RECLAMATION OF WASTE WATER FOR AGRICULTURAL USE

A DISSERTATION
submitted in partial fulfilment of
the requirements for the award of the degree
of
MASTER OF ENGINEERING
in
HYDROLOGY

by :
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C E R T I F I C A T E

Certified that the dissertation entitled 'RECLAMATION OF WASTE WATER FOR AGRICULTURAL USE ' which is being submitted by Sri S.P.Rout in partial fulfilment of requirements for award of the Degree of Master of Engineering in Hydrology of the University of Roorkee, is a record of the candidate's own work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for award of any other Degree or Diploma.

This is further to certify that he has worked for a period of more than nine months for preparing this dissertation.

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The author does not claim to have written anything new or original . The analysis of Waste Water has been done in Public Health Laboratory of the University of Roorkee by the author himself.

The matter embodied here is collection and systematic representation of available literatures, the sources of which have been duly acknowledged in the biblio- graphy at the end.

S.P.Raut

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CHAPTER-I

INTRODUCTION

1.1 Definition

Reclamation of waste water is the technique by which water originating from urban and industrial usage is upgraded in quality for its utilisation. Purpose of reclamation may be manifold for which water is required, but this dissertation, however, has been limited to the agricultural use only.

It is important to draw a clear distinction between disposal of waste water by irrigation and reclamation of waste water for agricultural purposes. Failures and disadvantages with the disposal of waste water by crop irrigation need not arise when reclamation for the agricultural purpose is the primary goal.

1.2 Necessity of Reclamation

It is needless to explain the need of water when the World's population is increasing at an alarming rate, while global water resources is constant. Due to impound standard of living per capita consumption of water has increased manifold and because of rapid technological advances, the industrial demand for water has also gone up considerably.

The global water resources[1] are approximately 137.6×10^{16} cu.metres, out of which about 95 percent in the oceans and seas and 2 percent in the polar ice caps. However 35 gms of salt in a litre of sea water and the remoteness of polar ice caps interfere with their uses. This leaves as the potential fresh water resources of the earth no more than 4.1×10^{16} cu.metres in lakes, streams, aquifers and atmosphere. Fortunately the hydrosphere is not static. Due to hydrologic cycle, there is no end of atmospheric water resources, though yearly 41.4×10^{13} to 49.3×10^{13} cu.meters of water fall as precipitation; out of which only about a quarter on the continents and islands and rest on oceans. To complete the hydrologic cycle annual runoff of about 3.8×10^{13} to 4.2×10^{13} cu.metres return to sea from where it is evaporated to atmosphere. In overall estimates, about a third of the landmass of the earth is classified as well watered, the remainder as semi-arid and arid.

Under these circumstances concept of reclamation of spent water for its reuse has been evolved in the minds of the technologists. Since the advent of civilisation, a number of waste water treatment plants have been established in India and abroad. Whether a waste water treatment operation is essentially reclamation or disposal, or both, depends on the point of view, that is, who is paying for it. On this basis reclamation may fall into two categories, i.e. either incidental [2] or planned.

The number in paranthesis [] refers to number in the bibliography.

1.2.1 Incidental Reclamation

Incidental Reclamation is the use of effluents produced at waste disposal facility, planned and financed as such and represents the best means of final disposal. Examples of Incidental reclamation of waste water are found since the treatment practice of waste water comes to civilization. For example the effluent from septic tank enters the soil and increases ground water storage. Sewage irrigated farms, are the other examples of incidental reclamation [3]. The first [4] sewage farm for treating municipal works was originated in Germany about the year 1559. A historical data [4] on sewage farming is given in Table No.1.1. In India sewage farms are also found in Calcutta, Madras and Kanpur.

1.2.2 Planned Reclamation

Reclamation may be planned, involving a process of recovery of water from the waste waters, that was originally planned and conceived with the primary purpose of putting the recogered water to beneficial use. One of the first planned operations for reclamation of municipal waste water began in Los Angels, California in early 1930's, It was demonstrated that a highly treated sewage effluent could be spread on soil, thereby contributing significantly to ground water supply without impairing its quality. Another pioneering reclamation project was constructed in Sans Fransisco's Golden Gate Park in 1932. At this plant approximately 4500 cu.metre per day of reclaimed sewage is used for irrigation and supply of decorative lakes and streams, within the park. Reclamation may be accomplished by discharge of treated waste water for percolation and then diversion from natural stream beds. As an example of such reclamation (amounting 74,000 x 10^3 M^3) was the upper Santa Ana River Basin [5] in the southern California which was the principal basis of quantity and quality of supply to settle major water rights litigation in 1971.

1.3 Utility of Reclaimed Water

1.3.1 Domestic Reuse

The utilization of reclaimed waste water for domestic use like drinking purposes may be normally discouraged, though it is possible. There are examples where reclaimed waste water is utilized for domestic consumptions. Past examples [6] of direct reuse exist also, such as the classic case encountered at Chanute, Kansas, U.S.A. in 1956, when due to severe drought, waste water was treated, chlorinated, and reused several times.

Partial recycling, such as the municipal use of large rivers and ground water recharge by percolation and injection, has been extensively practiced. However the only example, of the planned direct reuse for domestic water supply that can be cited is in Windhoek, South West Africa. At the end of 1968, Windhoek [7], became the first city in the history of the world to practice large scale and continuous reclamation of waste water effluent for drinking

Table No. 1.1

Historical Data on Sewage Farming(After Charles E.Pound et al.[4].

