

# G J MOHANRAO

## *Waste-water and refuse treatment and disposal in India*

### INTRODUCTION

#### A. General

India is predominantly an agricultural country and has a high rural population. The water carriage system of excreta disposal which is almost universal in the western countries is restricted in usage to the larger towns and cities in India. Even in these cities and towns, not all the population is served by sewers. The population on the fringes of the town generally use either house-hold septic tanks or the dry conservancy system. In most of the Indian towns, the sewerage system is either non-existent or not at all adequate for the population. In the villages even latrines, wet or dry, are scarce.

#### B. Population Served by Sewers

India's present population is 547 millions (1971 Census) out of which approximately 109 million people are known to live in the urban areas constituting about 20 per cent only of the total population. The urban population is classified as that population which lives in towns having population above 5000 and cities having population above 100 000. Out of the 2921 towns and cities, only 186 are sewered at least partially. This works out to 6.4% of the total number of towns. In terms of population, about 33 million (30 per cent of the urban population) is served with sewers which amounts to 6 per cent of the total population.<sup>1</sup>

### C. Types of Wastes in Different Sections

The problem of domestic wastes in India can roughly be classified in the following manner:

Cities: Sewage and town refuse (some night soil and sullage)

Towns: Sullage, night soil and town refuse (some sewage)

Villages: Sullage, night soil and refuse

While sullage (domestic wastes excluding faecal matter) and night soil are a minor portion in the cities, sewage is a minor portion in most of the towns. The problems of the urban and rural sectors in India are shown below.<sup>2</sup>

#### Urban Section

Sewered population	33 million
Volume of sewage	785 MGD
Unsewered population	76 million
Volume of sullage	960 MGD
Volume of sewage + sullage	1745 MGD

#### Rural Section

Unsewered population	438 million
Population served with piped water supply at 10 gpcd	22 million
Sullage volume at 80% of water supply	176 MGD
Population not served with piped water supply at 5.5 gpd	416 million
Sullage volume at 80% water supply	1830 MGD
Total sullage from rural sector	2000 MGD

MGD = Million (Imperial) Gallons per day

### D. Potential Growth of Sewerage

According to an extensive survey carried out by the WHO to study the status of community water supply and wastewater collection and treatment in several developing countries, the system of sanitary collection and disposal of household wastes is either non-existent or grossly inadequate throughout Asia, Africa, and Latin America.<sup>2</sup> This was in contrast to considerable success in expanding community water supplied in the same areas (Table 1). It should be emphasised that water supply and waste collection and disposal should go hand in hand to avoid repetition of past mistakes.

### E. Refuse

Refuse is generated in cities as well as in villages. The amount of refuse or solid waste generated per capita in India is nearly 4 times that of the dry weight of sewage solids. However, the amount of money and effort spent on solving the problems relating to refuse disposal is comparatively small.

Most of the cities and towns use somewhat primitive methods of refuse disposal which involve unhygienic and unsatisfactory manual handling of waste in loading, unloading and land-filling or composting operations. A majority of the smaller towns in

India dispose of refuse in pits for conversion into compost.

Table 1. Relative Importance Given to Water Supply and Sewage Collection and Treatment in the Urban Sector of Developing Countries

	<u>Urban Population</u>		<u>Total Population</u>		Sewage treatment
	Millions	% of Total Population	% of Population served with water supply	% of Population served by sewerage	
India*	80	13	12	5	
Japan	98	68	69	11	There is little or no treatment facilities in these countries except in 1 or 2 urban towns
Lebanon	2.4	32	85	few	
Phillippines	35	17	30	6	
Thailand	26	15	3	nil	
Ethiopia	22	8	8	nil	
U.A.R.	30	40	40	few	

\* Uttar Pradesh State only

A regular scheme for composting town refuse has been in operation since 1954. About 2400 urban centres are under such scheme. The annual urban compost production is of the order of 4.4 million tonnes.<sup>1</sup> Whereas the per capita production of town refuse in the western countries varies from 0.4 to 2.4 kg/day, it varies from 0.1 to 0.5 kg/day in India.

#### F. Night Soil

As mentioned earlier, about 94 per cent of the Indian population is not served by sewerage system. A minor population is served with septic tanks. A majority of the urban population uses the dry latrine which is served by the dry conservancy system. Most of the village population has neither latrines nor sewerage. The urban population which uses the dry conservancy system generates night soil which is disposed of by trenching or composting under anaerobic conditions.

#### G. Pollutional Aspects

With the spread of protected water supply to the majority of the communities in the western countries and the rivers flowing perennially, the major objectives of sewage treatment are not to allow the dissolved oxygen in the stream to go below a certain limit in order to protect the fish and to prevent foul conditions from being generated in the streams. On the other hand, in countries like India where the protected water supply is still very limited, the waste treatment (especially domestic waste treatment) assumes a much greater importance. As a majority of the citizens depend upon shallow wells or surface waters for drinking purposes, the contamination of these water sources will reflect on the health of the nation. One of the most important items of water pollution in this country is the biological

pollution which starts from the human excreta.<sup>2</sup>

It has been reported by the National Institute of Communicable Diseases, Delhi, that nearly 30% of the deaths (due to infectious diseases) and 50-60% of the morbidity in the country have been due to water borne diseases. In view of the above, it should be recognised that the elimination of pathogens is one of the most important objectives in the treatment of sewage in the developing countries.<sup>2</sup> The incidence of typhoid, cholera, dysentery, infectious hepatitis, poliomyelitis and diseases due to various helminthic parasites is very common in India. Certain areas which use shallow well waters are known to be endemic to cholera. It is obvious that this type of pollution is happening because of recycling of infection from the infected human through sewage or night soil and drinking water.

