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Rational Pattern of Sewage and Waste Disposal in Pakistan —PART I

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Chapter 1.

Introduction

The choice of methods of disposal of sewage, industrial waste and refuse should be determined by economic (1) considerations within the framework of sanitary needs.

The safe disposal of waste waters, on land and into water would require a study of viability of pathogenic and obnoxious organism in sewage, water, soil, vegetation, and the influence of various treatment processes. Until recently, the cost of construction of sewage and refuse disposal works was considered prohibitive, and very negligible work has been done in the East. This has taken a heavy toll both of life, and resulted in loss of health and vitality of inhabitants.

The effect of sanitary excreta disposal on the incidence of typhoid and paratyphoid in West Virginia(2) is indicated in Fig. 1.

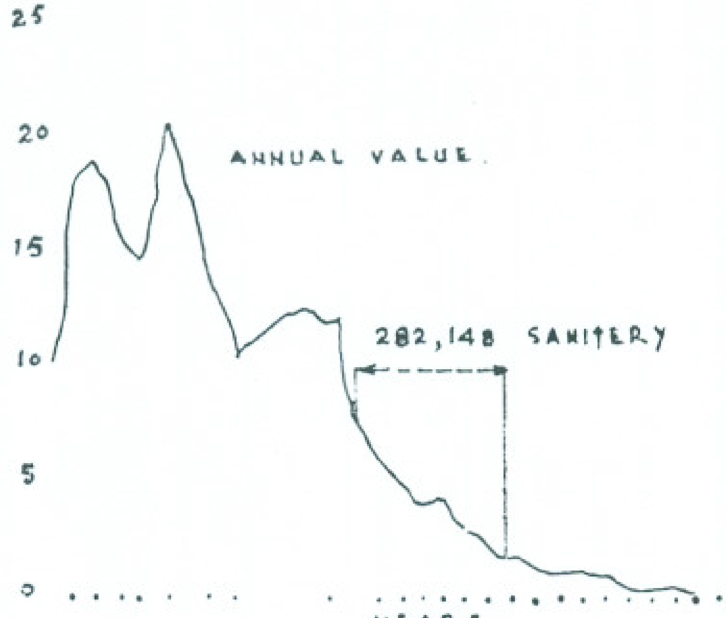

FIG. I. REDUCTION IN DEATH RATE FROM TYPHOLD FEVER

(1) *Water Supply and waste water disposal-Fair and Gyrer, John Wiley and Sons-New York.*

(2) *As on next page.*

Leach and Maxay[2] have tabulated rates of typhoid fever per 1,00,000 population in communities of different sizes in South U.S.A. These rates may be interpretted as showing relatively good sanitary protection (1) in rural area because of lack of contact (2) in larger communities because of good community sanitation, including both water supply and waste water disposal.

Table I. Typhoid Fever and Size of Type of Community.

Size or Type	Rural	500-1,000	1,000-2,500	2,500-5,000	10,000 25,000	25,000 and above
Morbidity	52	443	307	180	165	118

The Second Five-Year Plan[3] of Pakistan has provided the following sums for water supply and sewerage schemes :-

Schemes	East Pakistan	West Pakistan	Central Government	Total.
Water Supply and Sewerage	Rs. (Millions)	Rs. (Millions)	Rs. (Millions)	Rs. (Millions)
Project for Selected Rural Areas.	55·0	20·0	—	75·0
Projects for Selected Urban Area	25·0	25·0		50·0
	80·0	45·0		125·0
Karachi Water supply and Sewerage Schemes	—	—	110·0	110·0
Water supply and Sewerage Projects of Dacca and Chittagong.	160·0	—	—	160·0
		Grand Total		395·0 Millions

In this paper, a review is made of the literature of viability of pathogenic organisms and their reduction due to various treatment processes which include land disposal. In spite of the fact that many health authorities in the U.S.A. frown on sewage irrigation. (1) There is no reason why

Water supply and waste water disposal—Leach and Maxey, John Wiley and Sons—New York.

(3) *Pages 322-329. The Second Five. Year Plan-1960-65 June 1960, Government of Pakistan Planning Commission.*

it should not be adopted on conditions that ensure sanitation. In fact, the roll of land on pathogen removal is more effective than other agencies as would be evident from study of Chapter III. Elimination of raw sewage and sewage treatment effluent from lakes, and streams is becoming a real problem in U.S.A.. and to Hunt. (4) use of effluent for supplemental irrigation presents an economical means of final disposal.

Based on the study of epidemiology (Chapter II) patterns of sewage, waste and refuse disposal are proposed for rural and urban areas in Chapter III.

In Chapter IV sewage and waste disposal by lagooning is discussed considering to climatic and soil factors prevalent in Pakistan, and studies conducted by various authorities in U.S.A. This offers a very satisfactory treatment not involving any large capital outlay, employment of any highly skilled operators and workers, and large maintenance costs. A preliminary design for an installation to cope with sewage of 10,000 population is worked out, and costs of construction and operation together with direct benefits in form of revenue evaluated. In most circumstances sewage disposal would be a revenue producing (productive) proposition.

In Chapter V the value of sewage as a fertilizer is evaluated together with its applicability to different soils and crops.

In Chapter I (Part 2) sewage disposal by biosorption is discussed for larger populations. This would not involve, but for a very limited extent, import of machinery and its operation. The work outlay would be very small, and this also works out to be a productive proposition.

In Chapter II (Part 2) disposal of solid refuse together with night soil and sewage sludge is discussed by high rate area composting not involving very complicated mechanism and operation. The requirements of scientific composting are discussed at length. The design and cost of a plant dealing with a population of 50,000 are worked out which also turns out to be an economic feasibility.

For a successful project of waste treatment careful analysis of climate, soil (productivity, influence of wastes, population data, and its projections in forseeable future should invariably be made. Even on the basis of direct benefits in the form of revenue from the operation of installations, the proposals would work out to be worthwhile ventures, not involving large capital outlay, and maintenance costs. Besides, safety of human beings, cattle and wild life could be ensured against communicable diseases ; and land, air and water rendered free from pollution.

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(4) *Supplemental Irrigation with Treated Sewage by Henry S. Hunt Sewage and Industrial Waste Journal, Champaign, Illinois U.S.A. March 1954.*

CHAPTER II.

Removal of pathoganic organisms during sewage and refuse treatment oprrations.

Raudolf, Falk and Ratgozais (5) reviewed the literature on viability of organisms (especially pathoganic) in soil, water, sewage sludge and vegetation in 1950 in great details and summed up general points on Bacteria and virus diseases.

1. Raw fruits and vegetables growing in infected soils can be contaminated with pathoganic bacteria.

2. Such infected vegetation may be difficult to clean and disinfect, especially where injured or broken parts are concerned.

3. Among the factors influencing the survival of intestinal pathoganic bacteria in soil and on vegetation are the following :—

(a) Type of organism-Esch Coli, E-typhose and M-tuberculosis appear to be most resistent.

(b) Temperature-lower temperature increases viability.

(c) Moisture-longevity is greater in moist soil than the dry soil.

(d) Type of soil-neutral, high-moisture-holding soils favour longevity.

(e) Organic matter-the type and amount of organic matter present may serve as a food and energy source to sustain or allow bacteria to increase.

(f) The presence of other micro-organisms has an influence on the pathoganic organisms. This has been illustrated repeatedly by longer survival after inoculation of a pathogen into a sterilized soil, sewage, or water than into a corresponding non-sterile substrile.

4. Among the most common intestinal diseases and non-pathoganic bacteria, Eberthela typhosa, Mycrobacteriam tuberculosis, and Escherichis Coli appear to be the most resistant to natural conditions outside the human body.

