage.

96. Cattle showed no signs of ill-health from this slight infestation and so the farmer suffered no apparent loss. It was the butcher who footed the bill, and through him, the general public. The meat which actually contained the cysts detected by the meat inspector was rejected, but the rest of the carcase was allowed to be sold for human food provided that it was subjected to 3 weeks in cold store. There was some reason to doubt the efficacy of this treatment but Mr Bywater would not enter into that aspect of the problem. However, home-killed fresh meat had a higher sales value than frozen or chilled imported meat. Thus the purveyor of refrigerated home-killed beef had to accept a price comparable to the imported article. The butchery trade did not regard the financial losses thus entailed with pleasure. The Institute of Meat and other interested bodies had expressed concern in this connexion.

97. That sewage could be the means of transmitting the eggs of this parasite had been recorded in the American Journal of Hygiene.[24] It was demonstrated that if sewage was contaminated, the usual sewage-treatment processes, with the possible exception of sand filtration, could not be relied upon to produce effluent or sludge free

* From various reports of Medical Officers of Health with respect to meat inspection in their districts, prepared in accordance with the requirements of the Ministry of Health and from statistics prepared by the Food Hygiene Division of the Ministry of Agriculture, Fisheries and Food.

of viable tape-worm eggs. More recently Silverman and Griffiths[25] had reported their conclusions that tape-worm eggs could survive most urban and rural sewage-treatment processes and then be passed in the final effluent or air-dried sludge. Experiments with sand filtration and "micro-straining" devices used for the clarification of sewage effluent had shown that rapid sand filtration was not an effective safeguard against the eggs of the tape and common round worms of man, but that "micro-straining" was effective in filtering out 90–95% of the original concentration of worm eggs in the solution. "Micro-straining" was the use of a finely woven fabric of stainless steel capable of matting on the surface a cover of debris that was able to retain solids of sizes still smaller than those of the already minute apertures of the steel mesh, which had as small a grade as 20 microns (one thousandth part of a millimetre equals one micron).

98. It was further stated that circumstantial evidence suggested that the apparent increase in bovine cysticercosis in Britain might be associated with the breakdown of formerly more reliable sewage-treatment systems. The post-war increase in urban populations coupled with the increased use of water had caused overloading of the sewage works. The introduction of surface active and bacteriocidal agents (detergents and similar substances) in industry and the home, and their subsequent disposal into the drainage system, had resulted in considerable interference with the processes of sedimentation, putrefaction, and oxidation. This combination of circumstances might result in an increased survival and dispersal of the tape-worm eggs from even a small number of affected persons. It was also stated that the eggs could survive for 355 days when kept under cool moist conditions as, for example, in air-dried sludge.

99. Jephsen and Roth[26] had demonstrated that the eggs could remain alive for at least 71 days in liquid manure, 16 days in city sewage, 33 days in river-water, and 159 days on pasture. Seddon[27] in Australia had found the eggs were still viable after about 112 days on dry sunny land.

100. The population of the world was rapidly increasing and standards of living rising, thus the demand for expanding food production presented an urgent problem. It was a vital necessity that use should be made of all available methods to maintain and increase soil fertility. The national sewage systems dealt with a vast amount of potentially valuable fertilizers, much of which was wasted. Much was emptied into the river and the sea and Mr Bywater wondered if the time would ever come when it would have to be pumped back on to the impoverished lands!

101. It appeared to him that economic considerations might perhaps not be the sole criterion with which to govern methods of sewage disposal and utilization. Mr Fillingham Brown's mention of some system of composting might be one answer to the problem. However, whatever the method used, Mr Bywater suggested that consideration should always be given to ensuring that disease-promoting organisms did not escape on to the land and thus constitute a potential danger to animals or the human population. Composting might well assist to this end.

Mr P. V. Marchant (Borough Engineer, Wandsworth) confined his remarks to Paper No. 6263 by Mr Wylie. He challenged Mr Wylie, as Mr Knolles had done, on the question of tipping, and he also asked him to explain what he meant in the first paragraph of his Paper, in which he said that "today the bulk of Great Britain's refuse is dumped either in the sea or on the countryside in an unsatisfactory manner". Mr Marchant said that no refuse was dumped in the sea—no household refuse that was. The fact of the matter was that refuse was becoming increasingly light, and it was quite impossible to get the material out of the hoppers on the barges, and in consequence that system of disposal had been abandoned some years ago.