The seasonal nature of rain fall in countries like India is another factor to be kept in mind in the treatment and disposal of sewage. The fact that most of the rainfall occurs during 3 or 4 months of the monsoon season renders a majority of the rivers dry for 4-6 months of the year. During the dry season, the sewage or its effluents will essentially form the rivers from which the relatively uneducated people drink water (directly or from nearby wells) adding to the pollution recycle.

#### SEWAGE TREATMENT AND DISPOSAL

##### A. Status of Sewage Treatment and Disposal

It has been mentioned earlier that only 6.4% of the towns and cities are sewered serving 6% of the total population of India. Even in those few cities which are sewered, a majority of the sewage is being discharged into the sea, rivers or on land with very little treatment. With the exception of a couple, most of the large cities discharge their sewage into the sea, rivers or on to land with practically no treatment. A major portion of the sewage is used on land for irrigation of various crops including vegetables. The present practice of sewage disposal in the 20 largest cities in India are given in Table 2.

##### B. Types of Existing Sewage Treatment Plants

A variety of treatment plants exist in India today. Some of the older plants are of the mechanical aeration (Simplex type with a draft tube) activated sludge plants. Trickling filters mostly of the high rate type using 4-6 ft and one or two 12 ft deep (with forced air circulation) are quite common. Among the trickling filters various flow sheets and designs are used. In the very small units, compressed air activated sludge systems of the Fowler Type have been in usage. More recently, activated sludge plants with mechanical and forced bubble aeration, Inka grid low pressure aeration system are being used. The oxidation pond has come into existence about 10-15 years ago and is being increasingly used. A few oxidation ditches (Pasveer type) for small populations are coming up. A few aerated lagoons have come up but are finding greater use in treating industrial wastes than domestic wastes.

##### C. Problems Associated with Existing Plants

A survey made by CIPHERI, Nagpur has revealed that about .75 per cent of the surveyed sewage treatment plants of the conventional type (trickling filters and activated sludge plants) have not been

Table 2. Status of Sewage Disposal in Some of the Major Cities of India

City	Approximate Population (1971 Census) Millions	Present Practice of Sewage Disposal
1. Greater Calcutta	7.8	Only a part of the city is seweraged and primary treatment provided. Part used for farming. Balance to River in untreated condition
2. Greater Bombay	6.0	Only 10% of city sewage is treated partly with secondary treatment. Balance goes untreated to the sea, and an odour problem exists in some areas.
3. Delhi	4.1	Two modern plants with primary and secondary treatment.
4. Madras	3.2	Part of sewage used for irrigation and part goes direct to the sea.
5. Kanpur	1.3	No sewage treatment plant. Part for irrigation.
6. Hyderabad	1.8	Screens, grit and balancing tank followed by irrigation.
7. Bangalore	1.6	Primary sewage treatment plants under construction
8. Ahmedabad	1.7	Two modern sewage treatment plants. Also irrigation.
9. Poona	1.1 )	
10. Nagpur	0.93 )	
11. Lucknow	0.81 )	
12. Agra	0.63 )	No treatment. Pumped for farming.
13. Varanasi	0.61 )	
14. Madurai	0.71 )	
15. Allahabad	0.51 )	
16. Amritsar	0.46 )	
17. Indore	0.56 )	
18. Jaipur	0.64 )	Secondary treatment plants. Effluents used for farming.
19. Sholapur	0.40 )	
20. Patna	0.49 )	

working to their designed efficiencies. They were either not working at all or performing poorly. The reasons for such poor performance are: i) the plants were not designed properly, ii) they were lying idle because of mechanical breakdown or lack of maintenance, iii) not working properly because of the lack of skilled operators. A good number of the conventional sewage treatment plants in this country are based on the designs commonly used in temperate climates. In view of the warmer temperatures that are closer to the optimum of microbial activity, it should be obvious that there is a great need for changing the design criteria. It is also necessary to provide units which are simple to fabricate and easy to operate. An important aspect is to keep the mechanical content to as little as possible because of the non-availability of skilled technicians to operate and maintain these units.

Although training facilities for skilled technicians are increasing, it is still found that the waste treatment plants are in short supply of the properly trained people for reasons beyond the control of waste treatment engineers.

#### D. Waste Treatment Methods Suitable to India

From the discussion in the previous item, it must be obvious that if sewage treatment plants have to work efficiently and reduce water pollution in developing countries like India, they should be of a simple design with very little mechanisation and automation. Among the various treatment methods available, stabilisation ponds, oxidation ditches and aerated lagoons appear to be the most appropriate methods for the developing countries.

An economic analysis of the cost of various sewage treatment processes in India has revealed (Table 3) that the waste stabilisation pond is undoubtedly the cheapest method for all population ranges.<sup>4</sup> As long as the cost of the land does not exceed Rs. 55 000 (Rs. 18 per  $\text{ft}^2$ ), the waste stabilisation pond system will be the cheapest even up to a population of 250 000, provided land is available. The oxidation ditch system (extended aeration activated sludge) is always cheaper to construct. However, when running costs are taken into account, the conventional systems are cheaper than the oxidation ditch for population above 150 000. A scrutiny of a list of 72 plants constructed in India over the last few years revealed that 86% of them are below 4 MGD capacity, corresponding to a population of 135 000 or less.<sup>5</sup> Considering the various factors including intangible benefits such as ease and efficiency of operation, freedom from breakdowns, it should be obvious that the low cost waste treatment methods should be the methods of choice under the above circumstances.

