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Sewage is one of the most potent sources of nitrogen supply to the soil. Its application to land would be not only an economical method of disposal, but also an elegant means of returning to the soil the major part of the fertilising ingredients originally removed from it in the form of crops. There are, no doubt, several problems, agricultural as well as hygienic, connected with sewage farming, but these do not justify the enormous waste that is going on. It is, indeed, distressing to find that the major part of the world's sewage is either thrown away—discharged into the rivers or the sea—, or, if applied to land, managed so uneconomically that the maximum benefit is rarely ever attained. In the latter case, there are the additional dangers of water pollution, soil sickness and the production of unhealthy crops through profuse application of undiluted sewage. In view of these, it has been considered desirable to make a critical study of some of the problems relating to sewage farming, especially in India, and to suggest means of improvement.

In many parts of India, only the kitchen waste passes into the sewers, while night-soil, which is generally collected by hand, is disposed off separately. It is only very rarely that industrial wastes (such as those from dye-house, tannery, or brewery) get admixed with sewage so that the special problems connected with their application to land do not generally arise.

The composition of raw sewage is variable, depending on the density of population, the nature of the wastes that find their way to the sewers, the available water supply, the conditions of the sewers and such other factors. The following results (Table I) will illustrate the above.

TABLE I.

Composition of different sewages : parts per 100,000.

Origin	Suspended solids	Ammoniacal nitrogen	Albuminoid nitrogen	Oxygen absorbed in 4 hrs.	Chlorine
Indian.					
Dacca*	12·5	5·0	0·24	3·6	9·6
Bombay (Matunga)* ..	31·8	1·08	1·62	..	3·36
Calcutta (Sibpur)* ..	25·6	0·17	0·02	7·1	17·0
Jamshedpur*	..	1·88	1·98	11·3	3·5
Madras*	..	3·3	1·26	7·6	17·5

* Cited from Swaminathan, *Jour. Indian Inst. Sci.*, 1929, **12A**, 139.

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TABLE I—*continued.*

Origin	Suspended solids	Ammonia-cal nitrogen	Albuminoid nitrogen	Oxygen absorbed in 4 hrs.	Chlorine
English.					
Saltley*	57·7	4·06	1·52	26·3	18·9
Reading*	34·2	10·4	1·48	8·8	10·1
Sheffield*	77·4	5·09	1·22	13·9	..
Manchester (Davyhulme)* ..	17·8	2·32	0·76	7·2	10·8
American.					
Milwaukee*	25·9	1·56	0·89	12·5	19·4
Boston†	13·5	1·14	0·91	5·6	..
Chicago†	14·1	0·88	0·76	3·8	4·0

* Cited from Swaminathan, *Jour. Indian Inst. Sci.*, 1929, **12A**, 139.

† Cited from Kershaw, Sewage purification and disposal, 1925.

It may be noted that the English sewage is richer in nitrogenous constituents than the average Indian sewage. This is traceable to a number of factors, the most important of which are (*a*) the richness of the food consumed by, at any rate, a large section of the people and (*b*) inclusion of night-soil which is richer in nitrogenous constituents than ordinary kitchen waste. The dilute condition of the American sewage is accounted for by the liberal supply of water (some times as much as 200 gallons a day per head) in many of their cities.

There is periodical fluctuation in the composition of sewage (raw or treated) in any locality depending largely on the time of day or season of the year. The following observations relating to two important nitrogenous constituents will illustrate the possible extent of variation in one locality.

TABLE II.

Periodic fluctuations in the Ammonia and Albuminoid nitrogen contents of raw sewage, septic tank effluent and A.S. tank effluent : as parts per 100,000 *of N.*

Item	Raw Sewage	Septic tank effluent	A.S. tank effluent
Ammonia (free and saline) ..	1·68–3·25	1·8–3·3	0·51–0·76
Albuminoid nitrogen	0·69–0·89	1·14–1·54	0·12–0·15

These figures relate to the installation at the Indian Institute of Science.