5. As a whole, the literature leaves the impression that E. Coli is more resistant than E. typhone in soils, sewage and other outside environment.

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5. Rudolf etc. Literature Review on the occurrence and survival of Enteric pathoganic and relative organism in soil, water sewage, and sludge and in vegetation-Journal of sewage and Industrial Waste Champaign-Illinois Oct. 1950.

It is for the last reason that E. Coli, though not a direct index of contamination is considered a safe indicator of presence of communicable disease vectors, allowing considerable margin of safety.

Most natural soils, which are incidentally not sterile, have other organisms present, which appear to be antagonistic to pathogens. Smith (5-1) concluded that E. Typhosa can exist in natural soil for but short periods Supply of antagonistic organism by treatment processes *e.g.* antiboitic activity of algae in oxidation ponds (1) would remarkably reduce the number and striking power of pathogens.

Firth and Horrock (5-2) as quoted by Tanner, found that typhoid organism, do not multiply or move about in soil, but can be washed by water even from closely packed soil. Soil moisture increases viability-74 days in ordinary soil, and 25 days, in dry sand. Sedgwick and Winslow (5-3) found that in dry soil 99 % of the organism were destroyed in two weeks. Type of soil has a remarkable bearing on the survival of pathogens, and this be kept in view in recommending sites of sewage, farms, Beard (5-4) obtained the following results for survival of E typhosa in different soils :—

Soil.	% death First 24 hours.		In different soils Days of known survival.	
	Wet.	Dry.	Wet.	Dry.
Adobe	25	45	42	21
Adose peat	30	50	42	28
Loam	28	45	49	4
Sand	70	95	8	4
Peat	99·97	...	1	2

Most soils in West Pakistan are sandy and peaty. This together with high temperature could be relied upon reduction of pathoganic organism, if before application antibiotic organisms in the form of Algas are provided. Pesricha and Paul (5-5) found in soils of India as far below the surface as 3 ft. phages which were active, against bacillary, dysentery, typhoid and cholera.

5—1 Smith J.L. An investigation into the conditions affecting the typhoid fever in Belfast. Sour. Hyg. 4-407 (1904).

(5—2) Tanner F.W. "Public Health significance of sewage sludge when used as a fertilzer, swage work, Journal 7-611 (1935)

(5—3) Sedge wick W.T. & Winslow-American Academy of Science 12-508 (1902).

(5-4) Beor P. S. The survival of E. Thyphasus in various soils and 5,000 public Health 30-1077 (1904)

(5-5) Parischa C. L. and Paul S.M. "Bacteriophage in soil, Indian Med. Gaz. 76.-416 (1941.)

Viability of Pothogenic Organisms in Soil, Sewage, Water and Vegetation
SURVIVAL—NUMBER OF DAYS, AND AUTHORITY

Type	Soil	Vegetation	Water	Sewage and Sludge
Salmonella Types. E. Typhosa	Peat Wet-1 day Dry-2 days	Leaftips in infected soil=31 days (Lattuce etc., (5-6)	Survival in inverse proportion of contamination.	Sewage 3-5 days (Russel 5-13 1905) Anaerobic.
	Sand	(Creal-1912)	Sterile tap water-15-25 days	Sludge-7 days
	Wet-8 days	Redish=28-31 days	Unsterile tap water-1-4 days	(Wolman-1925)
	Dry-4 days	(Malik 5-7-1917)		
	Adobe, Loam, etc.	Straw Berries at-18°C 6 months. 23°-27°C-6 hrs.	Raw drainage (2 days) (Jordon 5-11-1909)	Sewege and Feces in India-1 week
	Wet-42-49 days	(Mc Closhey (5-11)—1941)	In sterile water 46 days.	(Stewart 5-18 1932)
	Dry-21-28 days (Beard-1941)	Vegetables at 2°-4°C 4-5 weeks.	With Flagallated protoza 13 days. (Fahrs 5-12 1896)	Stored Sludge 50°-60° C-80 days 68°-72°-13 days
Salmonella		Rain temp-2-5 weeks (Felsenfield 5-8 1945)	Surface water-8-10 days. (Russel 5-13-1905) River water. Temp °C — weeks 0 — 9 5 — 7 10 — 5 18 — 4 27 — 3 37 — 2	Feces-52 days (Jordan 5-18-1926).

Type	SURVIAL TIME AND AUTHORITY			
	Soil	Vegetation	Water	Sewage and Sludge
			(Houston 5-14 1913). Greatest survival at pH-5·0-6·4 (Cohen 5-15 1925) Destruction in high pH above 9·5 (Scott: 5-16 1924) Presence of Phages destructive in complete kill pH-10-11·52 hrs. (Wattie 5-17 1947).	Unsterile of Sludge & Sstorile 11 days Sewage-20 months (Rochaix 5-18 1930)
All bacteria.		Cannot penetrate unbroken skin of fruits and vegetables Remain on surace 15 days in moist condition Decayed portion 7-42 days (Mills 5-9-1925)		
Dysentry Typhoid and Cholera.	Presence of phages destructive upto 3 feet.			
Coli Aerogenes Group.	Complete absence in soils not polluted by humans as well above 60° C (Mudd 5-20-1947)	Strawherries Lettuce Carrots rinsed milk 0·2 per cent Chloronated Lime 0·5 hr. [Venda Velde (5-2) 1921] Watercess-grown in treated sludge washed with 0·25% bleaching powder 10min.	Raw water Sterile 0-°C-73 days 37°C-30 days	Feces at Room Temp. 36-48 days. 37°-C-10-20 days (Jordon 5-19 1926).

Survival Time and Authority

Type	Soil	Vegetation	Water	Sewage and Sludge
		Pottassium permagnate } No effect (Hogg 5-12-1944)		
Vibrio.			Larger than in sewage (Flu 5-23 1921) Infected Water 19-5° C-3 days Sea water 11 days Mixed sea and river water 13 days River water 8 days Tap water 8 days Well water 6 days (Yasuhara — 5-24 1926) River water at Calcutta 72 hours Sterile water 18 days (Lahiri 5-25 1940)	Septic tank 2-5 days (Flu 5-13 1921).
Streptococci.			Sterile water 2 weeks Sewage 5-26 1951)	Sewage Survival less than E. Coli (Sewage 5-26-1917).
Bovine tubercle Bacilli.	Addition of dung Survival 178 days (Maddock 5-27 1933)	Grass 49 days (Meddock 5·27 1933). (Maddock 5-27-1933)		Treated sewage and sludge more than a year. Chlorination 10 ppm kills (Jensen 5-28 1942).

A study of the above table shows that the viability of pathogenic organisms in sewage is not greater than in raw water, and is actually in the inverse proportion of pollution, and the health hazards are no greater in the case of irrigation by sewage than by raw water. However, under all circumstances, vegetables and fruits, especially which do not have tight skins, or are damaged should always be eaten *after immersion in boiling water* for a short time, as simple rinsing of raw vegetables even in chlorinated or potassium permengnate solution is not enough. Rudolf (5) has concluded from indirect evidence from various parts of the world, that raw fruits and vegetables grown in contaminated soil or irrigated with sewage or sewage contaminated water may be a source of increased or above-normal typhoid incidence. High temperatures and light are antagonistic to pathogenic organisms. Other precautions would be (i) supply of antibiotic organisms like algae or Flagellette protoza (5-12) by lagooning or through oxidation ponds for short periods, prior to crop irrigation, (ii) selection of peaty and sandy soils for the farm (iii) prevention of direct contact with the sewage of vegetable and fruits by means of furrow irrigation (iv) proper drainage of farms (v) avoidence of shady trees in the farm.