Table 3. Per Capita Cost Estimates for Various Sewage Treatment Processes in India<sup>4</sup>

Process	For Construction of plant (including land cost at Rs 10 000/acre)	Capita cost plus capitalised running costs	Total annual expenditure to defray all running costs including repayment of loan
	Rs.	Rs.	Rs.
1. Waste stabilisation pond	8.80 to 15.70	10.60 to 27.20	0.93 to 2.30
2. Aerated lagoon	12.00 to 19.00	32.20 to 55.80	2.80 to 4.86
3. Oxidation ditch	14.00 to 21.00	43.75 to 79.60	3.80 to 6.06
4. Conventional treatment	16.00 to 65.00	40.88 to 152.00	3.55 to 13.22

LOW COST WASTE TREATMENTA. Stabilisation Ponds1. General

Although waste stabilisation has been occurring in ponds for a long time, ponds designed on an engineering basis have come up only recently and are in operation for the last 15 years. The stabilisation ponds can be utilised for partial, complete or tertiary treatment. The stabilisation ponds may also be used to treat wastes in conjunction with other treatment methods. The principle of waste stabilisation in these ponds is the oxidation of the organic matter through the bacteria and the supply of oxygen through the algae. The process is known to be symbiotic, as there are two major groups of organisms helping each other. The bacteria oxidise the organic matter and release carbon dioxide, water and minerals. The algae utilise carbon dioxide, water and minerals and release oxygen using sunlight as a source of energy.

2. Types of Ponds

Stabilisation ponds are primarily of 3 types: i) oxidation ponds that are completely aerobic, ii) facultative ponds that are aerobic in the higher layers and anaerobic in the deeper layers, and iii) anaerobic ponds which are mostly anaerobic. Only the first two categories are discussed in this paper.

Although in the past, the ponds were designed primarily as aerobic ponds, it is now apparent that it would be of much greater advantage to design them as facultative ponds especially in the warmer regions of the world. It has been found that there is no danger of having the lower layers of the pond anaerobic provided at least 1 foot depth of the water layer below the surface is aerobic.<sup>6</sup> This will prevent any potential odour nuisance. In the

facultative ponds, a part of the BOD is stabilised by means of anaerobic decomposition, releasing volatile acids and alcohols. These are oxidised aerobically in the upper layers as they diffuse upwards. The suspended organic solids settling in the bottom layer of the pond undergo stabilisation through conversion to methane which escapes the pond in the form of gas. It can be seen that the oxidation of the organic matter and fermentation into methane would reduce the BOD load on the aerobic organisms.

### 3. Performance of Ponds

There are more than 50 stabilisation pond installations in India, a majority of which are of the facultative type. These were found to give 75-90 per cent reduction when the loads were reasonable. The ponds vary in their size from 0.029-63 acres and the depth varies from 2 ft to 5 ft with a depth of 4 ft predominating.<sup>7</sup> The influent BOD ranged from 160-418 mg/l.

At 200 lb BOD/acre day loading, oxygen penetration was up to the pond bottom during day time. At night, it was only up to 1.5 ft from the surface. At a loading of 600 lb BOD/acre day, the pond was completely anaerobic at night but had an aerobic layer in the day time (Fig. 1). Even under such conditions of operation, the pond did not cause odour nuisance.<sup>8</sup>