103. Most of the tips in Britain were stringently controlled by local Acts of Parliament, and so he ventured to think that there were very few of the larger tips which could be regarded as unsatisfactory.

104. He was a little disturbed by Mr Wylie's comments, and he thought that Mr Wylie must be "flying a kite" when he said that the value of the land reclaimed just was not worth it! Many towns had benefited from the land which had been brought back

into use; playing fields, parks, allotments, and land of that sort had given great benefits to the towns.

105. It seemed to him that the only possible justification for the abandonment of tipping by those authorities which now used that system of disposal, was when the tips were so far away that the material had to be hauled over long distances and it became more economic to use other methods of disposal equally satisfactory to that of tipping.

106. The other satisfactory methods of disposal open to large authorities were somewhat limited. He would mention incineration as being satisfactory in some districts, but certainly not in heavily built-up areas, because of the possible nuisance from grit and smoke and the disposal problem with regard to the residual tailings and clinker. Furthermore, he did not think that a single planning authority would welcome the erection of a destructor plant, no matter how modern. They had heard quite a lot about grinders, but although these were all very well for individuals, he thought that if they became universal there would be a very serious problem created owing to the inadequate capacity of sewers, and also at the sewage works because of the high B.O.D. of the refuse sludge.

107. Probably the composting method was the most intriguing of all known disposal methods, since it set out to convert waste materials into an end-product of real value. There were, however, a lot of imponderables involved. For instance, what was the residual content of compost on the land? Was there a possible danger that when compost composed of house refuse and sewage sludge from an industrial town was applied regularly to the land for some years, it might result in lowering the fertility of the land owing to the build-up of a high non-soluble mineral content in the soil? The question also arose as to at what stage in the decomposition of refuse did the compost and tailings become sufficiently innocuous to permit their being tipped, either in dry or wet tips, without the precautions applied to the tipping of crude refuse. It was quite possible that if the compost was to be resold it must be tipped, and in any event the tailings must be tipped.

108. It was doubtful if the expenditure on costly composting plant could be justified solely on the grounds of reduction of bulk content of refuse. The system had much to commend it if only on the ground that the refuse was quickly rendered comparatively innocuous. But regrettably the market for compost was far from being assured in the densely populated urban areas. Local authorities were not designed to enter into commerce, and he suggested that until there was a semi-governmental sales organization set up, similar to those on the Continent, it would not be possible to adopt composting for the whole of the authorities of Britain. Alternatively, would it be possible for the manufacturers of composting plants to erect and operate the plants near the source of the refuse, subject to the councils paying the manufacturers as operators of the plants a suitable rate per ton for the refuse received? Subject to that payment being made, the contractors, as they would then become, would assume full responsibility for the treatment of the refuse and the disposal of all the end-products, including salvage.

109. While on the subject of salvage, he would remark that the ideal method of collecting salvage was undoubtedly pre-separation at source, but this could never be achieved without the full co-operation of the householders, which was extremely unlikely. There were few more unpleasant and unhygienic jobs than that of hand-picking of salvage, and he would suggest the need for the further development of mechanical means for the extraction of materials of value, such as woollens, non-ferrous metals, bones, paper, and so on. It would probably be much more efficient, and certainly it would be less degrading to the operators than the present methods.

Mr F. E. Bruce (Reader in Public Health Engineering, Imperial College of Science and Technology) thought that all of them wanted to avoid waste of usable products. However, in this matter of towns' wastes, he felt that they had to keep a sense of perspective, and some of the figures that had been quoted in the Papers and in the discussion did show that on a country-wide basis all the best efforts that they could make at salvage and the avoidance of waste would not have a very big impact.

111. They had been told, for instance, that if they composted all the available refuse with sewage sludge, they would produce 2% of the total amount of farmyard manure that was used on the land, and the Zuckerman Report[5] had stated that even if this was done only one-quarter of all the sewage sludge available would be used; they would still have to find some other means of dealing with the other three-quarters. So far as the salvage of metals was concerned, he believed that the salvage of ferrous metals over the past few years had been running in the region of 60,000 to 70,000 tons/year, and it was stated in Paper No. 6263 that 20 million tons of scrap were required annually. In other words, municipal refuse was supplying only one-third of 1% of the total requirements.