Rudolfs Folk and Rugotzkie (5 & 6) followed their review of literature mentioned before, investigated in the field and laboratory to evaluate :—

1. The factors involved in the contamination of vegetables grown in polluting environment.
2. The survival of animal and pathogenic organisms.
3. Method of cleaning vegetables which may become contaminated through growth or handling.

The tomato was selected for the study as (i) it is commonly eaten raw (ii) grows relatively closely to the ground, therefore subject to picking contamination (iii) splashings could be prevented (iv) could be both exposed to sunlight and shaded (v) has a smooth skin but could have cracks and crevices lodging contamination. Experiments with lettuce, spinach and carrots were also made.

The organisms utilized were—Solmonalla and Shingella species. Endamocia histolytica cysts, Ascaris eggs. Suspensions of organisms, and feces were applied to the plants in the laboratory and the field. Plants were grown under normal field conditions with and without sewage.
Farming practice - The decontaminating methods emplyed were :—

(i) Storage (ii) Washing with water, detergents, and germicidal rinses.
(iii) Treatment with gases (iv) Application of heat.

The conclusions drawn were :—

(i) Cracks and crevices harbour organisms.
(ii) No relationship between height of plant to contamination except in actual contact.

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6. *Writiam Rudolf, Lloyd L. Falk and Robert A. Regotzkie Sewage and Industrial Waste Journal—Champion Illinois-Mare 51, Vol. 23 No. 3.*

(iii) Splashing of soil does not affect.

(iv) Exposure to sun reduces organisms except in crevices and cracks.

(v) Only damaged fruit with crevices and cracks showed greater number of organisms in polluted than normal evironments.

(vi) On direct application of contaminating matter, the residual coliform concentrations decrease to zero or below that of uncontaminated condition by the end of 35 years.

When fecal material is applied directly to growing fruit such applications should be stopped one month before harvest begins.

(vii) Survival of representatives of the Salmonalla and Shingella genes does not exceed seven days.

The results showed that normal vegetables, not subject to crevices and cracks grown in polluted environments, did not show greater contamination than those grown in non-polluted environments. The authors state that, epidemiologically, the consumption of raw fruit has not shown to cause directly even small outbreaks of intestinal bacterial disease, The experiments were carried out in a temperate climate. Higher temperatures in the tropical climates would reduce contamination, further, except when humidity is high.

If fruits and vegetables are eaten raw sewage irrigation or night soil application should be stopped one month before harvest, and they would not be likely vectors of the transmission of human enteric diseases.

In a study Norman and Kabler (7) have found that the enterrococcus indices of soils and vegetables have no direct relationship to the indices of irrigational matters. Even when Salmonalla wexre present in the irrigation water in large numbers they would be present in soil only in low concentration, and insufficiently numerous in the vegetables. The coliform density of leafy vegetables is more than that of smooth vegetables.

Before a treatment process is adopted, a study of the efficiency of removal of pathogenic organisms by various methods in practice would be worthwhile.

All processes stress the removal of non-viable organic compounds. For the economy of a country, like Pakistan, the organic constituentes of a waste should be retained for their fertilizing value, The treatment processes be viewed purely from the point of view of either removal of or rendering pathogenic organisms innocuous.

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7. *Norman and Kabler. 1950, Sewage and Industrial Wastes Journal Champain Illinois.*

8. *Paul Kabler : Removal of Pathogenic Organism by Sewage Treatment Processes. Norman Kabler : Sewage and Industrialy Waste Journel,* 1950.

Effect of Sewage Treatment Processes on the Removal of Pathogenic Micro-organisms

Investigator	Date	Organism Studied	Percentage of Organism Removed, by Trickling Filter	Activated Sludge	Anaerobic Digestion	Chlorination	Stabilization Ponds	Remarks
Conymount and Rochaix.	1922	(a) *Enteric Bacteria.* teria.	—					
		Typhoid Fever		Present	—	—	—	5 to 6 hrs.
		Cholera Vibrus		Not found				Same treatment
Burns and Sterp.	1927	Typhoid Group	—	96	—	—	—	do
		Cholera Vibrios	—	98	—	—	—	do
		Total Count	—	95-98	—	—	—	do
		Two Paratyphoids	—	97-98	—	—	—	3 hr. with 15% sludge.
		Shig. Kruse	—	97·5	—	—	—	
		Shig. Fever	—	97	—	—	—	
		Shig. V.	—	98	—	—	—	
Pesech and Soaberons	1929	Typhoid Group	—	95	—	—	—	24 hrs. treatment.
Rumchoft	1934	S. Typhosa	—	99·2	25-75	98-99	—	5½ hrs. aeration and settling
Metcalf and Eddy.	1935	Total Bacteria	70-85	90-98	—	—	—	—
Mon and Scheefer	1940	S. Typhosa	—	—	Not found	—	—	After 6-8 days.
		Total Bactcria	80-93	—	—	—	—	—
Allen and Brooks and Williams	1949	Coliforms	80-95	—	—	—	—	—
		B. Coli Type I	83-92	—	—	—	—	—
		Strap. Fecel.	94-94	—	—	—	—	—

Investigator	Date	Organism Studied	Percentage of Organism Removed, by Trickling Filter	Activated Sludge	Anaerobic Digestion	Chlorination	Stabilization Ponds	Remarks
Allen and Books	1949	Total Bacteria	—	—	—	96-98·7	—	Residual by Orthedoline after 15 min.
Davy. Horchler and Marks	1953	Coliforms	—	—	—	99	—	Ortholidina residual of 1-1·2 mg/l for 15 min.
Gilchrist & Kelly	1954	Coliforms	95	—	—	99	—	0·2 mg/l residual
Cooke and Kabler	1955	Allescherx boydii	Present	Present	—	—	—	Also present in dry sludge
		Aspeogillus Fumigetus			—	—	—	—
		Geotrichum Candidum			—	—	—	—
Imhoff and Fair	1956	Total Bacteria	90-95	90-98	—	98-99	—	—
Mathews	1956	Coliforms	—	91-98	—	—	—	—
		Total Bacteria	—	70-99	—	—	—	—
Ware and Mellon	1956	Coliforms	97	—	—	—	—	—
McCoy		Coliforms	94-96	—	—	—	—	—
	1957	B. Paratyphes B	84-99	—	—	—	—	—
Mc-Kinney, Lensley and Tomsindon	1958	S. Typhosa	—	—	94-92·9	—	—	6 and 20 days respectively
Bloom, Mock and Mallinon	1958	Salmonalla	—	Present	—	—	—	22 and 35 for effluent positive. 83 species
Towne, Bartsh and Davis	1957	Coliforms	—	—	—	—	59·5-99·9	—
Merz Merel and Stone	1957	—	—	—	—	—	50-91	—
Fitzgerald and Roblen	1958	—	—	—	—	—	98·2-99	—

Investigator	Date	Organism Studied	Percentage of Organism Removed by					Remarks
			Trickling Filter	Activated Sludge	Anaerobic Digestion	Chlorination	Stabilization Ponds	
Gillespe	1944	S. Typhosa	—	—	—	—	See Remarks	Reduced from 41/ml to not demonstrable
	(b) Tubercle Bacilli.							
Pramer Heukelekian and Ragotako	1950	M. Tuberculosis	99	—	90	—	—	With chlorination in filters
Jensen	1954	,,	Survive	Survive	Survive	99	—	Otholindine Residual of. 1 on 5 mg/l for 2 hrs.
Kelly, Clarks and Colmen	1955	,,	Survive	—	—	Survive	—	No residual chlorine
Heukelekian and Albanesa	1956	M. Tuberculosis	66	88	69	99	—	Ortholidone residual of 2 mg/l for 30 min. or 1-ms/l for 1 hr.
Greenberg and Kuplia	1957	,,	Survive	Survive	Survive	—	—	Literature review.
	(c) Viruses.							
Carlson, Ridenour and Mc-Khena	1943	Mouse Adopted Poliovirus	—	Mostly removed	—	—	—	After 6 hr. 6 of 30 mice died.