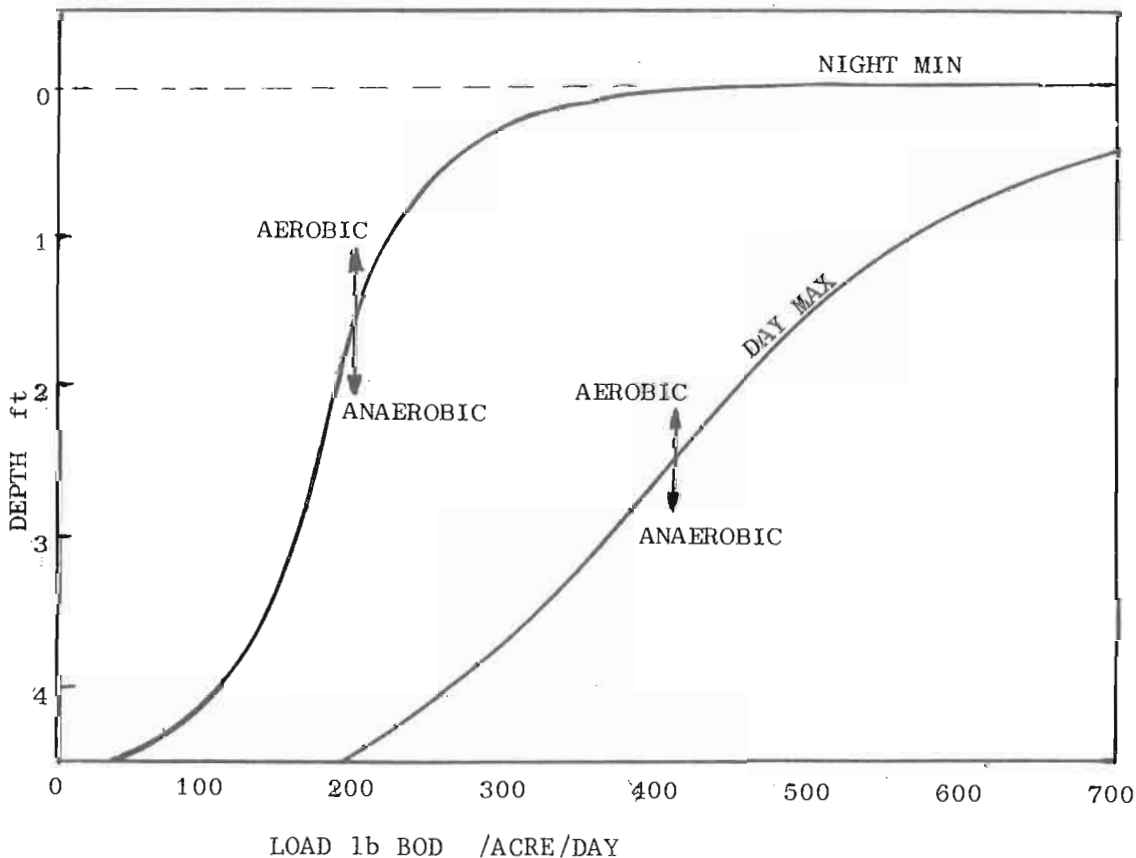


FIG. 1 - AEROBIC AND ANAEROBIC ZONES IN STABILIZATION POND



#### 4. Approaches for Design

Two basic approaches have been used for designing the stabilisation ponds. One proposed by Oswald<sup>9</sup> and recommended by some investigators in India equates BOD load to the oxygenation capacity of algae which is a function of the available solar radiation. The other approach given by Herman and Gloyna,<sup>10</sup> emphasises the influence of temperature on pond volume. Recently Marias has forwarded a model based on Phelps' approach to describe the behaviour of facultative ponds taking into account both aerobic and anaerobic reactions. However, its utility as a basis for designing ponds is questioned by Siddiqi because of difficulties in evolution of various kinetic constants used and generalising this from the limited experience.<sup>6</sup> Although the approaches proposed by Oswald as well as by Herman and Gloyna are sound, they should not be applied directly for designing ponds in India for the following reasons: i) the ponds which receive raw sewage invariably develop an anaerobic zone at the bottom and hence the BOD stabilisation through anaerobic reaction must be taken into account for sufficient and intensive utilisation of land area, and ii) temperature influences efficiency in the case of stabilisation of the organic matter in the anaerobic zone only when pond temperatures fall below 15°C. For most of the locations in India, the temperature of the pond does not fall below 15°C for any extended period of time. For a majority of location in India, the volume concept would be more useful. Hence it is possible to design ponds in Central and South India at a depth of 5 to 6 ft. This would automatically reduce the area required for the pond which is one of the important factors in the design.

Under Indian conditions, the BOD due to settleable fraction in the domestic sewage may be considered as 50 per cent in view of the low hydraulic loading on ponds. The surface area of the pond required can be calculated on the BOD of settled sewage on the basis of the figures given by Arceivala *et al*<sup>7</sup> (fig. 2), and not on raw sewage. A depth of 5-6 ft can be used. The detention time thus obtained should be equal to or more than 6.5 days which is the time required for 90 per cent reduction of BOD assuming the overall reduction rate constant of 0.15/day. In areas where the temperature of ponds is likely to be below 15°C for long periods of time (above 30° latitude in India), the stabilisation of BOD through anaerobic activity may be neglected.<sup>6</sup>

#### 4. BOD Reduction Efficiency

Ponds that are well designed and operating well can be expected to give 75-80 per cent BOD reduction. McGarry and others<sup>11</sup> and Siddiqi and Handa<sup>12</sup> have given empirical relationship between the efficiency and surface loading. Both these relationships show a suitable response to the pond in the loading range of 300-500 lb/acre day, which should be the design value for most of the Indian sub-continent, according to the procedure outlined above. If the influent sewage BOD is taken to be 250 mg/l, an effluent with a BOD of 50-60 mg/l may be expected. Under summer conditions, the performance of the pond and the quality of the effluents would be still better.

#### 5. Removal of Pathogenic and Indicator Organisms

As mentioned earlier, in a country like India, the removal of pathogens during sewage treatment is of primary importance. Stabilisation ponds when properly designed and operated have proved to be better than the conventional methods from the point of view