112. He did not want to suggest by these comments that their efforts at salvage were useless. On a nation-wide basis, perhaps they were quite a small drop in the ocean, but locally they could have a valuable effect. The economic application of salvage methods depended, he suggested, mainly on geographical conditions; for instance, on the possibility of bringing sewage sludge and refuse into proximity so that they could be composted, the proximity of land and farmers willing to use the compost, and similar matters.

113. He felt that they had lost an opportunity in this respect in the new towns where surely, starting from scratch, there had been a chance to plan the sewage treatment and refuse-disposal services on a unified basis. So far as he knew this had not been attempted in any of them, but he would be very glad if anybody could correct him on this point.

114. He would like to put forward one or two figures which suggested that Mr Wylie had not been altogether fair in his criticisms of controlled tipping. The latest Public-Cleansing Costing Returns[28] which were available to him, those for 1954–55, showed that the average net cost of disposal of refuse by mechanical means, i.e. sorting, separation, and incineration, was 10*s* 11*d*/ton. For controlled tipping, the cost was 9*s* 0*d*/ton, a very appreciable reduction. This applied to the towns where there was accurate assessment of weights. In the towns where only a small proportion of the refuse was weighed, or where it was not weighed at all, the corresponding average net costs were 12*s* 0*d* and 2*s* 2*d*. Presumably this big difference came from overestimation of the weights where there had not been complete weighing. These figures referred only to disposal, but the Costing Returns also indicated that there was very little difference between the transport costs for the two methods of disposal. Mr Wylie's estimate of 40 miles' carriage, on which he based some of his figures, was excessive, because out of 365 authorities listed in the Public-Cleansing Costing Returns, only twenty-four had hauls of more than 5 miles. The remaining 341 had hauls averaging about 2 or 3 miles.

The following contributions were received in writing.

Mr E. A. Drew (Chief Engineer, Middle Lee Regional Drainage Scheme) observed that his contribution to the discussion on Paper No. 6259 had, of necessity, to be limited to an appraisal of the difficulties that had had to be overcome in the design and initial operation of the Regional Sewage Purification Works of the Middle Lee Regional Drainage Scheme at Rye Meads.

116. This Scheme had come into being primarily as a solution of the drainage problems of the New Towns of Stevenage, Harlow, and Welwyn Garden City, but generally its intention was to prevent the River Lee from the possibility of being "killed" once and for all as a source of clean water for London.

117. The Works at Rye Meads were designed for an ultimate population of 320,000 and the capacity to handle half this population had already been provided. By April 1958 it was expected that a population of 110,000 would be connected. Flows had first been received into the new Works in June 1956.

118. The Works were situated in open country astride the Hertfordshire-Essex boundary between Hoddesdon and Roydon at the confluence of the River Lee and its major tributary the Stort.

119. Whereas the speakers at the discussion had limited their remarks to the difficulties of disposing of sludge and refuse, Mr Drew emphasized the fact that the Middle Lee Regional Drainage Scheme had, in addition to sludge disposal, the problem of effluent disposal. In the normal sense of the word the Works had no direct connexion to the river. Complete purification was provided by a diffused air bio-aeration plant. Final tank effluent had then to be disposed of, either by recharge into the gravel stratem or by sand filtration. Approximately 65 acres of effluent lagoons with gravel banks had been provided, from which it was expected that 4 m.g.d. would either percolate vertically into the underground reservoir or horizontally through the banks into a cut-off ditch which surrounded the lagoon area. All sand filtrate was to be passed to the lagoons or the cut-off ditch. The cut-off ditch was connected directly to a watercourse of the River Lee and it was the effluent from this ditch which was subject to a quality standard of: 5 p.p.m. suspended matter and B.O.D. during May to October (inclusive), and 10 p.p.m. suspended matter and B.O.D. during the rest of the year. In addition the effluent should not contain more than 10 p.p.m. free ammonia.

120. Effluent had been turned into the lagoons in October 1957 but the rapid gravity sand-filtration plant would not be commissioned until May 1958.