Percentage of Organism Removed, by

Investigator	Date	Organism Studied	Trickling Filter	Activated Sludge	Anaerobic Digestion	Chlorination	Stabilization Ponds	Remarks
Neefe, Stokes, Baty and Reinhold	1945	Infections Hepetitus	—	—	—	Survive Inactivated	—	1 mg/c chlorine residual after 30 min.
Gilercas and Kelly		Coxackie A	60	—	—	—	—	
	1954	B Coli B. Phage	15	—	—	—	—	
Kelly, Clark and Colmen	1955	Coxsebic	Reduced	—	Survive	—	—	More numerous in late summer.
Ware and Mellon	1956	B. Coli B. Phage	57-73	—	—	—	—	Greater reduction with added B. Coli.
		Poliovirus I and III	—	Survive	—	—	—	Virus isolated more often from Sludged than from liquid
Mack, Mathimann Bloom and Kvaeger	1951	Coxsachie E. E. CHO	—	—	—	—	—	
Weidenkopf	1958	Poliovirus I	—	—	—	—	—	For 2-5 min. with 5 mg/l For 6·5 min. with 1·95 mg/l. For 14 min. with 0·53 mg/c residual.
(d) Parasites.—								
Vassilkova	1936	Tapeworm ova	18-26	—	97	n-effect	—	Air drying for 2 hrs. removed all.
		E. Histolytics Cysts,	88-99·9	No. reduction	Removed	—	—	—

Percentage of Organism Removed by

Investigator	Date	Organism Studied	Trickling Filter	Activated sludge	Anaerobic Digestion	Chlorination	Stabilization Ponds	Remarks
Gram	1943	Ascaris Lumbricoides ova Ansylestema Caninum ova (dog hookworm) 70·76. Toxescaris leanine ova (dog asceris)	Does not affect viability		—	—	—	Viability not reduced after 3 months, viable after 64 days at 30°C.
Hamlin	1946	Tapeworm ova	—	Not removed	—	—	—	—
Jones et at	1947	Schistosoma Japoinion	Reduced	Excellent hatching Media	90 in 25 d 30 days.	—	—	—
Jones and Humrnel	1947	S. Japansen ova Miracidia	—	—	—	Killed	—	30 min. residual of 3·9-11 mg/l
		S. Manson Moracida.	—	—	—	—	—	30 min. residual of. 0·2-0·4 mg/l
Reinhold	1947	A. Lumbricocdas	—	—	Reduced	—	—	Removal by 1 hr. of settling.
Newton Benett Figgat	1949	T. Saginata	62-70	Little effect.	Very slow	—	—	Normal egg., recovered, after 6 months of digestion at 75-25 °C.
Bhaskaren Sampat Kumaran S. and Radhikashan	1956	Ascaris Hookworm Tricknosis	99·8 100 —	93-92 81-5-96 91-8-100	45 — —	— — —	— — —	In 105 days at 80-92° F.

Of extreme importance in the Tropics is the removal of parasites like E. Hystolitics, Ascaris, tapeworm and hookworm. The efficiency of various treatment processes for removal of ova is not very encouraging. Specific data in relation to ova of parasites is very scanty, however, data from suspensions in water indicate such ova are quite resistent to chlorine and can be removed more efficiently by sedimentation or slow filtration. The latter is provided in crop irrigation.

To increase the efficiency of pathogen removal in soil, and prevent their affecting vegetables, and fruits, anti-microbial substances should be provided e.g. algae from oxidation ponds.

Where oxidation ponds cannot be constructed due to prohibitive land costs, the process which is next most economical be selected. A variation of Activated sludge in the shape of biosorption process offers an ideal solution, as it would not involve expensive civil works or any machinery except, simple pumps and aerators, not subject to excessive breakdowns.

Not enough data, on stabilization ponds, is available but inferences can be drawn because of their high efficiency in removal of coliform and E. typhosa, which are more resistent than other pathogens. Besides, no sludge problem is involved as pathogens find a harbour in the sludge. The killing of pathogens occurs only at a sustained temperature of 135°-for one hour or at 161° F for a few minutes. At Damstedt Germany-only primary settling tank is provided. The primary sludge is digested and then heated to 161° F. for a few minutes. The sludge is injected back into the effluent, which is used for broad irrigation. This was undertaken to reduce incidence of Ascarosis, Disposal of sludge by high rate composting, also offers a most satisfactory solution, as it is rupid, and no smoke is emitted.

For treatment of wastes from tuberculous sanitoria, sputum should be separately destroyed by burning and heavy chlorination of sewage effluent be adopted.

Effects of Sewage on Cattle.

Synder (11) examined the effects of sewage on cattle and garbage on Hogs. He has drawn the attention towards the statement of Smith (11-1) regarding similarity of responses of men and higher blooded animals. The common diseases of men and cattle include bovine tuberculosis anthrax, malta and undulant fever, foot and mouth diseases, actinomycasis, tapeworm, etc., Another hazard that has to be considered is the effect to toxic waste upon cattle having access to sewage plant effluents.

The sewers of any town receive the eggs, ova bacteria of diseases of men and animal. The survival of these organisms is dependent on their physiological characterics, e.g., (i) ability to form spores, the very resistant from of bacteria, (ii) their resistance to heat and cold (iii) their resistence to antiseptics (vi) their ability to withstand competition with other organism (v) the presence of bacteriophages. Their ability to cause infection depends

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11. Charles W. Synder : Effects of Sewage on cattle and Garbage on Hogs-Sewage and industrial wastes Oct : 1951-Vol. 23-No. 10.

upon factors, like (i) loss of virulence, (ii) the pressure and their numbers required to be infective (iii) the chances of being infested by proper host.

Pramer and Heukelekian, working on the survival of tubercula bacilli in sewage treatment processes state that those bacilli would be removed by sedimentation chemical, coagulation and sand filtration. The latter process is inherent in sewage farming (11) Minnett (11-1) and others, as well crawford (11-3) and others report.

That no adverse effects showed when cattle and swine drank treated sewage. Neither tuberculin tests nor postemortem examination on killing them and injections of concertions of lesiens into guinea pigs from one cow failed to produce any evidence of any disease in them. The plant in the case of crawford and Frank, consisted of coarse bar screens, grit chambers, floculating tanks, primaty settling tanks, etc. All processes, except coarse bar screen and grit chamber could be replaced by oxidation ponds of 3 days capacitv and sewage farm where antibiotic activity of algae and slow filtration through soil would eliminate any chances of disease production.

During a conference on the "Grazing of cattle on sewage farm at Pretoria, South Africa (1947) it was (11) observed that grazing of cattle on sewage was a sound economic proposition. However, there was danger of the udders of cattle, being infected with typhoid bacilli and cattle being infected with various types of measles. which may or may not be communicable to humans.

Synder quotes Wilson (11-4) that after more than 100 years of practice of sewage farm irrigation from small to colossel, no epedlmic of formiddable cattle or animal has been traced to sewage farming. Sewage Farms in advanced countries are well managed.

This discussion points to the value of treating sewage before application to farms. Furrow irrigation be practiced to keep the plants and udders of animals from being infected. Fruits and vegetables soiled by sewage and soil should be invariably rejected together with damaged parts-Vegetables and fruits not having tight skin, and with cracks and crevices should be immersed in boiling water for a short time before consumption.

11-1. Smith U. "Parasitism and Diseases P.S. Princeton University Press. 1934

11-2. Pramer and Heukelekian — The survival of tubercle bacteria Bacilli in Sewage Treatment Processes-Journal of Sewage and Industrial waste. 29.9.1123 (Sep : 1950).