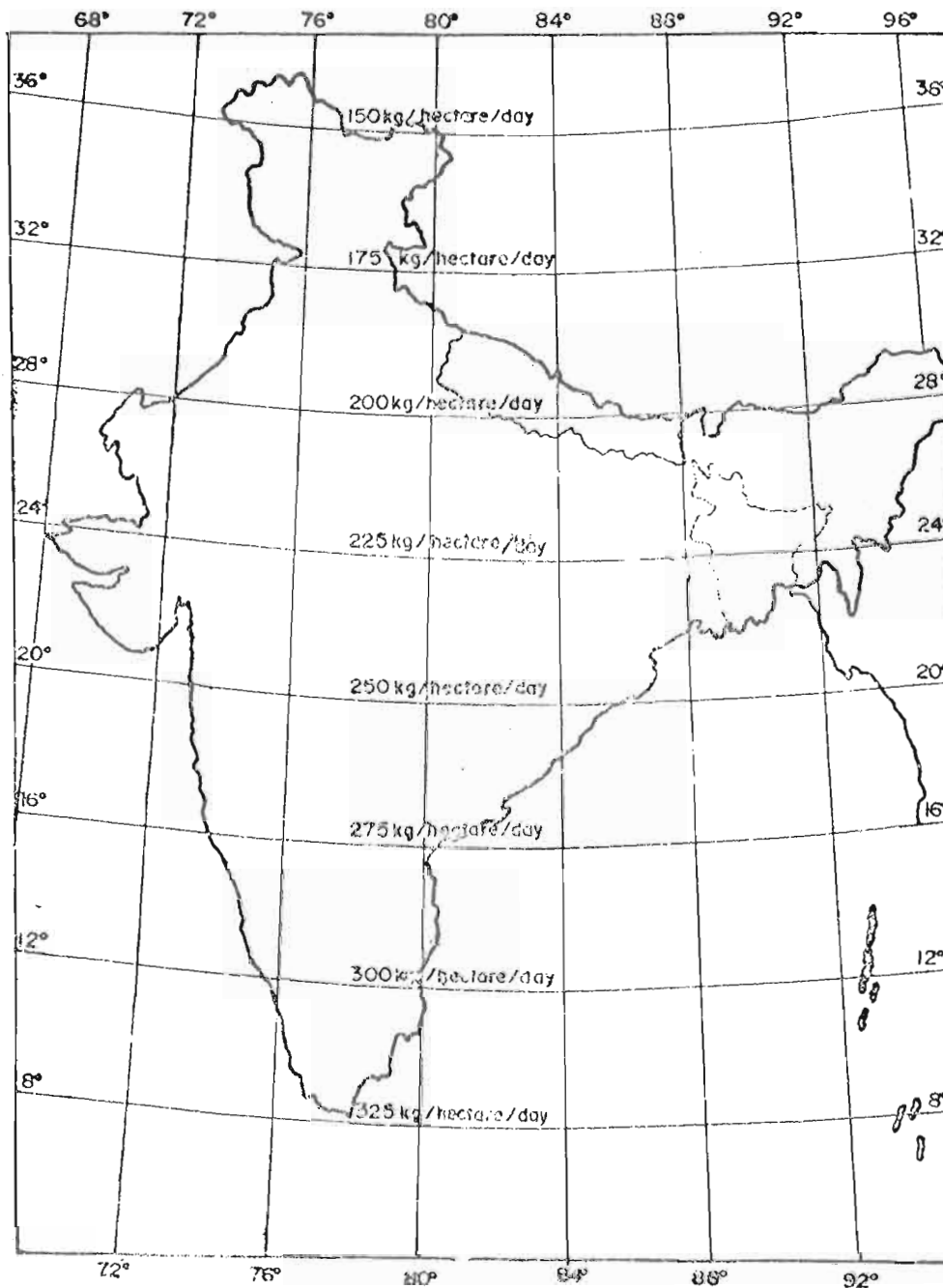


Fig. 2 The approximate BOD loading in Kg/hectare day that can be given at different latitudes (to convert to lbs/acre day divide by 1.12)

of removal of pathogenic and indicator organisms. Due to extremely favourable conditions for sedimentation, treatment by ponds provides almost 100 per cent removal of helminths and amoeba. Anaerobic conditions in the lower layers of the facultative ponds also contribute to their destruction. In a 3-cell stabilisation pond system having a total detention time of 6 days, 90-99 per cent of all forms of helminths were removed in the first cell. Only a few larvae of *Ancylostoma* were found in the final effluent.<sup>13</sup> It was reported by Joshi et al. that a total of 99.99 per cent reduction was obtained in indicator organisms (*Coliforms*, *E. coli* and *S. faecalis*), in a 3-cell pond system of one acre each. The increase in pH due to photosynthetic activity of algae was found to be the main cause of such reductions. Salmonella organisms which are commonly observed in raw sewage in India were found to be eliminated in the stabilisation ponds at Nagpur. Over a period

of 6 months, it was observed that one litre samples (taken once a week) were always negative. During the period of study the influent contained 4-450 organisms/100 ml.

## 6. Maintenance

Grit and digested sludge accumulate in the ponds. Experience in India has shown that the accumulation rate is about 2-3 cft/cap year. Most of the accumulation takes place in the primary cell which may be cleaned once in 5 or 6 years.

It is advisable to divide the total pond area into 2 or 3 ponds in view of the space required for sludge accumulation. The first pond may be kept deeper than the second and the third. Multiple cell ponds have proved better primarily because of less short-circuiting. The shore lines should be kept free from vegetation as otherwise there is a possibility of mosquito-genesiis. The tanks should be safeguarded against erosion. Any scum accumulated on the shore lines should either be removed or broken.

## B. Oxidation Ditch

1. General: The oxidation ditch is operated mainly on the extended aeration principle. It is, in short, a modification of the activated sludge process which does not have the primary sedimentation and digestion units. The aeration is done by means of mechanical rotors which splash the sewage into air and allow oxygen to dissolve into the medium. The name oxidation ditch comes after the earthen models that were originally installed in Holland, the cross-section of which looked like an irrigation ditch.

Stabilisation ponds and aerated lagoons, although very simple to construct and operate, require substantial amounts of land area. Where land is expensive, those systems would be relatively expensive. Under such circumstances, the oxidation ditch which employs sludge recirculation is used. In this system, the raw sewage is directly pumped to the ditch and the BOD loading on the microbial mass is so regulated as to produce a well stabilised sludge (does not require further treatment), and can be dried directly on sand beds. Due to low organic loading, excess sludge production is kept to minimum. Looking at it from another point of view, excess sludge solids are oxidised by endogenous respiration. The process may also be thought as an aerobic sludge digestion coupled with activated sludge system.

2. Design: Oxidation ditch system is designed at a low BOD loading with reference to the amount of mixed liquor suspended solids maintained in the system. Whereas conventional activated sludge process uses MLSS in the range of 2000-2500 mg/l, oxidation ditch systems are designed with 3000-5000 mg/l MLSS. The organic gravimetric loading used in these systems varies from 0.05-0.1 lb BOD/lb of MLVSS in the temperate zones. However, in the tropics like India, the loading can be considerably higher, i.e., up to 0.5 lb BOD/lb MLVSS.<sup>6</sup> The higher temperature in these regions helps oxidation and stabilisation of organic matter at a higher rate.

Working on a 20 000 gal capacity pilot plant at the CIPHERI campus, treating 5000-40 000 gal waste/day it was found that specific resistance of the sludge (a measure of sludge filtrability, sludge stabilisation or mineralisation) increased sharply as the loading

was increased from 0.5-1.0. Excess sludge production also increases acutely above a loading of 0.5.

3. Fabrication and Installation: The fabrication of the oxidation ditch is relatively a simple operation and can be accomplished at many local workshops in the developing countries. The installation of the ditch is also quite simple. The mechanical parts that are required are an electric motor, a reduction gear, a rotor and a sludge pump. The system includes a settling tank to separate the clear liquid from the sludge and to return the latter. In India there are several installations of the oxidation ditch system in small townships which are too large for servicing by septic tanks. The system occupies a small fraction of the land that is needed by the stabilisation pond.