121. So far as sludge disposal was concerned, the Works were provided with primary and secondary digestion tanks (75% above ground level), a liquid sludge draw-off point from the secondary digestion tanks for filling tankers by gravity, 60-ft × 180-ft rectangular sludge-drying beds (underdrained), and enclosed by concrete walls on which mechanical conveyors traversed at about 2 ft 6 in. above media level. A pilot heat drying plant, of 5 cwt/hour capacity when drying to 10%, and fed with sludge at 50% moisture-content, was also likely to be provided.

122. Mr Drew could make no useful comment from experience gained from sludge disposal during the 1½ years since commissioning of the Works. The primary sludge-digestion tanks had not been commissioned until May 1957, and up to that date raw sludge had been lagooned as a temporary measure.

123. Mr Drew's committee was at present considering proposals for the disposal of sludge, but he thought it was safe to say that they felt that:

(*a*) every endeavour should be made to persuade the local farmers to accept liquid digested sludge either as a dressing to grass lands or to arable lands, and
(*b*) the remainder of the liquid sludge should be passed to the drying beds for normal air drying followed by stock-piling for heat drying.

124. In discussions with farmers on the subject of disposal of liquid digested sludge, it had been represented to Mr Drew that in the case of T.T. attested herds and from the present technical information available, it was unwise to use either liquid or cake sludge as a fertilizer. The transmission of tuberculosis by waste water had been summarized in an article by Greenberg and Kupka[29], but he felt that the findings set out were inconclusive so far as infection of cattle was concerned. He would welcome any comments or information that might be available on this problem.

125. During the discussion, Mr Bruce had referred to the fact that the Development Corporations might have developed composting plants to overcome refuse-disposal problems in the New Towns (§ 113). With respect, Mr Drew submitted that Development Corporations had no powers to assume refuse-disposal responsibilities. This duty could only be carried out by the local authority. However, the Corporations, when submitting the report on the Master Plan, were required to satisfy the Minister that the problems of refuse disposal from the designated area of the New Town could be overcome. It was known that one Development Corporation had given serious consideration to the economics and possibility of composting refuse with the sludge from the new sewage-purification works constructed by the Corporation.

Mr B. F. P. Babcock referring to Mr Brown's Paper and particularly to the heat input required to lower the water content of the sludge, as removed from the drying beds or filters, below the 65–70% figure, suggested the possibility of some of this water being dispersed by allowing the sludge, when lifted, to undergo aerobic fermentation, and therefore heating, in sheds. He agreed that the mechanical de-watering of sludge plus heat drying, as practised in America and by one local authority in Britain, while possibly being worthy of consideration for use by a very large authority, was still a very complicated process requiring highly skilled supervision and control, and careful maintenance.

127. Regarding the employment of covers or roofs over drying beds (used on certain American and Canadian works and tried experimentally in Britain), while there were substantial advantages to be gained by protecting the drying sludge, during its first few days on the beds, from rainfall, snow, etc., the fact that the covers and their supporting structures might obstruct the drying effects of the wind should be borne in mind. Thus such covers should be light and, in some way, readily removable and should be supported on large-span frames of such a form as to minimize the wind-break effect and allow ample space for the manoeuvres of sludge-skimming and removal units.

128. With reference to the mechanization of sludge lifting from drying beds, while it might be possible to devise large and complicated machines to replace the man, his spade, and his barrow, these might defeat themselves because of the nature of the material being handled and thus cause complications. It was suggested that further slight modifications to some machines, adapted to the water-works field, might be considered. These machines were based on one make of light crawler tractor, some units of which had been adapted, and fitted by the makers with a mechanism for skimming the sand from the surface of slow sand filters, while other units had been provided with suitable tipping skips for the transportation of the sand lifted by the former.

129. Turning to Mr Mattingly's Paper, which so thoroughly epitomized the considerable literature on his subject, certain questions arose. First, what percentage of the total United Kingdom agricultural production was achieved solely by the use of inorganic fertilizers? If this figure should be at or above the 2% quoted by the Author as that proportion of production which could be supported if all sewage sludge and compostable refuse was applied to the land, then one was faced with the progressive impoverishment of the land in humus content, and the solution of the problem of making sewage sludge and domestic refuse agriculturally acceptable became increasingly urgent and important. Further, it also followed that the figures in Tables 4 and 5 should be viewed with inorganic fertilizers as the yardstick and not farmyard manure.