11-3. Minnett F.C. Wolaridge C.H. 1nd Sheather A.C. An experimental inquiry concerning so called sewage poisinous the cattle-Vet. Reæord (Feb. 10.1934) visit, feeding sewage-Civil Eng : 10-8-935 (1940).

11-4. *Nelson H. Wilson H. and Robinson M.C. "The grazing of cattle on sewage farms" Jour. and Prac. Inst. Sewage Purification Prot i.* 189 (1947).

CHAPTER III.

PROPOSED PATTERN OF SEWAGE AND WASTE DISPOSAL SYSTEM FOR THE COUNTRY.

The survey of the efficiency of various waste disposal processes to remove pathogen in Chapter II would indicate pattern best suited to the country.

Pathogens of the parasite group, e.g., tape-worm ova, E. histolytica, Ascaris, Hookworm are not very effectively removed by the conventional sewage treatment works (vide table in Chapter II). Kelly (12) points out that primary treatment and secondary treatment by trickling filters do not reduce frequency of virus. Virus were found in receiving waters of a stream 400 ft. below a primary treatment plant. Effluent from activated sludge plant did not contain viruses.

These considerations rule out the final disposal of sewage and wastes into streams, rivers, lakes and canals, which are the main source of drinking water in the country ; and for a long time adequate water purification works may not be built, due to financial stringency. It may not also be possible to provide secondary treatment by activated sludge process including its modified variation, e.g., biosorption, except in metropolitan areas. Though adequate direct data is not yet available on the efficiency of pathogen removal by oxidation ponds, yet by inference from its very high efficiency in reduction of coliforms and E. typhosa, its actual efficiency should be high and its effluent rich in predatory anti-biotic organism could be relied to remove all pathogenic organism in conjunction with scientific crop irrigation.

Heukelekian (13), an eminent Sanitary Engineer, while as a member of F.A.O. mission to Israel considered the health hazard, of unrestricted crop irrigation with sewage, subjected to secondary treatment and disinfection, to be greater than giving sewage minimum treatment possible and utilizing the effluent for irrigation of crops not eaten raw by human beings.

He emphasised that pre-reatment of sewage should not have the objective of B.O.D. removal since B.O.D. can be removed in the soil in conjunction with crop irrigation. The author is of the view that this minimum treatment could be (a) removal of grit and garbage by coarse screens, (b) settlement of solids in earth basins, e.g., oxidation ponds with a capacity of less than 3½ days, as worked out in the Chapter IV. This would ensure removal of 99% of coliform organisms and E. Typhosa and by inference all other pathogens. The cost of construction and operation would be minimum, not involving any complicated machinery, civil works or highly skilled operators.

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12. *Sally Kelly and Wallace W. Sanderson - The Effect of Sewage Treatment on Viruses Sewage and Industrial Waste, Journal Washington - June* 1959.

13. *Heukeleikn a Utilization of Sewage for Crop Irrigation in Israel : Sewage and Industrial waste journel washingt on August 57 Vol 29.*

In a recent paper, the author (14) has advocated that oxidation ponds be developed and operated on zonal basis, by village-AID authorities-or the Basic Democracies, for crop irrigation, fish culture and harvesting of algae, which is an untapped rich source of proteins.

For metropolitan areas, where enough land could not be made available either due to pressure on land or by building activity, or price, it is recommended that activated sludge in its modified form boisorption be adopted, being more effective than any other conventional process. The cost of the civil works could be kept low by having only earth basins as far as possible and employing relative simple mechanism like pumps and modern mechanical aerators on floats. The effluent should then be utilized for crop irrigation. For disposal of garbage and excess sludge from the final settling tanks high rate composting on the "*Area Composting Method*" be employed which renders garbage and sludge free from all pathogenic organisms. It has been emphasised that the total kill of all pathogens in refuse and sludge can only be effected thermally at temperature of 161°F (15) for a thort time.

This would ensure disposal of refuse free from air po.lution, and at the same time furnish organic fertilizer. The Second Five Year Plan of Government of Pakistan lays a great stress on the supply of organic fertilizers. Another advantage is that pending completion of sewerage, night soil, instead of sludge, could be composted together with garbage.

The effluent should preferably be utilized for crop irrigation, but where it is not possible due to unsuitability, or non-availability of land for crop irrigation, it may be discharged into drainage channels or canals with adequate minimum discharge necessary for dilution after disinfection.

The patterns of sewage and disposal are as follows :—

I. Rural and urban population up to 50,000 : coarse screen, grit removal, oxidation ponds, and restricted crop irrigation.

II. Urban population above 50,000 : coarse screen, grit removal, biosorption plant and crop irrigation for sewage.

Digestion of garbage, sludge and night soil by high race area composting.

III. Where land is unsuitable or not available for crop irrigation ; disinfection and discharge of effluent into drainage channels and canals be allowed after ensuring adequate dilution.

IV. In case of industrial wastes having toxic constituents, the injurious elements be removed by rationalising processes, and separately, treated and only harmless end products be admitted to sewers.

14. *Sheikh Abdur Rawoof - planning in the Tropics. North western Union Illinois* 1960.

15. *Gottass-verbal communications to author, 1960.*

CHAPTER IV

SEWAGE STABILIZATION (OXIDATION) PONDS

There is a growing acceptance of sewage stabilization (oxidation) lagoons (ponds) as a method of sewage disposal, which have proved highly satisfactory especially for small communities in U.S.A, Many health departments in that country have accepted the premise that a stabilization lagoon is a proved method of waste disposal, which should receive the same consideration as other methods of treatment when engineering and economic analysis are being made and Van Heuvelen (16) and others have formulated design, construction and operation practices, criteria.

Basically, the stabilization process consists largely of the interactions of bacteria and algae. Bacteria digest and oxidze the constituents of sewage and render it innocuous. Algae utilize carbon dioxide, ammonia and other substances resulting from bacterial action, and through photosynthesis produce oxygen needed to sustain the treatment process. During the detention period the objectionable characteristics of sewage largely disappear. The efficiency of the process in the removal of pathogenic organisms is high as already pointed out in Chapter II.

Cloyna and Hermann (17) have recounted as below at least six reasons why waste stabilizations pond technology should be more fully understood.

1. Waste stabilization pond systems are economical, especially for small communities and possibly also in many cases for the large cities.

2. A small city can use its limited funds to expand waste collection systems rather than pay for the building of secondary treatment system.

3. In the operation of waste stabilization ponds highly skilled personnel are not required.

4. The reclaimable water derived from waste stabilization is readily usable for some purposes, and is urgently needed in many areas to bolster the irrigation demands.

5. Stabilization ponds are not nearly as sensitive to fluctuating organic loads or excessive ground water infiltration and some other forms of secondary treatment.

6. Also the convertible and useable protein is a potentially valuable resource, which in time will be used.

To this list may be added fish culture, which is extremely important to replace meat of sheep and cattle in the diet of Pakistanis for sustaining its economy.

Oswald and Gotaas (14) experimented in Richmond, California (37° Lat) that shallow stabilization ponds which are oxygeneted through photosynthesis have given B.O.D. removal of 90-95%.

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16. *Wills Van Heuvelen, Jack K. Smith and Alen Hopkins : Waste Stabilization Logoons Designs Construction and Operation Prectices among Missions Design Statics Journal of Water and Waste Control Federation Washington D.C. U.S.A. September* 10 *Vol. 32 No. 9.*

Removals above 85 per cent on a sustained basis while under B.O.D. leads of 225 lb. per acre per day in summer and 100 lb. per acre per day in winter. This would maintain oxygenation factor (capacity) of a pond to produce oxygen in relationship to B.O.D. loading of 5·2, and would be odour free. The maximum loading factor (ratio of depth to detention) is 52 in summer and a detention period of 3·5 days. In winter conditions the loading factor is about 2·3 and a detention period of five days.