### C. Aerated Lagoons

1. General: Aerated lagoons have come into prominence in the last 10 years in the western countries especially in the U.S.A. In India, the CPHERI had started recommending aerated lagoons for the treatment of sewage and several industrial wastewaters. The aerated lagoon is preferred to stabilisation pond for the reasons that it requires less land and gives greater reliability of performance.<sup>6</sup> Oxygen is supplied through surface aeration by the mechanical rotor or compressed aeration. The lagoon is usually constructed 8-12' deep. The waste enters at one end and leaves at the other. Two types of aerated lagoons are described in literature: 1) completely aerobic lagoons requiring power input of 0.1 H.P./1000 gal of basin volume, and 2) facultative lagoons requiring 0.01-0.02 H.P./1000 gal of basin volume. Due to the lower requirement of power in the facultative lagoons and consequently low mixing velocities, suspended solids settle to the bottom and undergo anaerobic decomposition. For most wastes only facultative lagoons are possibly used in view of economy of operation. The power requirement is calculated on the basis of oxygen requirement of the system. Very little data is available on aerated lagoon performance in this country. Data from the pilot plants of CPHERI are utilised for this discussion. The aerated lagoons are normally designed to discharge a mixed liquor. The CPHERI has tried a modification in providing a settling compartment before the outlet in order to retain and recycle the sludge solids. The latter work on the basis of extended aeration principle whereas the former would be somewhat close to the high rate activated sludge systems. In both the cases, it must be recognised that the solids are not completely mixed. Some amount of BOD removal takes place under anaerobic conditions in the bottom layers where sludge is settled.

2. BOD Removal Efficiency: In the common aerated lagoons, there is no separation of the biological solids from the liquid waste. Therefore, the effluent from the lagoon will contain suspended solids essentially as much as in the upper layers of the lagoon. The effluent BOD will be that exerted by the clear effluent and the biological solids. The rate of respiration of the biological solids decreases with increasing detention period. In the modified aerated lagoon using settling compartments, the effluent would exert primarily soluble BOD. In the aerated lagoon working on the basis of extended aeration, the following 3 advantages were envisaged:

- 1) the effluent will be free from suspended solids;

- 2) an increase in the efficiency of the system will be obtained because of increase in biological solids concentration in the lagoon; and
- 3) by creating an anaerobic zone for stabilisation of the BOD and biological solids, the oxygen and power requirements of the lagoon are decreased.<sup>6</sup>

The operation data on the pilot aerated lagoon at the Institute is shown in Table 4.

Table 4. Operational Data from the Pilot Aerated Lagoon

1. Detention time	1.8 days
2. Influent BOD <sub>5</sub>	205 mg/l
3. Effluent BOD <sub>5</sub>	21 mg/l
4. Aerobic depth	2-3 ft (0.6-0.9m)
5. BOD <sub>5</sub> load	1223 lb/acre-day (1370 kg/ha d)
6. Gas produced	11090 cft/acre-day (776 m <sup>3</sup> /ha d)

---

Area = 1370 sft (127 m <sup>2</sup> )	Water depth = 8 ft (2.4m)
--	------------------------------

Table 4 shows the average of three months operational data. Gas was collected by means of a floating cover. On an average the gas had 62 per cent methane gas. It is seen from the data that the lagoon was producing effluent comparable to that from any conventional aerobic system. Assuming that 10-12cft of gas is produced for each pound of BOD stabilised, almost all stabilization was through anaerobic reactions. The lagoon was provided with an aerator which was supplying about 1000 lbs of O<sub>2</sub>/acre-day. This resulted in creation of a top aerobic layer of 2-3 ft depth and nuisance associated with anaerobic reactions was avoided. It is therefore indicated that with slight modifications in operation and design of aerated lagoons not only a better quality effluent may be obtained but the power requirement may also be reduced. In such a lagoon, with total retention of solids, there will be a gradual deposition of digested sludge. The rate of deposition may be expected to be the same as that in a facultative stabilisation pond. Cleaning may be required once in five or six years. Aerated lagoons should therefore be constructed as multi-celled units, the various cells operating in parallel, to facilitate sludge removal.

#### REFUSE COLLECTION AND DISPOSAL

##### A. Character

The character of refuse in India is considerably different from that obtained in the western countries. In the major cities like Calcutta and Bombay, the refuse, as deposited in the street bins, contains green cocunut shells, torn paper, rags, metals, garbage, broken glass, earthenware, china-ware, ashes and soil. In these two cities green cocunut shells form 10-11 per cent of the total refuse.<sup>15</sup>

The character of the refuse at the disposal site is considerably different from that at the point of collection. This is primarily

because of the fact that paper, rags, metals, unbroken glassware and sometimes even broken glass are salvaged. The per capita quantity varies from city to city. In the larger cities like Calcutta and Bombay, the contribution is about 0.5 kg/head day. In the smaller cities, it is around 0.3 kg/hd<sup>16</sup>. There could be a few industrial townships where high income population lives which dispose of a larger quantity of waste. The above figures are at the points of collection. At the disposal site these figures will be slightly lower.

A survey conducted on the character of refuse all over Calcutta indicated an average moisture of 41 per cent and an organic content of 35.2 per cent, the latter being on dry basis. Carbon was found to be 19.6 per cent of the total solids and carbon to nitrogen ratio was 37.4. It should be obvious that Indian refuse contains a much higher inorganic content than that of the western nations resulting in smaller values of calorific values on dry solids basis (1500 Kcals/kg at Calcutta as against 2728 the 1963 average of 4 cities in the U.S.A.).