130. Secondly, when referring to sewage sludge, Mr Mattingly did not define the processes from which it had been derived, excepting in one instance where West Middlesex was mentioned; in this instance, it could be inferred immediately by those interested that the sludge had been well digested and matured. It was impossible to infer similar data from the other references in the Paper. Surely the Author would agree that the nature of the treatment of sludge prior to its composting with straw or refuse and to its use in agriculture was most relevant to the assessment of its success or otherwise as a fertilizer or soil conditioner?

131. Finally, referring to the figures in § 22, Mr Babcock was somewhat puzzled that, although about 800,000 tons of sludge dry-matter were recovered annually from sewage, this, if treated with all compostable refuse, would produce only about 700,000 tons, presumably in dry solids, in the same period.

Mr S. A. Gothard (Consultant Engineer, States of Jersey Sewerage Board, Jersey) thought that Mr Mattingly's comments (Paper No. 6262) seemed to imply that refuse sludge compost was of little real value in agriculture, certainly that it was much inferior to farmyard manure, but from the published data available he would say that the experiments so far carried out in England were so limited in number, scope, and length of period as to provide no grounds as yet for fair comment.

133. The Zuckerman Report[5] was quoted to the effect that the amounts of compost

which could be produced by composting all the organic matter of household refuse with sewage sludge would be 700,000 tons/year, "only about 2% of the total quantity of farmyard manure at present used in Great Britain". Even if that statement was true, surely that 2% was worth having, especially in areas where there was shortage of farmyard manure, but was it true? The same report stated that 800,000 tons of sludge dry-matter were recovered annually, and by proper methods all that sludge dry-matter could be composted with the corresponding output of refuse dry-matter. The amount of dry-matter per head in the compostible portion of refuse was roughly five times the sludge dry-matter from the same population, so that from this source was obtained 4,000,000 tons/year, making the total available dry-matter 4,800,000 tons/year. Matured compost would be about 40% moisture, therefore the gross tonnage became 8,000,000 tons theoretically available, instead of 700,000. This, of course, presupposed that the whole of the sludge from a given community could be composted with the refuse from that community, and that had now been proved to be a practical proposition.

134. There was a check on these figures from the Netherlands. There, something approaching 250,000 tons of compost was produced annually, mainly from refuse alone, sludge being used only to a small extent so far, and it was stated that the refuse from approximately 25% of the population was used. This immediately showed a maximum potential output of 1,000,000 tons/year. The population of Great Britain being about five times that of the Netherlands, there was a potential of 5,000,000 tons/year without sludge, and the latter at 40% moisture would add some further 1,300,000 tons.

135. Table 1 in Mr Mattingly's Paper made refuse-sludge compost appear much inferior to farmyard manure on analysis, but was this really so? The percentages given were on dry weight and the moisture content of the two materials in their natural state was very different. When a farmer bought a ton of compost or a ton of farmyard manure he was interested in the amount of the plant foods he got in that ton; in other words it was the percentage of the total wet weight which mattered to him. If, therefore, the figures given in Table 1 were converted to the wet-weight basis, Table 10 was obtained.

TABLE 10

Material	Moisture content: %	Percentage of total weight				
		Total N	Inorganic N	P_2O_5	K_2O	Organic matter
Farmyard manure	74	0·57	0·057	0·42	0·52	16·6
Refuse-sludge compost	40	0·60	0·03	0·54	0·25*	18·0

* Average of Jersey compost.

136. However, this was only part of the story, for as Mr. Mattingly had so rightly pointed out the value of organic manures depended not only on the content of plant nutrients, but also on the effect on the physical properties of the soil, and many students of the use of compost believed that the latter was the most important.

137. In § 31, the Author had referred to applications of refuse-sludge compost for periods of 4 and 5 years as giving lower yields of crops than inorganic manures, but he did not describe the nature of the soil to begin with. If it had been good soil, rich in humus, as might be expected on a well-conducted farm or experimental station, then the only benefit from the compost would be due to its content of nutrients, and obviously better results could be expected from concentrated plant foods. How long, however, would the soil remain good if it received only the concentrates, and nothing to maintain the humus and soil structure? For optimum results both types of manure were needed in

conjunction, inorganics to supply the maximum nutrients, and organics to maintain the soil structure and render the nutrients more completely available to the plants than would otherwise be the case.