The greater concentration is generally observed during the hot and dry months of the year. That also happens to be the season when liberal watering is needed by market garden and other crops which are generally raised on sewage. This important fact has to be taken into account when considering the effect of prolonged application of undiluted sewage on agricultural crops.

The changes in composition are not, however, very considerable when the samples are collected over only a limited period and the daily collections are mixed together prior to application to land. The following observations relate to the effluent from one of the septic tank installations at the Indian Institute of Science.

TABLE III.

Weekly changes in the composition of septic tank effluent used for irrigation.
Parts per 100,000.

Weeks	Total solids	Chlorine	Ammoniacal N.	Albuminoid N.	Nitrite N.	Nitrate N.	Total N.
0	42·0	5·7	3·3	0·6	0·8	2·5	7·4
1	45·5	5·5	3·2	0·5	0·8	2·4	7·2
2	48·2	5·6	2·6	0·5	0·7	2·4	6·5
3	62·0	5·7	2·4	0·6	0·7	2·5	6·5
4	59·4	5·7	3·1	0·4	0·9	2·6	7·5
5	62·2	5·6	2·4	0·4	0·2	3·6	6·9
6	62·4	5·5	3·3	0·5	0·09	2·4	6·5
7	48·2	5·6	3·2	0·5	0·06	2·7	6·8
8	66·2	4·6	3·1	0·6	0·09	2·7	6·8
9	56·8	5·5	2·2	0·6	0·08	3·2	6·4
10	58·8	5·7	2·1	0·4	0·06	2·8	5·8
11	61·4	5·6	2·0	0·6	0·04	3·7	6·6
12	56·6	4·3	1·8	0·5	0·02	2·4	5·1
13	58·4	5·6	2·1	0·6	0·04	2·2	5·2
14	48·6	5·4	2·0	0·4	0·06	2·5	5·5
15	49·2	5·6	2·8	0·6	0·04	2·3	6·0
16	50·1	5·4	2·4	0·5	0·04	2·4	5·9

On application to land, all types of sewage undergo oxidation, yielding first ammonia and then nitrate. The rate of such oxidation is determined by various factors—the nature of the soil, the concentration of sewage, the efficiency of the previous treatment, especially in regard to removal of albuminoids, the manner and rate of application to land, cultivation operations, and such like. It may be stated, in general, that light soils are more efficient than heavy ones. Pre-treatment, especially that involving aeration, facilitates subsequent oxidation in the soil. Application in small instalments at a time and uniform spreading over land leads to quicker transformations than heavy or uneven applications. Cultivation operations improve the rate of oxidation. If the applications are heavy and are continued indefinitely, the rate of oxidation tends to slacken. Even the best soils turn steadily sewage sick. There is multiplication of pathogenic and putrefactive organisms and the soil becomes smelly. In many cases there is fly and mosquito breeding and the soil gets infected with hookworm. The standing crops, if any, show the effect of adverse soil conditions. The plants get diseased and the yield is considerably depressed. Such soils are generally inadequately drained and any effluent that may pass out becomes a source of pollution to the water supplies in the neighbourhood. It would thus be seen that sewage-sick soil is undesirable not only from the agricultural point of view, but also from considerations of public health. It is extremely important, therefore, that the oxidising efficiency of the soil should be maintained and sewage sickness carefully avoided.

There is fairly extensive literature on the subject of sewage sickness, but the available biochemical data are still not sufficient to show the precise nature of the agents or the products responsible for the various phenomena which have been reported. Furthermore, it is not very clear whether sewage sickness is exclusively responsible for the abnormalities observed in the case of certain crops which are raised on sewage. Some crops seem to tolerate even fairly high concentrations of raw sewage whereas others suffer considerably even if moderate quantities are applied. A useful amount of information in this direction has been accumulated by a number of workers in different parts of the world. Among the Indian stations, particular mention should be made of the Hadapsar Farm near Poona and the Sewage Farm at Jamshedpur. The experience of the Poona workers, as also that of ours, have shown that it is not desirable to apply sewage (especially in the raw condition) as such to the soil. Many agricultural crops show undesirable effects (though the soil is itself not apparently sick), which are traceable to excessive supply of certain constituents, especially nitrogen. Suitable dilution of sewage (so as to contain between 0·5 and 1·0 of total nitrogen part per 100,000) removed these undesirable effects. This, combined with proper cultivation operations and periodic fallowing, should render sewage irrigation suitable for practically all types of crops. In our experience, the effluent from the septic tank has to be diluted three to five times if consistently beneficial effect is to be attained. The activated sludge effluent is reasonably safe during certain months of the year (especially when there are periodical rains to effect the necessary dilution), but even that has to be diluted with two or three times its volume of water if it is to be freely used in all seasons of the year and for a variety of crops.