#### B. Collection

Refuse is generally dumped in either metallic or concrete, square or round street bins. It is generally collected through open trucks and carried to the disposal site. Some of the progressive municipalities have been using closed trucks but have no compression of the refuse. Compression of the Indian refuse perhaps is also not as important as the refuse in the western countries, as the former does not contain large quantities of loose paper or paper cartons. The density of Calcutta refuse is 470 kg/m<sup>3</sup> at source and 540 kg/m<sup>3</sup> at the disposal site. It is not uncommon to see that during the transport of the refuse from the collection to the disposal site, the refuse is lost from the trucks because of wind action, a phenomenon that is ugly and that can be unhygienic.

#### C. Treatment Methods

1. Composting: Two well known processes of town refuse treatment to make compost have originated in India. In spite of this fact, the methods practised presently in India are far from satisfactory. With a view to conserve as much of the plant nutrients as possible, the Bangalore process and the Indore process have been developed for composting of refuse.

a) Indore Process: The Indore process developed during the period 1920-1930 uses easily decomposable organic material such as night soil, animal manure, sewage sludge and garbage which are laid in alternate layers with relatively stable material like straw, leaves, town refuse and stable wastes. The material is kept in piles or windrows on the ground to a height of about 5 ft or put in shallow pits (2-3 ft) raised up to a height of 5 ft and in an area as large as practicable. The composting material is turned twice for aeration by manual labour during the period of decomposition which is generally about 3-4 months. The liquid draining from the piles or windrows is sprinkled to moisten the decomposing mass or added to other drier piles of windrows. The moisture content is maintained roughly at about 13-14 per cent. The method has been further improved by adding digested sludge as seed material, thus reducing the period of decomposition. It is supposed that the material is aerobic for a few days after the initial piling and after each turning, and anaerobic for the rest of the time. This method of composting is useful where labour and

land are cheap. The process is partially mechanised where high quantity of waste is to be handled. The material is directly put in shallow trenches and turned as many times as needed by means of mechanical gadgets to keep the process aerobic for most of the time. Increased number of turnings reduce the total time taken for composting. Under aerobic conditions the piles reach a temperature of 60-75°C which would help eliminate helminthic parasites and their eggs. The process however, has the following disadvantages:

- i) high labour and land requirements;
- ii) the material is not protected from extreme weather conditions and hence is suitable only in milder climates or requires shelter;
- iii) it may create odour problems.<sup>17</sup>

b) Bangalore Process: The Bangalore process was developed by Acharya in 1939. In this process the town refuse, night soil and cattle waste are used for the preparation of compost. The night soil and other wastes are put in alternate layers in the pits (3-4 ft deep). The breadth and length of the trenches depend on the availability of land and the quantity of material to be composted. After each filling the pit is covered with 6-9" thick layer of refuse. The material is left in the pit in this condition with no turning for 3 months. During this period the material settles down and additional refuse and night soil are placed on the top and covered finally with earth to prevent loss of moisture and fly breeding.<sup>18</sup>

This system of composting provides aerobic conditions and high temperature rise in the pits only for a few days. Although the material decomposes under anaerobic conditions for the remaining period, high temperature is retained for about 15 days due to insulation. As the decomposition under these conditions is slower it requires about 4-6 months to achieve the same degree of compostability. The advantage of this method is the fact that it does not require any labour for turning the refuse in the interim period. However, this method suffers from the disadvantage of requiring longer time for composting and hence more space as compared to the Indore method. The reduction in pathogens is lower and the odour and fly problem is higher.

2. Incineration: Incineration of town refuse is practically non-existent in India. It is generally found in hospitals and occasionally in private institutions and some industrial townships.

#### D. Disposal

The most common method of disposal of refuse in India is uncontrolled tipping in low lying areas. Here again a few of the progressive municipalities are trying to control the tipping. Where composting is practised, the refuse is put in pits in a controlled manner and transferred to the crop areas after composting.

### NIGHT SOIL

#### A. Character

The night soil handled in India primarily consists of human faeces. The average night soil contains 10-12 per cent total solids, 72-83 per cent of which is volatile. It contains 3-5 per cent nitrogen

(N), 2.5-4 per cent phosphorous ( $P_2O_5$ ) and potassium ( $K_2O$ ) 0.7-1.9 per cent, all on dry basis. The average per capita contribution of night soil excluding urine is estimated to be 0.18 lb/d (80 g/day) on dry basis and 1.8-2.2 lb/d (0.8-1.0 kg/day) on wet basis.<sup>19,20</sup>

#### B. Collection

It has been mentioned in the earlier pages that a major percentage of urban population is served by dry conservancy system in which the human excreta is manually collected in the form of night soil. By and large, this night soil excludes human urine as the collection chambers are provided in such a manner that they are kept relatively dry. The night soil is manually collected from individual houses in buckets and carried to night soil carts in the different municipal wards. The night soil carts are hauled by bullocks to the disposal site. In the larger towns trailers are used for the transport of night soil and hauled by tractors to the disposal sites.<sup>19</sup>

#### C. Treatment Methods

The most common method of treatment and disposal is by way of trenching. The other popular method is to compost with town refuse by the Bangalore process. Trenching has the major disadvantage of requiring large areas and of contaminating shallow wells. Unless done extremely carefully, trenching also has a tendency to create fly nuisance especially in the warmer weather.