The winters of West Pakistan plains are comparable to summers of= Calofornia, and detention period of 3-5 days is adequate.

The factors involved in the operation of oxidation ponds are (a) temperature (b) light (c) B.O.D. loading (d) size and (e) shape of ponds (f) apprentunances. Hermann and Cloyna (17) have adopted the above design criteria based on experimental evidence upon observed results from actual pond installations and experiences reported by research workers of note, *e.g.*, Bush Fritz, Oswald, Gotaas, etc. The findings are summarized as below.

A Temperature :—It has been established that the chemical and biological reactions often follow the Van Woff Arrhenins equation whhic may be given practical form as as below :—

$$\frac{t}{to} = e^{c(T0-T)} = Q^{(T_o - T)}$$

Where t is the reaction time at any temperature T, and t_o is the original time of reaction at an original temperature T_0'c' is an energy temperature constant. The range of temperature adopted by Hermann is 3°C (Lower limit due to theoretical inactiviation of most types of algae to retardation of al-gal activity) and 35°C (Upper due c=0·0693 for moderate climates. For warm tropical climates (like Pakistan Plains) a lower constant but not lower than c=0·0555 may be used.

$$e^{0\cdot0693} = 1\cdot072$$

$$\frac{t}{t_o} = 1\cdot072^{(T_o - T)}$$

The operating mean day time temperature of pond content, is moderated considerably by ground temperature and by evaporation.

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17. *Hermann and Cloyna-Waste Stabilization Ponds III, Formulations of Design Equations: Journal Sewage and Industrial Waste* : *Washington, August* 1958 *Vol.* 30 *Nov.*

18. *E.F. Gloyna and R.A. Hermanm : Discession on Algue in waste Treatment :- Sewage and Industrial Waste Journal Washington April 57 Vol. 29*

19. *W.J. Oswald and H.B. Gotaas, C.G. Goilucke and W.R. Kelen :- Sewage and Industrial Waste Journal. Washington April* 1956 *Vol.* 29,

B. ***Light*** - Photosynthetic activity increases with light intenstiy upto a critical intensity as at that point algal cells are saturated and additional intensities are not utilised, e.g., saturation light intensity for chlorella pyrendosa is estimated at 600 ft. Candles. The light intensity of a homogenous suspension is decreased by concentration and depth in accordance with Beer-Lambert Law.

$$I = I_o e^{-kcd}$$

$$\text{Long } I^o/I = ked = D$$

where k=absorbtion coefficient.

c=concentration of absorbing meterical of pond.

d=depth of pond in centimeters.

D=optical density.

$$d = \frac{\log I_o/I}{kc}$$

For Austin, Texas integrated light intensity is 2100 ft. candles. For Chlorella Pyrendidose the light intensity $I_c \lesssim 24$

$$d = \frac{\text{Log } 2100/24}{0{\cdot}056} = 35 \text{ cm}$$

$$kc = D/d = 0{\cdot}1/1{\cdot}8 = 0{\cdot}056 \text{ Cm-1}$$

$$D = 0{\cdot}10$$

$$d = 1{\cdot}8 \text{ cm.}$$

For low algal concentrations high light intensity is not a requirement for successful waste treatment. However it should be enough to drive photosynthetic process about one half day, and for most geographical locations this is ensured.

C. *B.O.D. L ading* - A review of the data compiled on 188 stabilization ponds in Texas showed removal of 76 per cent with average B.O.D. loading of 34 lbs/day/acre with average effluent of B.O.D. of mg/l.

The B.O.D. removal of typical biological treatment device

$$y = \frac{a}{b+cx} d$$

For Higher loading this would assume the following form.

$$y = a+bx \quad \text{or} \quad \frac{y}{At}$$

y/At = B.O.D. loading in weight per unit area

$$p = 100-0{\cdot}05\frac{y}{At}$$

(based on actual performance data)

P=Percentage of B.O.D. Removal.

Examination of loading-depth relationship for experimental ponds for constant B.O.D. loading and detention period, but variable depth indicated, upto a maximum 8·00 loading of 30 1bs/acre/day, that the more shallow the pond the more efficient it is. However, sanitary conditions *e.g.* growth of mosquito require a minimum depth of 36 inches, While light energy may be the controlling factor in a pond which is abundant in algal growth, it was suggested by Hermann and Cloyna that that loading units on a volume basis be adopted, as it would isolate the factor of depth to note its influence. For low algal growth temperature is far more influental thon light, and hence volume is a more approuriate basis for B.O.D. loading for light intensities, greater than 400-500 foot candles, available for a few hours every day.

$V=Qt$ V=Volume of pond

t=Detention (reaction) time

Q=Quantity of waste/day

$Q=Ng\gamma/100$ N=Number of geople

g=Daily waste American gallons/capita/day.

γ=Influent B.O.D. mg/l

200=Average B. O. D. value of sewage in U.S.A.in mg/l $c(To-T)$

$t=t.e$

$$V=Ng\frac{Y}{100}to_0 \quad e \quad c\,(T_0-T)$$

(a) Optimum operating temperature =35°C

(b) Optimum reaction time 3-5. days.

(c) Energy temprature coefficient=0·0697

Substituting above value :

$$V=5.35c\times108\times Ng\gamma\ (1.072^{\ 35-T})$$

When V=Acre feet

N=Number of people

9=Americas Gallons sewage/capita/day

Y=5 day B.O.D. in mg/l

c=0·6

D. *Optimum Depth* :—from available information Hermann and Cloyna conclude that a depth of 3 feet is satisfactory. With the range varying from 2·0 to 3·5 ft. the lesser depth will provide better mixture and dispersal of settleable matter by temperature convection current and wind action, while deeper pond will tend to retain ground heat better during winter months and thereby moderate retardation of stabilization process from lowered temperature. To prevent unwanted growth of rooted aquatic plants and prevention of mosquito growth higher depth than 3ft. will be necessary.

E. *Size*:—To economize on design relative to length of piping, embankment construction and maximum pond area, the pond should be longer than it is wide with first approximation being 2:1

F. *Orientation.*

Orientation to prevailing winds is not essential. Preconvection of effluent of a single pond back to the influent end is of little value except for its mixing effect. Mixing is accomplished by temperature convection and wind action.

At least two ponds should constructed in parallel and a third as a stand-by.

Example.

A typical example of a Pakistan town of 10,000 population may be considered :

Sewage solids 0.17lb/ capita/day

Total B.D.O. load $=0{\cdot}17\times10{,}000=1700$ lbs.

Maximum summer sewage influent 500 gallons/capacity/day.
$=500{,}000$ gallons.

B.O.D. strength of sewage $=1700\times10/50{,}0000\times8{\cdot}34$
$=400$mg/l

Max. summer operating temp. 35°C

Minimum winter sewage influent at 30 gallons/capita/day
$=300{,}000$ gallons.

Min. winter operating temp. 20°C

Summer Volume of Ponds

$$V=537=10^{-8}\times10^{4}\times50\times400\ (1{\cdot}072^{35-35})$$
$$=10{\cdot}54 \text{ Acre/ft.}$$

Assume depth $=3{\cdot}5$ ft.

Surface Area $=10{\cdot}64/3{\cdot}5=3{\cdot}40$ Acres.