A few towns in India possess storm water tanks, which are generally situated near the Sewage Works, the water of which can be used for suitably diluting the sewage used for irrigation. When this facility is not available and the soil is of the heavy type, the crops have to be chosen carefully for, otherwise, many of them may fail altogether.

An alternative procedure for controlling the concentration of sewage effluent used for irrigation would be that of adopting a suitable system of pretreatment which will not only remove the suspended matter but also retain a considerable part of the soluble nitrogen in the form of sludge. None of the present systems of sewage treatment is entirely satisfactory, however, from this point of view. The septic tank effluent contains a large amount of the nitrogen in ammoniacal form : albuminoids ammonify in the tank and thus increase the ammonia content of the effluent. The activated sludge process is highly efficient in holding up albuminoids which are clotted out in the form of sludge, but even that cannot retain nitrates and the small quantities of ammonia which may escape oxidation. The nitrate content of the effluent would depend partly on the ammonia content of the original sewage and as the average Indian sewage undergoes considerable amount of septic action (in the drains) before reaching the final disposal stage, it may be reasonably expected that it will contain considerable quantities of ammonia which will nitrify in the activated sludge tank and thus pass into the effluent. The other methods of sewage disposal are more or less intermediary in character between the septic tank and the activated sludge systems and will discharge a portion of the soluble nitrogen (partly as ammonia and partly as nitrate) into the effluent. In some cases, other forms of non-protein nitrogen may also pass into the effluent.

It has been shown by Richards and Weekes (*Proc. Inst. Civil Eng.*, 1921) that if sewage is passed over straw filters, a considerable part of the soluble nitrogen is held up by the straw. Straw filters are highly useful in a small way, but are rather inconvenient to handle when dealing with large quantities of sewage. Moreover, the straw loses its efficiency after some time and has to be replaced by a fresh lot. Furthermore, straw filters will not find favour in India because almost every kind of straw fetches a useful price as dry fodder for cattle. The experience with straw suggested, however, that there may be other cellulosic materials, which are at present going to waste and which can be utilised either by themselves or in association with some other system of sewage treatment for adsorbing the soluble nitrogen of sewage. Some encouraging results in this direction have been obtained by Messrs. S. Rajagopal and M. S. Muthuswami Iyer in these laboratories who have shown that if any powdered, cellulosic material is stirred up with raw sewage and the suspension aerated, not only the suspended matter but also the soluble nitrogen are taken up by the sludge. The resulting sludge settles down fairly easily and, under ordinary conditions, dries rapidly without giving any offensive odour. The modified procedure thus offers considerable practical possibilities and deserves to be tried out on a large scale.

It is well known that dilution of sewage is of assistance not merely in reducing the concentration of nitrogen but also in facilitating biological oxidations, thus leading to destruction of organic matter which would otherwise prove offensive. Ammonia is oxidised to nitrite and nitrate and the quantity of albuminoids considerably reduced. These effects are best seen when the diluted sewage is run for some distance in open channels prior to application to land. The effect of mere dilution is illustrated by the following results which were obtained with septic tank effluent at the Institute. The experiments were carried out with different proportions of water to effluent, but for the sake of convenience only one set of results have been cited.

TABLE IV.

Effect of dilution on nitrogen transformations in septic tank effluent.
Parts per 100,000.