Anaerobic digestion of night soil has been proposed as an alternative to trenching in the towns where night soil is collected. Experiments at CIPHERI have indicated that digester capacities of 1 cft/capita at Madras and 1.8 cft/capita at Delhi are required. The variation in the capacity required is due to difference in winter temperatures. It has been found that 7-9 cft of digester gas can be obtained per lb of dry solids of night soil charged. It was also found that the digesters could be loaded to as high a figure as 0.1 lb total solids/cft day at a place like Nagpur. However, a loading of 0.05-0.08 would be preferable to avoid any strain on the operation of the digester. Higher loadings result in digester failure. Total solids in the digester influent will have to be restricted to a maximum of 8 per cent. It is preferable to use a 5 per cent slurry which obviously requires some water for dilution.

It has been observed that digested night soil is completely free from bad odours and that it could be dewatered and dried quite easily. However, it was found that the eggs of helminthic parasites such as that of hook worms were not completely eliminated during the digestion. Hence it may be worthwhile to consider aerobic composting of refuse using digested night soil as a supplement for the nitrogen and phosphorous content. Incidentally, this will also help in reducing or eliminating the cysts of the parasites of Ancylostoma and Ascaris. Alternatively, heat treatment of night soil either before or after digestion will be needed to totally eliminate the parasites.

#### D. Disposal

As mentioned earlier, the most common method of disposal of night soil is by trenching with or without refuse. By and large, the trenched night soil is used as a plant manure after allowing it to decompose for 6-9 months.



### SUMMARY AND CONCLUSIONS

1. The type of sanitary services existing in India in the cities, towns and rural areas are described.
2. The water pollution loads from solid and liquid domestic wastes in India are presented.
3. Sullage and night soil should be considered as domestic wastes in addition to sewage and town refuse.
4. Pollution due to pathogenic organisms emanating from human excreta is one of the most important aspects to be considered in waste treatment.
5. It has been observed that conventional waste treatment plants with considerable mechanical content do not function properly in developing countries due to inadequacy of properly trained personnel. Hence waste treatment plants with simpler design will have to be developed.
6. Oxidation ponds, aerated lagoons and oxidation ditches would be most appropriate and low in cost for a majority of the towns and a few cities. The design criteria for these processes suited to the Indian conditions have been described.
7. The character, collection and treatment methods of refuse and night soil presently being used are described with suggestions for improvement.

### REFERENCES

1. 'Report on Environmental Degradation', CPHERI, Nagpur, India, pp 85, (1971)
2. Mohanrao, G. J., "Waste Collection, Treatment and Disposal", Presented at Workshop on 'Water in Man's Life in India', Indian National Science Academy, (1971)
3. Dieterich, B. H. and Henderson, T. M., "Urban Water Supply Conditions and Needs in Seventy-five Developing Countries", Public Health Papers, No. 23, WHO, Geneva (1963)
4. Arceivala, S. J., Bhalerao, B. B. and Alagarsamy, S. R., "Cost Estimates for Various Treatment Systems in India", Proc. of Symp. Low Cost Waste Treatment, CPHERI, Nagpur, India, 239 (1972)
5. 'Cost of Sewage Treatment', Technical Digest, No. 10, CPHERI, Nagpur, India (1970)
6. Siddiqi, R. H., "Design and Construction of Low Cost Waste Treatment Systems in India", Indian Association for Water Pollution Control 10th Anniversary Commemoration Volume, CPHERI, Nagpur, India, 96 (1973)
7. Arceivala, S. J., Lakshminarayana, J. S. S., Alagarsamy, S. R. and Sastry, C. A., 'Waste Stabilisation Ponds Design Construction and Operation, in India', pp 100, CPHERI, Nagpur, India (1970)
8. Manuel, A. C. and Siddiqi, R. H., "Observations on a Facultative Stabilisation Pond", Unpublished data, CPHERI, Nagpur, India
9. Oswald, W. J., 'Fundamental Factors in Stabilisation Pond Design', Proc. 3rd Conf. Biological Waste Treatment, Manhattan College, New York, N.Y. 357 (1960)

10. Herman, E. R. and Gloyna, E. F., 'Waste Stabilisation Ponds-III Formulation of Design Equations', Sew. and Ind. Wastes 30, 963 (1958)
11. McGarry, M. G. and Pescod, M. B., Stabilisation Pond Design Criteria for Tropical Asia, Second International Symposium for Waste Treatment Lagoons, Univ. of Kansas, Lawrence, Kansas, 114 (1970)
12. Siddiqi, R. H. and Handa, B. K., "Evaluation of some Stabilisation Ponds in India", J. San. Eng. Div. ASCE, 97, 91 (1971)
13. Lakshminarayana, J. S. S. and Abdulappa, M. K., 'Effect of Sewage Stabilisation Ponds on Helminths', Proc. Symp. Low Cost Waste Treatment, CPHERI, Nagpur, India, 290 (1972)
14. Joshi, S. R., Parhad, N. M. and Rao, N. U., 'Elimination of Salmonella in Oxidation Ponds', Proc. Symp. Low Cost Waste Treatment, CPHERI, Nagpur, India, 284 (1972)
15. Report on 'Alternate Methods of Garbage Disposal for Calcutta City', CPHERI, Nagpur, India, pp 268 (1970)
16. 'Refuse Disposal Studies at Calcutta', Technical Digest No. 15, CPHERI, Nagpur, India (1971)
17. Gotaas, H. B., 'Composting', WHO Monograph No. 31 (1956)
18. Acharya, C. N. and Subrahmanyam, V., 'Hot Fermentation Process for Composting Town Refuse and other Waste Material', 1-Introductory, Indian J. Agric. Sci. 9, 741 (1939)
19. 'Digestion of Night Soil and Cow Dung', Technical Digest No. 8, CPHERI, Nagpur, India (1970)
20. Trivedi, R. C. and Mohanrao, G. J., 'A Pilot Plant Study on Night Soil Digestion', Proc. Symp. Community Water Supply and Waste Disposal, CPHERI, Nagpur, India, Vol. II, 117 (1966).