Winter Operating Temp $=20$°C

Sewage Discharge $=300{,}000$ gallons/day

$$V=5{\cdot}37\times10^{-8}\times10\times30\ 667\ (1{\cdot}072^{35-20})$$
$$=5{\cdot}37\times2\times1{\cdot}072^{\ 15}$$
$$=10{\cdot}72\times2=32{\cdot}22 \text{ Acre/ft.}$$

Surface Area $=32.32/3.5=9.2$ Acres.

Provide 3 tanks 3.1 Acres $=$ i.e. $250\times500'$
with $=2$ to 1 slopes for sides.

See Figure.

The above tanks have been designed to equalize amount of cut. and fill and to provide a head of 1·5· ft. for irrigation.

Cutting $=254' \times 594' \times 2=250{,}000$ Cft.
Fill $-2(546) \times 34' \times 4{\cdot}52=25000$ Cft.

approximately.

Pumping machinery.

Max. Summer Sewage $=1{\cdot}5 \times 500{\cdot}000=750{\cdot}000$ gpd.
$=520$ gpm.

Max. lift $=30$ ft i/c Suction.

B.H.P. of motor – at 85% efficiency

$$\frac{520 \times 8{\cdot}34 \times 30}{550 \times 60 \times 0{\cdot}85} = .5 \text{ BHP}$$

Minimum Sewage – 300,000 gpd – 4.6 cft.

Area Irrigated $=4{\cdot}6\ 250=1150$ Acres.

Preliminary cost of disposal work,		Rs.
Grit chamber 20′×5′ =100 sft Rs.	...	1,000/-
Bar screen	...	2,000/-
Sump Well 20 ft dia 314 sft. Rs. 30/-	...	6,420/-
Pump House above sump well 314 skd Rs. 15/-	...	5,174/-
2 Pumps 300 gpn with 3 BHP motion 3 Rs. 2500/- each.	...	5,000/-
B.F.	Rs.	19,595/-
Earthwork of Tank cut and Fill 3 Nos. × 25,000 = 75,000 cft. Rs. 40/- % cft.		3,000/-
Piping 6″ with fittings 150′ Rs. 10/-		1,500/-
Outlet Works		2,000/-
Electric over-head line‘		2,000/-
Land Acquisition 20 Acres @ Rs. 1000/- Acre.		20,000/-
	Rs.	64,495/-
	Say Rs.	65,000/-

Annual maintenance cost :

1. Suptd. @ Rs. 200/- p.m.	2400/-
1. Driver @ Rs. 100/- ,,	1200/-
1. Oil 70/- 480/- ,,	840/-
3. Attendents @ Rs. 70/- ,,	2520/-
	Rs, 6,960/-

Electric consumption :—
(Av.sewage 400,000 gpd lift 30 ft.)

Efficiency 70%

$$\frac{400{,}000 \times 8.34 \times 30}{0.70 \times 24 \times 550 \times 3600} \times 0.746 \times 24 \times 365$$

$$= 19200 \text{ units.}$$

Cost of electricity 19200 units @ Rs. -/2/- unit	24,00/-
Repairs to Machinery	500/-
Annual Maintenance of building.	1,000/-
	10,860/-

Annual capitalized cost of disposal interest and depreciations works 4% interest per annum :—

Machinery Rs. 5000/- life 20 years 5000 × .07358/-	Rs. 369/-
Buildings 65000 – (20,039 + 30,00) = Rs. 42000/- life 60 years. 42000 × .04420	Rs. 1856/-
Land and earthwork life 100 years	92/-
@ Rs. 23000/- × 0.04	Rs. 2317/-
Annual maintenance and operation cost.	Rs. 10860/-
	Rs. 13177/-

Revenue from sewage effluent

Irrigation of 1150 Acres of Rs. 20/- per acre

Rs. 23,000/-

Net revenue to local Government
=Rs. 23000 – 13,177 = 9823

It is amply demonstrated that disposal of sewage through lagooning and crop irrigation is an economically sound proposition with a very high benefit to cost ratio of 23/13= 1·9

The sewage when it passes through lagoons is rendered innocuous due to anti-biotic activity on pathogenic bacteria by predators like algae and toxic substances liberated by algae as reported by Caldwell (19) as quoted by Fitzgerald. (20) The latter also quotes Smallhorst (21) that the long storgg with setting and extreme competition are responsible for reductions in in Colifrom bacteria in ponds. There might be additional destructive effects on the pathogenic bacteria in an oxidation pond because of high oxygen levels; and pH of the water frequently goes as high as 9·0 to 9·5 during the day time due to the absorbtion of crbon dioxide in the water by algae.

To prevent mosquito breeding depth of the tank should be more than 3 feet to prevent growth of weeds like Hyacinth, very common in East Pakistan.

The ponds should be in an open area with an obstructed view on the leaward side of the habitations, at least a quarter mile away. The slopes should be protected against erosion and seepage by low root local grass.

A possible economic crop of sewage would be the algae which is rich in protiens and is excellent fodder.

Fish culture has been tried in U. S. A. with Top minhows, Gumbusia fish such as rainbow frout, Black Boss, Pike, Perch and Trench. Gloyna and Hermenn point out that 46% of 188 ponds in Texas have supported fish life in varying degrees,

In waterlogged areas, where crop irrigation cannot be practised the lagoons could be connected to depressions and drains.

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(19) *Caldwell D. H "Sewage" Oxidation Ponds-Performance Operation and Design "Sewage Works Jour.* 18, 3433 (*May* 1946).

(20) *Georage P Fitzgereld and Gerald A Rolilich—An Evaluation Sta-abilization Pond literature wewage and Industrial Wastes Wahington Oct.* 1958 *Vol.* 30. *No.* 10.

(21) *Smallhorst B. F. Walton B. N. and Mayers "Design and application of Oxidation Pond Public Work Jowrnal* 8212, (1957). *Washington.*

CHAPTER V

CROP IRRIGATION

In previous chapters the health hazards due to application of untreated sewage and night soil, and the direct Rupee benefits to the local Government of applying sewage affluents for crop irrigation have been fully discussed.

In this chapter, methods to increase benefits without causing injury to land, and health of human beings and cattle are described.

While, by well-managed irrigation, considerable increase in crop yield results, on the other hand, over-irrigation results is killing of the crop, deleterious effects on the soil, and some alleged cases of pollution of nearby shallow wells.

It is imperative to investigate the amount of waste woter of a given quality that could be applied, ond determine the effect on crops, soil and ground conditions. Such investigations were carried out by Oscar Mayer(22) and company in 1950 =52 on Miami silt loam soils and pect, with canary reed, crop with effluent from packing plant. Similar investigations should be carried out on soils and crops in Pakistan to improve yield and safeguarding soils against deterisration.

The initial investigations were carried on with Lyssimeter, which made possible accurate measurements of the amounts used by the crop and the amounts that percolated through the soil. The table below gives average concentration of various ions in the packing plant during the irrigation period. The treatment plant consisted of primary settling tank and trickling filters.

Table-Average concentration of various ions in sewage effluent from Oscar Mayers and Company packing plant during the irrigation period.

Period	NH_4-N (ppm)	Total N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)
Aug : Oct :	1950	3·2	10·1	2·0	9·9		
May : Oct :	1951	13·7	27·7	8·9	36·9		
May : Oct :	1922	25·0	44·9	7·7	19·7	67·7	46·4 68·0

This table indicates that high amount of sodium were added by 1952. The harmful affects of sodium concentration can be amelionraed to some extent by favourable concentrations of calcium and magnesium in the irrigation water.