Time in days	No Dilution				Diluted with 5 times its volume of water			
	Ammoniacal N.	Albuminoid N.	Nitrite N.	Nitrate N.	Ammoniacal N.	Albuminoid N.	Nitrite N.	Nitrate N.
0	7·1	0·8	0·0	0·0	1·02	0·10	traces	0·02
1	6·3	0·7	0·0	0·0	0·93	0·11	0·02	0·028
2	6·5	0·6	traces	0·0	0·83	0·08	0·05	0·033
3	6·3	0·4	0·06	0·0	0·55	0·07	0·04	0·030
4	6·2	0·5	0·1	0·0	0·50	0·07	0·05	0·066
5	7·1	0·5	0·1	0·0	0·38	0·07	0·66	0·066
6	7·1	0·4	0·1	0·0	0·25	0·05	0·72	0·043
7	6·7	0·3	0·07	0·0	0·20	0·03	0·70	0·04

The above results show only the effect of allowing diluted effluent to stand for some time. The oxidation will be more complete and the nitrite converted almost entirely into nitrate when the diluted effluent is applied to land.

TABLE V.

Ammonification and Nitrification in soil irrigated with diluted septic tank effluent. Nitrogen in parts per 100,000.

Time in weeks	Ammoniacal N.	Nitrite N.	Nitrate N.
0	0·014	0·00	0·002
2	0·12	0·002	4·1
4	0·97	0·002	5·8
6	1·01	0·003	6·1
8	1·80	0·003	7·2

In the above experiments diluted sewage was applied to uncropped soil. It may be seen that the ammoniacal nitrogen shows a slight increase. Nitrite nitrogen is either absent or present only in traces. Nitrate nitrogen shows a steady increase and is, in fact, the chief product of oxidation of sewage in the soil.

If the diluted sewage is applied to soil under crop, there is very little accumulation of nitrate. This observation has been verified by trials with a number of crops, but the following results relate to only three of the crops which were watered with diluted septic tank effluent,

TABLE VI.

Distribution of nitrogen in sewaged soil under crop.
Nitrogen in parts per 100,000.

Time in weeks	Soil under Ragi			Soil under Dolichos Lablab			Soil under Tomato		
	Ammoniacal	Nitrite	Nitrate	Ammoniacal	Nitrite	Nitrate	Ammoniacal	Nitrite	Nitrate
0	0·02	0·01	0·05	0·02	0·02	0·03	0·06	0·01	0·08
2	0·4	0·02	0·6	0·4	0·03	0·8	0·9	0·04	0·9
4	0·6	0·03	1·1	0·7	0·04	0·9	0·8	0·04	0·9
6	0·9	0·02	0·8	0·8	0·04	0·7	0·8	0·03	0·8
8	1·2	0·04	0·7	0·8	0·02	1·1	1·0	0·05	1·1
10	0·6	0·03	0·9	0·9	0·03	0·3	0·9	0·04	0·9
12	0·8	0·03	1·8	0·7	0·03	0·8	0·9	0·03	0·8
14	1·6	0·04	0·96	1·1	0·04	1·2	1·1	0·03	0·8
16	1·2	0·04	1·4	0·9	0·04	0·9	0·8	0·04	1·2

It may be mentioned that the ammoniacal nitrogen remains more or less at the same level as in uncropped soil. Nitrite is present only in traces. Nitrates are used up nearly as fast as they are produced.

Mineral fertilisers like superphosphate or potash (if applied in moderate quantities) have no influence on the oxidation changes. On the other hand, they stimulate plant growth and thus indirectly facilitate increased intake of nitrogen. The nature of the crop (and especially its root system) is also an important factor determining the active concentration of nitrogen left in the soil. It may be stated generally that grasses and other dense crops not only tolerate fairly high concentrations of sewage nitrogen but also utilise it nearly as fast as it is applied.

Yield of crops raised on diluted sewage effluent.—All the commoner agricultural and market garden crops can be raised successfully on diluted sewage. It is difficult to prescribe any single formula for the dilution as it will depend largely on the strength of the original sewage and the pretreatment received by it. With the septic tank effluent of the composition given in Table III, dilution with three times the volume of water has been found to be most satisfactory. The diluted sewage can be applied to almost any crop with consistently satisfactory results. In the case of some crops, there is delayed ripening of grains but this can be overcome by either reducing the volume of sewage or further increasing the dilution until the approach of the harvest period.