138. A 245-page study of the influence of fermented city refuse had recently been published in Holland by Kortleven[30]; Mr Gothard quoted extracts from a summary of it, as follows:

> "This . . . gives a description of a great number of experiments with refuse compost, and based on the results of these experiments conclusions are drawn with regard to the 'short term effect' of fermented city refuse on crop production. It must be emphasised that the conclusions only refer to the short term effect of this compost. The greater part of the tests mentioned were carried out between 1946 and 1954, and this period of time is too short to draw conclusions with regard to the long term effect caused by regular and continuous use of fermented city refuse, which could come to expression by an increased fertility level of the soil, resulting from a gradual increase in the humus content.
>
> "The short term effect of refuse compost as described . . . is thus exclusively the result of those chemical components in the compost that can produce such an effect, i.e. the plant nutrients, including lime. This means that in soils which are not deficient in one or more plant nutrients the short term effect of the compost will be negligible, while on the other hand a field deficient in these nutrients, such as lime, magnesium and trace elements, this effect will be striking.
>
> "With respect to the short term effect of city refuse compost the following conclusions are drawn:
>
> (1) If large quantities of compost are used on poor soil, and if this compost will be the only nutrition for the crops, yields can be improved by 100% and more.
> (2) Compost applied to fertile soil, without adding other fertilisers, effects an increase of yield of about 20–30%.
> (3) Compost applied to normal soil in normal quantities, together with usual amounts of the most important artificial fertilisers will effect an average increase of 5–6% of the crop yield.
>
> "It can be seen from the above that the short term effect of compost is greatest on soils which are deficient of certain elements, and will rarely be noticeable on soils which are in good condition. Application of compost on well-kept and good soil only serves as a means to keep the land in good condition, and the long term effect is more important here. Investigations as to the long term effect of compost have not yet been concluded."

139. Regarding economics, Mr Gothard said that his experience from the many enquiries he received was that there was a tendency to approach compost from the angle of "what does it cost to make and what is its market value?" and if the latter figure did not at least balance the former, then composting was said to be uneconomic, but why? A filter bed was not expected to show a profit, so why should a refuse-disposal plant be expected to do so? Refuse and sludge had to be dealt with, and that cost money, and all that should go to the debit of composting was any excess cost over disposal by other methods. If the alternative available happened to be controlled tipping on a suitable site in the near vicinity, then the excess cost would be appreciable, but such convenient facilities were becoming rare, and should the alternative be carting over long distances or separation and inceneration, then composting might well prove no more costly, and any revenue at all from the product would show a credit.

Mr W. Fillingham Brown, in reply, thanked Mr Griffiths for his contribution, which had supplemented his Paper in a very valuable manner. One must agree with Mr Griffiths that local conditions must be taken into account in assessing the best way of utilizing or disposing of sewage sludge.

141. Referring to Mr Bywater's contribution, it was correct that, according to the

findings of Dr Silverman, a temperature of 59°C (138°F) for a period of 10 min would kill the ova of cysticercus bovis, i.e. any respectable composting process would get rid of that danger completely, as would any of the sludge drying processes using high temperature heat, but sludge digestion, which was usually carried out at about 90°F, would not.

142. He disagreed with Mr Bywater that sewage effluent was distasteful to cattle, his experience being that they preferred it to purer water by reason of its salt content.

143. One must agree, of course, that while the possibility was present of transmission of this disease to cattle by the application of unheated sludge to land, the findings of Dr Silverman had been that the chances were extremely remote, and that in fact there was no evidence that it had ever occurred, but of course there was that possibility, and it should be guarded against in the assessment of any use of sewage sludge, just as the use of raw sludge on land used for the growing of crops to be eaten uncooked should also be avoided.

144. He agreed with Mr Babcock that provided sewage sludge was dry enough not to slump into a homogeneous mass, it could be dried further through the heating action of aerobic fermentation, but much of the sludge partially dried on vacuum filters and on drying beds was still too wet for this condition to be achieved, unless it was first mixed with drier, more open materials such as house refuse. This was one of the values of house refuse; it allowed air to be entrained in the mixture and thus created the conditions necessary for aerobic fermentation to be set up and to continue.