According to Wilcox the suitability of water for irrigation can fairly accurately by judged by determining what percentage of the total cations in

(22) *C.D. Henry, R.R. Moldenhaner L.R. Englbert and E. Trunsg : Sewage Effluent disposal ihrough crop irrigation-Journal of Sewage and industrial Wastes-Feb* : 54 *Vol.* 26-*No.L, Champaign Illinois.*

(23) *Wilcox L.V. "The quality of water for irrigation Use", O.S. Dept : of Agr : Tech : Bull.* 962 (1948), *U.S.A.*

the water i.e. representrations being in gram-equivalents per million.

$$\text{Percentage Na} = \frac{\text{Na} \times 100}{\text{Ca} + \text{Mg} + \text{Na} + \text{K}}$$

To be suitable for irrigation the equivalent percentage of sodium in water should not exceed 80, nor should the total concentration of cautions in equivalents parts per million exceed 25.

The effectiveness with which the soil and crop remove nitrogen, phosphorous and pottassium is evident from the figs 1 & 2.

Losses of phosphorous and Pottasium are negligible and that of nitrogen very small of the order of 3% for peat soil over 3 years period.

Even for silt loam soil the losses of nitrogen are not great, once it is stabilised.

This amply illustrates, that sewage effluent even when given secondary treatment contributes richly to the fertility of the soil.

Heukelkian (24) "during survey of sewage irrigation in Israel, observes that the use of sewage adds to the soil 2·5 to 3 kg of nitrogan, 1·0 kg of phosphorous and 1·3 to 1·6 kgs of potassium per capita per year. He advocates only primany treatment and restricted crop irrigation, as he is of the view that even with the secondary treatment to health hazards are not lewered. The objective of pretreatment of sewage should not be removal of B.O.D. etc. this could best he done in the soil in conjunction with crop irrigation.

In a subsequent Chapters it would be shown that even secondary treatment could be made simple and economical, and in fact could amply repay its cost as productive proposition.

Henry (22) indicated the increase in yield of crops due to sewage irrigation *vide* table.

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(24) Haukelekian Utilization of sewage for crop irrigation in Isreal Sewage and industrial waste journal. August, 57 Vol. 29-No. 9 Washington.

Table of Yields of Reed Canary Grass Growth in Lyssimetvis irrigated with Sewage Effluent and city water, and inches of percolate and transpiration under different treatments:-

Kind of Irrigation Water Applied	1951 Season				1952 Season.			
	Applied in	Percolated in	Transpired & Evaporated in	Dry Matter Tons/Acre	Applied in	Percolated in	Transpired & Evaprated in	Dry Matter Tons/Acres
(a) Miami Silt Loam								
City Water Sewage	39	13.6	44.9	2.9	50	4.5	65.6	3.2
Effluent	41	31.9 6 peat	46.6	3.9	54	4.9	69.2	4.3
City Water Sewage	39	9.7	49.8	6.9	64	4.4	80.2	6.4
effluent	43	8.5	54.0	8.7	69	3.4	85.7	7.7

Note: In addition, there were 19.5 and 29.14 inches of rain during the irrigation period of 1951 and 1952.

The results of Lyssimeter studies were corroborated by field results.

The effectiveness of soil to remove pathogens and coliforms is extremely great. The pathogens do not persist in soil, even when their presence in effluent is considerable and there is little danger of contamination of ground water.

It would be wise to restrict the types of crops for sewage irrigation.
With Primary Treatment:-

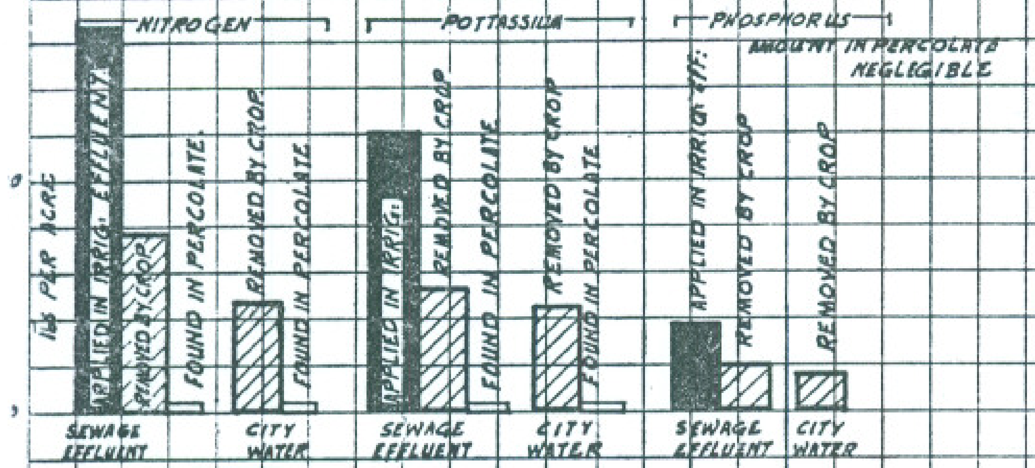
As permitted by Isreali Ministry of Health varieties of beets raised for the manufacture of sugar and for stock feed, cotton, pastures and hays, vegetables that are eaten only after cooking, such as egg plants, white and sweet potatoes, okra, lady-fingers, sweet corn, olives and dry onions, fruit trees such as citrus, bannana, nut, date and avocado, nurseury plants, ornamental plants and flowers, sun flowers and carrots, when furrow irrigated, apples, pears and plums, when irrigation is stopped at least one month before harvesting and plants grown for seed.

Heukelekian adds to this list, broccoli, cauliflower, and tomatoes for canning when furrow irrigated.

Odours will not be present when sewage plant is properly operated to avoid septicity. Odours in case of spray irrigation are more common and hence furrow irrigation only be adopted.

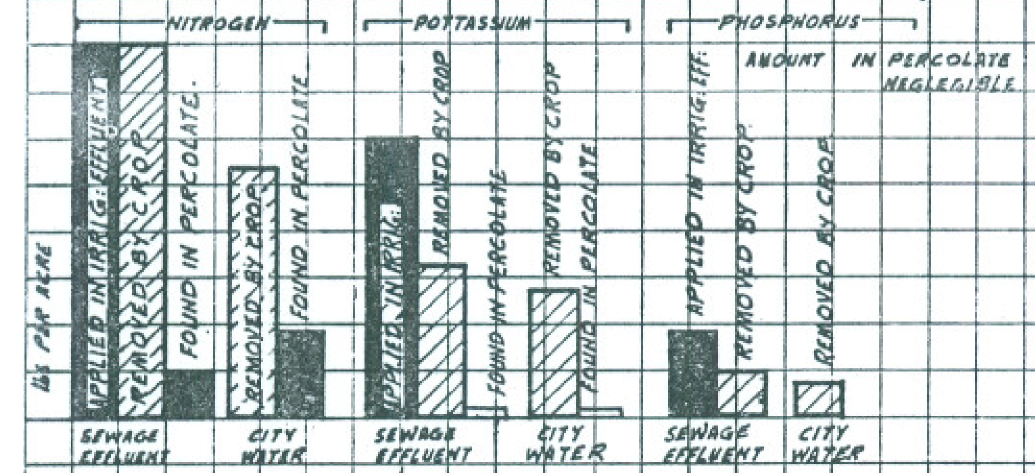
When incidence of hookworm and ascaris is there, the effluent be passed through micro-filtration,or slow sand filters.

FIG. 1



LYSIMETER. CONTAINING MIAMI SILT COAM CUMULATIVE AMOUNTS OF NITROGEN, POTTASSIUM APPLIED IN IRRIGATION, REMOVED BY CROP & PRESENT IN PERCOLATE.

FIG. 2



LYSIMETER, CONTAINING PEAT CUMULATIVE AMOUNTS OF NITROGEN, POTTASSWM & PHOSPHORUS APPLIED IN IRRIGATION, REMOVED BY CROP & PRESENT IN PERCOLATE THROUGH THE GROWING SEASON 1951 - 52

TANK 250'x500' PAPER No. 348