Elephant grass.—The experiments were conducted on small plots laid out on a uniform area of land. One set of plots was watered while the other received diluted sewage. Four plots were allotted to each treatment. The plots were distributed at random. The cuttings were taken just before flowering and the yields have been presented in Table VII.

TABLE VII.

Effect of sewage irrigation on yield of elephant grass—successive cuttings
(Area, 400 sq. ft.)

Date of harvest	Yield in Kilograms	
	Sewage irrigated	Water irrigated
6th June	102·4	46·0
11th July	206·8	101·7
7th August	210·6	115·5
5th October	222·3	141·2
23rd November	92·2	66·9
8th January	68·2	43·4
11th February	46·8	19·5
25th March	93·4	36·3
28th May	291·1	91·3
13th July	302·6	154·3
4th October	213·9	146·5
22nd November	121·0	89·3

The yields from individual cuttings have been considerably modified by the season, the wet months (July to October) being generally more favourable than the dry ones (December to April). The effect of season was of more or less the same order in both the sets and it may be seen that the sewaged plants did consistently better than the watered ones.

Lucerne.—The experimental details were similar to those in the case of elephant grass. The yields (Table VIII) show a striking difference between sewage and water irrigation.

TABLE VIII.

Effect of sewage irrigation on yield of lucerne—successive cuttings.

Date of harvest	Yield in Kg.		Date of harvest	Yield in Kg.	
	Sewage irrigated	Water irrigated		Sewage irrigated	Water irrigated
15th May ..	31·3	16·8	26th March ..	25·5	9·1
12th June ..	21·8	11·6	10th April ..	26·1	8·3
8th July ..	18·8	9·3	30th April ..	15·3	5·9
6th August ..	24·8	14·0	16th May ..	14·3	5·4
22nd August ..	21·5	13·9	5th June ..	11·1	4·4
12th September ..	22·3	10·3	23rd June ..	15·4	4·9
7th October ..	31·9	16·1	17th July ..	24·7	6·2
1st November ..	41·0	18·3	2nd August ..	31·7	8·3
28th November ..	35·5	17·9	25th August ..	24·6	6·7
16th December ..	40·3	17·5	11th September	25·7	6·6
7th January ..	36·2	15·4	3rd October ..	29·1	7·7
27th January ..	33·9	13·0	23rd October ..	23·9	7·7
18th February ..	35·4	13·5	15th November	25·3	8·0
6th March ..	35·6	11·7			

It may be observed that while the watered plants tended steadily to deteriorate with time, the effect was not so prominent in the case of the sewaged ones. Lucerne also shows the effect of season, but not so pronouncedly as elephant grass.

Grain and Market garden crops.—These experiments were conducted in pots. The pots were divided into two sets, one receiving basal dressing of superphosphate and the other left untreated as control.

Of these, again, one half was watered with diluted sludge and the other with tap water. The results have been given in Table IX.

Table IX.

Yield of grain and market garden crops (pot expts.).

Crop	Yield per pot (in g.) after treatment with			
	Super followed by sewage	Sewage alone	Super followed by water	Water alone
Barley	51	42	8	6
Tomato	1,400	1,390	508	175
Peas	38	34	17	15
Dolichos	431	175	149	70
Potato	300	167	117	100

It may be noted that barley responds very well to sewage, the yield being more than five times that in the watered control. Basal dressing with superphosphate leads to further increase in yield. The effect on tomato is also striking, the sewaged plants being vastly superior to the watered ones. The effect of super is, however, more pronounced in the case of the watered plants than in that of the sewaged ones. Peas have also responded well to sewage, but the effect is not so striking as in the case of other crops. Dolichos and potato have both done well on sewage, but in their case the effect of super is even more striking. This is particularly noticeable in the case of sewaged plants.

Other Crops.—These experiments were carried out in plots, the conditions being similar to those described previously (Table X). The total yields of elephant grass and lucerne from the respective plots have also been included.

TABLE X.