Mr J. C. Wylie, in reply, thought that it was ridiculous to suggest—and he thought the speaker in the discussion who had done so knew it—that one could make land worth £6,000 an acre from domestic refuse. In point of fact, they had come to the very ridiculous situation where nearly every local authority throughout the country was trying to persuade neighbouring authorities to receive its waste. No London borough tried to make land within its own district, and although there were a few authorities in other parts of the country which had reclaimed land and indeed had made quite striking structures out of their refuse, it nevertheless remained true, he thought, that the bulk of the refuse disposed of by tipping was shoved away by the responsible authority in such a way as would protect its own ratepayers from high costs and inconvenience.

146. He apologized for saying that some refuse was still being tipped into the sea. He had not appreciated until this evening, just before the meeting, that the last culprit had stopped doing so. That at least, was progress.

147. He had not suggested that controlled tipping should be stopped, but he did have some sympathy with the people of the village of Harewood, in Middlesex, who had, quite recently, appeared in Downing Street to object to a suggestion that they should receive refuse from some Metropolitan boroughs in their district.

148. Controlled tipping would continue. There was no suggestion on his part that everything that was being done was evil; it was only suggested that composting was a relatively new process which, as engineers, they should look at carefully and use.

149. It had been suggested that it was a pity that the New Towns had not taken the opportunity in this matter, and he agreed, but it must also be recognized that existing plants for sewage disposal and refuse disposal did wear out; some of them were already obsolete; they had to be replaced and similar opportunities arose in this way.

150. Before leaving the question of controlled tipping, he would remark that the difficulties were progressive—the refuse had constantly to be taken increasing distances away as bulky refuse used up all the available space. Refuse from London was in fact being carried 40 miles, and at that rate it could hardly be disposed of for less than 25*s* a ton. There were a number of authorities which claimed to dispose of it at less cost, and their claims might be true, but there was a general trend of increasing cost in disposing of refuse by controlled tipping.

151. He was pleased that no doubts had been cast on the efficacy of the process of composting. Only a few years ago the composting process itself had been ridiculed as being ineffective and inefficient in making these potentially harmful wastes innocuous

and valuable for agriculture. No one responsible for the disposal of either sewage sludge or refuse had claimed that they were going into competition with I.C.I. or Fisons. They were not going to be put out of business.

152. There was no reason at all why a composting plant should be expected to pay, any more than a percolating filter should be expected to pay. He was drawn to composting plants in preference to sludge boats and destructors because they did not pollute the sea or the atmosphere, and they produced this material which agricultural advisers rated at something only slightly less valuable than farmyard manure. He would not argue with those agricultural experts; he accepted happily their assessment. Within recent months he had visited a Scottish farmer and that farmer, on going through his yard and passing his manure heap, had raised his hat in respect. But that farmer had also given him an assurance that if he could get an equal quantity of compost made from town waste, he would do the same to it! Scottish farmers, like all farmers, drove a hard bargain, and they did not want to pay more for a manure than they had to, but he saw no reason why a local authority, because it got into the happy position of being able to make from these wastes something that was saleable, should hesitate to produce it in case they should get a few shillings less than they ought to get and the farmer benefit accordingly.

153. It was true, of course, that the two wastes were quite often at separate ends of the town. The reason for keeping them apart was less good than the reason for bringing them together, and was no more difficult. The suggestion which had been made that towns' waste compost would only equal 2% of the farmyard manure used by farmers must be questioned, but it at least removed any suggestion that there would not be a market available for the product.

Dr G. E. G. Mattingly, in reply, said that there were one or two points that he wished to make, some of which arose from the discussion that had taken place. He was quite sure that any activated sludge that was produced and dried would almost certainly be used in horticulture. The nitrogen in it, so far as American experience had gone, was quite readily available to plants, but very little was known about the phosphate. No extensive experiments on activated sludge had been carried out in Great Britain, and naturally results from field experiments would be necessary to assess accurately its value as a source of both nitrogen and phosphate.

155. The fact that composts from sewage sludge and town refuse were not comparable with farmyard manure had been more readily accepted than he had imagined. This did not imply, however, that they should not be produced and used locally with guidance from the National Agricultural Advisory Service.

156. Mr Knolles and Mr Merchant had asked about trace elements in refuse and composts. It was easier and safer to correct minor element deficiencies of crops by spraying them with nutrient solutions than by applying sludges or composts. Toxic concentrations of zinc and copper have been reported in the Midlands from heavy applications of industrial sludges and zinc toxicity in lettuce due to heavy applications of household refuse had been observed in greenhouse experiments. The successful use of both refuse and sewage sludge in agriculture required the co-operation of both engineers and the local staff of the National Agricultural Advisory Service.