Yield of grain, market garden and fodder crops (in plots)

Crop	Yield (in Kg.) after treatment with—	
	Sewage irrigated	Water irrigated
Maize	15·6	10·8
Radish	135·6	71·6
Carrots	80·6	31·2
Elephant grass (13 Cuttings) . .	1454·8	750·9
Lucerne (27 Cuttings)	723·0	288·5

It may be observed that in all the cases the sewaged crops gave much higher yields than the watered ones. The most striking response was from lucerne and carrots, the sewaged plots yielding nearly thrice as much as the watered ones.

Manurial value of sewage sludges.—Pre-treatment of sewage involving the separation of sludge offers an additional advantage in that the sludge can be used as a fertiliser. The sludge may be separated by chemical precipitation, intensive aeration or mechanical agitation. Any two or all the three types of treatments may also be combined into one system. Prolonged septic action also yields a sludge but the product is generally very small in quantity as compared with those obtained by other methods. All these sludges have only limited application when present in the wet condition and tend to revert on standing. They are also inconvenient to handle, so they are not of much commercial value unless they can be properly dried.

Several methods have been proposed for the drying of sewage sludge. Most of them are comparatively expensive. The most efficient are those involving the filtration of sludge from the adhering water followed by machine drying. These involve costly outfit and are not suitable except on a very large scale. The recently introduced Fowler mat is exceedingly simple in design and is, at the same time, highly efficient as a filter unit. It yields a spadeable sludge which can be dried on the mat itself or by any one of the other methods. The mat sludge can also be easily dried in the sun.

Some experiments were carried out at Bangalore, comparing the manurial values of sewage sludges obtained by different methods. Starting from the same type of raw sewage, sludges were obtained after intense or limited aeration, chemical precipitation by different methods or prolonged septic action. Among these, the product obtained after intensive aeration was the most satisfactory. It kept after some time and offered no difficulty in filtration. The dried product obtained from it was the richest (3·5 to 4 per cent) in nitrogen. Reduced aeration yielded a slightly smelly product which did not keep well even for a few hours. It also offered difficulty in filtration. The dried product was comparatively poor in nitrogen (2·5 to 3·0 per cent). This was traceable to the fact that the sludge receiving limited air supply had very poor clotting action, so that a part of the nitrogen was allowed to pass into the effluent.

The results obtained by chemical precipitation (by ferric or aluminium sulphate) were nearly similar to those after limited aeration, except that the filtration was slightly easier. On the other hand, the sludge was bulky and the dried product poor in nitrogen. There was very poor yield of sludge after prolonged septic action. The dried product contained larger quantities of mineral (soil) matter and was the poorest in nitrogen (1·5 to 2·0 per cent). Both from the point of view of quality and quantity, the septic tank sludge (which would correspond in some respects to the residue left after digestion for gas) is rather poor and cannot be regarded as possessing any high manurial value.

When applied on equivalent nitrogen basis, sewage sludges were generally found to be superior to inorganic fertilisers. The following results (Table XI) obtained at Bangalore with three different types of crops will illustrate the above.

TABLE XI.

Manurial value of Sewage Sludge (Pot expts.).

Treatment	Yield (in g.)			
	Lucerne	Potato	Ragi	
			Grain	Straw
No manure (control)	704	400	9	22
Super alone	1,772	250	12	31
Nitrate alone	805	270	10	26
Nitrate *plus* Super	1,687	410	16	37
Chemically precipitated sludge ..	2,871	990	39	110
Chemically precipitated sludge *plus* Super	3,373	1,000	40	111
Activated sludge	4,983	1,130	..	..
Activated sludge *plus* Super ..	4,283	1,160	37	109

Lucerne showed better response to super than to nitrate. Chemically precipitated sludge yielded better and activated sludge the best. Addition of super proved useful in the case of the chemically precipitated sludge, but there was evidence of depression when combined with activated sludge. The response of potato was similar to that of lucerne though not so striking. The yields of ragi were also of the same order except that the chemically precipitated sludge was nearly as effective as activated sludge. This may be due to the fact that ragi is a crop of fairly long duration (six months), so that both the types of sludges would have had sufficient time to undergo the necessary decomposition in the soil.

Physiology of crops raised on sludge.—There is comparatively scanty literature on this important aspect of sewage farming. Most of the available records relate to the abnormalities observed when undiluted sewage is persistently applied for watering crops. Under such conditions, crop lodging is often observed. In many cases the adverse effects are not seen till a late stage. The leaves get crinkled and, in some cases, there is practically no flowering or seeding. Many of the crops also get diseased, stem and root rots being the most common. Insect attacks of various types have also been reported.

The researches carried out by S. A. Rafay at the Indian Institute of Science with a variety of crops showed that the crops raised on diluted sewage exhibit none of the above-mentioned abnormalities. The plants come out quite healthy. The vegetative growth is of the same type as that obtained with a liberal supply of a nitrogenous fertiliser. The leaf area is increased and the shoot height distinctly improved. There is also greater tillering, the number of tillers in sewaged plants being about 50 per cent more than the watered controls. Flowering and seeding are favoured with attendant improvement in yields. There is delayed ripening in some cases, but this can be largely overcome by suitable basal dressing of superphosphate.

Crops that respond most favourably to sewage treatment.—This observation would apply primarily to sewage farms which have no facilities for either dilution or otherwise reducing the concentration of nitrogen in the effluent. The crops have to be carefully chosen and planted in the right season, for, otherwise, they may fail altogether. The experience on the Bangalore farm during the past fourteen years would show that grasses (of different varieties), lucerne, cholam (fodder), plantains, papaya and cocoanut do fairly well even on undiluted sewage, at any rate, for a few seasons. Among the market garden crops, cabbage, cauliflower, tomatoes, lettuce, amaranthus and such like respond favourably. Certain creepers such as pumpkin, snake-gourd and cucumber also do well, at any rate, in most seasons. On the other hand, brinjals, chillies, lady's-finger, peas and most grain crops are very erratic in their response. In certain seasons they do well, while in others they fail completely. It is generally difficult to predict the results and considering that the failures are more numerous than the successes it would be advisable to leave out such crops altogether. Among the fruit trees, apples, oranges, and limes did not do well on sewage. Guavas and figs did somewhat better, but the results were not, on the whole, very satisfactory.

Quality of crops raised on sewage.—Attention has already been drawn to the fact that crops—especially those of the market garden type—raised on sewage do not keep well. It may also be added that in certain localities—especially if the drainage is unsatisfactory—they also smell of sewage. Certain sections of consumers have complained of inferior taste but the majority cannot distinguish between the taste of vegetables raised on sewage and those on water.

Hygienic aspects of Sewage Farming.—The available evidence would suggest that suitably diluted sewage undergoes complete oxidation in the soil, so that it is hardly likely that it will be a source of pollution. The same cannot be said, however, of undiluted sewage, especially when the application is prolonged. The effluent draining out of the soil will not be a completely oxidised product and will be a source of pollution to unprotected water supplies in the neighbourhood.

In addition to the above, sewage contains a large amount of insect life, which is not destroyed except during prolonged septic action or intense aeration. If raw or incompletely treated sewage is applied to land, these are released and become a source of danger to crops as well as to public health. Separation of sludge—by one of the known methods—followed by its drying or digestion for gas is the most satisfactory way of eliminating insect pests.

Even under the most favourable conditions (including proper dilution), it may be reasonably expected that market garden crops raised on sewage will get polluted, at least mechanically, in the process of watering. Proper washing (preferably with a dilute solution of permanganate) followed by cooking (involving frying or prolonged boiling) will, no doubt, kill out a large part of the associated putrefactive organisms, but these operations are not and cannot ordinarily be carried out quite thoroughly even in the best managed households. In hotels and restaurants, foods are generally prepared in great haste and are often only incompletely cooked. In such cases, it is not unreasonable to expect that some of the putrefactive and even pathogenic organisms originally present in sewage will still persist in the food and be taken by the consumers.