157. It was not possible to give an estimate of what percentage of the total United Kingdom agricultural production was achieved solely by the use of fertilizers; the estimated quantites of nitrogen, phosphorus, and potassium used annually in inorganic fertilizers and farmyard manure were given in Table 11 together with the quantities recovered in sewage sludge, of which approximately one half were at present returned to the soil.

158. As Mr Babcock suggested, there were small differences in the agricultural value of different sewage sludges. Digested sludges were easier to handle and contained somewhat more inorganic nitrogen than primary sludges.

159. The figures given in § 22 were taken from the Zuckerman report.[5] Allowing for losses of dry matter and moisture during composting, only 700,000 tons of compost

TABLE 11

	N	P_2O_5	K_2O
	Tons × 10^3	Tons × 10^3	Tons × 10^3
Inorganic fertilizers	300	380	310
Farmyard manure	180	80	180
Sewage sludge	20	10	2

would be available if 1,000,000 tons of the putrescible organic matter in refuse were composted with 2,000,000 tons of *fresh* sewage sludge.

160. In reply to Mr Gothard, Dr Mattingly said he thought that sufficient experiments had been carried out on a national scale to assess the value of composts from town refuse and sewage sludge. A limited number of experiments on horticulture crops in areas where such material was available in sufficient quantity for commercial use would be worth while.

161. There would always be disagreement about the total amounts of household refuse available for composting; the figures quoted by Mr Gothard presumably included screened dust with a high ash-content.

162. Farmyard manure and composts from refuse and sewage sludge have, admittedly, a similar nitrogen and phosphorus content in the fresh material and equal fresh weights have usually been compared in the field experiments which showed the composts to be inferior to farmyard manure. The data in Table 1 were given on a dry-weight basis to emphasize how low the concentrations of nutrients were in refuse. No mention was made in the paper about the quality or "availability" of nutrients which was considered to be outside the scope of the meeting. However, "total" analyses merely indicate the *maximum* amounts of nutrients present; much less can be regarded as useful to crops in one year. Very much less nitrogen nitrifies from refuse composts in one growing season than in composts from straw and sludge[12, 31] or farmyard manure. Furthermore, the phosphorus compounds in farmyard manure are largely organic whereas refuse contains a high proportion of bone which releases phosphate to crops only very slowly. Most of the potassium in farmyard manure is water-soluble; there is less total potassium in refuse and much of what is present is in the form of silicates[32] that were probably derived from soil or coal ash; these are of little value to crops.

Dr J. Longwell, in reply, noted the point made by the Chairman that it was very undesirable to endanger water supplies, with which he fully agreed. That was why the Ministry of Housing and Local Government had set up a Committee on the disposal of refuse in dry and wet tips. The Committee had investigated the percolation of water through refuse, assessed the chemical and bacteriological quality of the effluent produced, and measured the degree of purification when it was passed through various lengths of gravel and sand. The Committee had not yet issued it's report and Dr Longwell emphasized that he could not in any way anticipate it.

164. Mr. Finch had spoken about a survey of safe areas. There were many areas where it was quite safe to tip, and although he was not taking sides on the question of tipping *versus* composting, he must admit that when he walked round Teddington and looked at some of the reclaimed ground by the riverside, he thought there was a lot to be said for it.

165. One point he wished to make was that tipping into derelict gravel pits full of water would not necessarily be dangerous even though the ground water was subsequently used for drinking. It had been found in Holland, the United States, and recently in this country that bacterial pollution was rapidly removed by filtration, even under anaerobic conditions, through gravel and sand; a complete removal of *Bact. coli* and faecal streptococci being effected in less than 100 ft from the source of pollution.

Organic carbon and organic nitrogen compounds were also largely removed, but ammonia and inorganic compounds, for example chlorides and sulphates, persisted. Ammonia would eventually be oxidized to nitrate and chlorides would be diminished by dilution. If then, at a suitable distance from the tip, the concentrations of ammonia and of chloride were not excessive, abstraction of water should be quite safe particularly having regard to the normal treatment, filtration, and chlorination usually given to such supplies.

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