It is well known that digestive fluids—especially gastric juice—kill out most of the undesirable organisms present in food, but this may not always proceed satisfactorily. In some cases, the internal secretions may be inadequate or the organisms so numerous that some may escape destruction. The effect of this on the health of the consumer is still not properly understood. Systematic work on this aspect of the problem will yield results of considerable practical importance.

Taken on the whole, it would appear that sewaged crops—especially those of the market garden type—are not very desirable as articles of human food. On the other hand, farm animals flourish well on them. They are either immune or, at any rate, highly resistant to the effects of sewage pollution. It would appear to be highly desirable therefore to utilise sewage primarily for raising fodder or forage crops. The farm animals will, in turn, produce human food, which is comparatively safe to handle. In this manner the fertilising ingredients of sewage can be utilised to the maximum advantage and with safety to public health.

SUMMARY.

(1) The importance of sewage farming as an economical means of returning to the soil the various fertilising ingredients—especially nitrogen—originally removed from it in the form of crops is indicated.

(2) The nitrogen content of domestic sewage is determined by a number of factors, of which the nature of the wastes passing into the drainage and the water supply are the most important.

(3) The strength of sewage—especially in regard to nitrogenous constituents—varies with the season and, to some extent, with the time of day. The changes are not, however, very considerable when daily collections are mixed together prior to application to land.

(4) The difficulties arising through continued application of undiluted sewage—soil sickness, water pollution, plant diseases and insect pests—are indicated. Dilution of sewage with three to five times its volume of water—preferably after some system of pre-treatment involving the separation of sludge—eliminates the above-mentioned defects and leads to healthy crop production. Attention has also been drawn to the advantages of a modified system of treatment (involving addition of finely powdered cellulosic waste materials combined with intensive aeration) which yields a rich sludge containing practically all the nitrogen of sewage and an effluent which is quite innocuous.

(5) Even mere dilution followed by standing for some time lowers the albuminoid and the ammonia content of sewage. Nitrification—at any rate to the nitrite stage—proceeds quite rapidly. On application to land the oxidation is complete and, if the land is fallow, there is steady increase in the nitrate content of soil.

(6) When diluted sewage is applied to soil under crop, the nitrogen is taken up nearly as fast as it is applied. Addition of phosphatic or potassic fertilisers in small quantities has no direct effect on the transformations of nitrogen, but assist nitrogen intake by stimulating plant growth.

(7) Response of different crops to sewage irrigation has been discussed. Elephant grass raised on diluted effluent gave consistently higher yields than that irrigated with water. Lucerne did still better, the yield from sewaged plots being nearly three times that from the watered ones. Grain and market garden crops are also greatly favoured by diluted sewage. Basal dressing of phosphate is highly beneficial in some cases while, in others, very little improvement is observed.

(8) Fertilising value of sewage sludge—especially in regard to nitrogen—is indicated. Experiments with three different types of crops have shown that sewage sludge (activated sludge or the chemically precipitated product) is very much superior to mineral fertilisers (single or combined) applied on equivalent nitrogen basis.

(9) The physiology of crops raised on diluted sewage effluent has been

discussed. The beneficial effects are largely traceable to the steady supply of readily available nitrogen.

(10) Grasses and leaf crops in general respond best to sewage. They even tolerate undiluted sewage for fairly long periods. Among the market garden crops, some respond favourably, while others fail after some time.

(11) Sewaged crops do not keep so well as those irrigated with water. Some of the former also smell of sewage. It would be ordinarily difficult, however, to distinguish between the tastes of the two sets of products.

(12) Even under the most favourable conditions (including liberal dilution) sewaged crops cannot be entirely free from pollution. Careful washing combined with proper cooking will kill out most of the associated putrefactive and pathogenic organisms. When consumed, the digestive fluids will ordinarily destroy the rest. These operations may not, however, always proceed satisfactorily and, especially under certain unfavourable conditions, market garden crops raised on sewage may become a source of danger to public health. Farm animals, on the other hand, are fairly immune to pollution and do well on sewaged crops. In view of this and the fact that fodder and forage crops do best on sewage, it has been suggested that sewage farming may be mostly confined to raising such types of crops.

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