Location	Date	Type	Flow mgd.
Non United States.			
1. Bunzlau, Germany	1559	SF	-
2. Croydon-Beddington, Germany	1861	SF	4.5
3. Berlin, Germany	1869	SF	150[b]
4. Birmingham, England	1880	SF	22
5. Melbourne, Australia	1893	I	50[c]
6. Mexico City,Mexico	1902	I	570[c]
7. Paris, France	1923	I	120
United States			
1. Augusta, Maine[d]	1872	1	0.007
2. Pullman, Illinois[d]	1880	1	1.85
3. Cheyenne, Wyoming	1881	1	7.0[e]
4. San Antonio,Texas	1895	I	20[b]
5. Salt Lake City, Utah	1895	1	4
6. Bakersfield, California	1912	1	13.0[e]

a. SF - Sewage Farm I = Irrigation

b. Data for 1926

c. Data for 1971

d. Abandoned around 1900

e. Data for 1973,

cu.metre per day of reclaimed sewage is used for irrigation and supply of decorative lakes and streams, within the park. Reclamation may be accomplished by discharge of treated waste water for percolation and then diversion from natural stream beds. As an example of such reclamation (amounting 74,000 x 10^3 M^3) was the upper Santa Ana River Basin [5] in the southern California which was the principal basis of quantity and quality of supply to settle major water rights litigation in 1971.

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1.3.2 Industrial Use

This is one of the principal reuses of waste water, which involves little health hazards. Reclaimed effluents have been particularly suited for cooling, for which large quantities, rather than high quality is prerequisite. Powell[8] states, 'Industry can profitably employ reclaimed waters for plant processing, boiler feed, sanitary uses, fire protection, air conditioning, plant clean up and lawn sprinkling'. He does not advocate that reclaimed water should be used in processing products for human consumption, as the treatment and sanitary complications would be impracticable and costlier. Veatch [9] lists three conditions necessary for industrial use of reclaimed water.

1). There must be a local industry in need for the purposes that donot involve human consumption.
2). There must be a waste water treatment plant enough to furnish the amount of effluent required.
3). The cost of processing and furnishing effluent of the required quality must be less than that involved in the use of anyother alternative source of supply.

The examples of utilizing reclaimed waste water for industries are many in the western countries. In Table 1.2 some examples of waste water reclamation projects and

Table No. 1.2

Some of the Industrial Users of Sewage Treatment Plant Effluent(After C.A.Sastry et al.)

User	Source of effluent	Use	Qty. (mgd.)
Bagdad Copper Co.	Bagdad Treatment Plant	Copper recovery	--
Bethlehem Steel Co.	Baltimore Backriver Treatment Plant	Process-ing and cooling	118
California Elect-ric Bower Co.Calif.	San Bernardino treat-ment Plant	Cooling	--
Champlin Refining Co. Enid, Okla.	Enidtreatment Plant	Cooling and Boiler Water	1.0
Columbia Geneva Steel Co, Provo, Utah.	Plant Sanitary treat-ment Plant	Processing	0.3
Cosden Petroleum Corpn.,BigSpinning Texas.	Big Spinning Treatment Plant	Boiler water	0.7
Grand Canyon National Park	Park Treatment Plant	Cooling	0.2
Inspiration Conso-lidated Copper Co. Inspiration,Ariz.	Inspiration Treatment Plant	Copper recovery	--
Kaiser Steel Co. Fontana, Calif.	Plant Sanitary Treat-ment Plant	Processing	0.50
Kennecott Copper Corp.,SantaRita,N.Mex.	Santa Rita treatment plant	Copper recovery	0.50
Kennecott Copper Corp.,Hurley,N.Mex.	Hurley treatment plants of three towns	Copper recovery	0.30
Los Abamos Sci.Lab. N.Mex.	Los Almos treatment Plant	Cooling	0.50
Southern Neveda Power Co.Los Vegas,Nev.	Los Vergas Country Treatment Plant	Cooling	1.7
Texas Co.Amarillo,Tex.	Amarillo Recl.Plant	Cooling and Boiler water	1.5

use of waste water for different purposes have been given. In India a tertiary treatment plant [10] for purifying municipal waste water has been put into operation in 1973 at Bombay to supply 5000 m^3 water for cooling and processes to an Industry. The National Environmental Engineering Research Institute (NEERI) Nagpur has recommended reuse of water for cotton textile mills and chemical and pharmaceutical industries to conserve regular water supply.

1.3.3 Agricultural Use

Use of waste water for agriculture is an old and common practice. However quality of waste water is important to prevent contamination of crops. Once the desired quality is achieved, the reclaimed waste water can safely be used for agricultural purposes. Through out the world at many places the reclaimed waste water is used for irrigation. A detailed report of reclaimed Municipal wastes used for Irrigation in U.S.A. has been given in Tables 1.3 and 1.4.

1.3.4 Recreation

Reuse for recreational purposes such as swimming, boating etc. are common in U.S.A. The South Tahoe Public Utility District Water Reclamation Plant at South Lake Tahoe, California is perhaps the first one to go into full scale operation using for the purpose. Since March 31, 1968 the South Tahoe Plant was in operation without shut down upto 1971 [7]. The continuously high degree of pollutant removal

Table No. 1.3

Sewage Effluent Reclamation in United States after Veatch

State and City	Industry served	Use	Remarks
ARIZONA			
Casa Grande	Agriculture	Irrigation	Used directly
Nogales	Agriculture	Irrigation	Used directly
Phoenix	Agriculture	Irrigation	Diverted from stream
Tucson	Agriculture	Irrigation	Used directly
CALIFORNIA			
Bakerfield	Agriculture	Irrigation	Used directly
Banning	Agriculture	Irrigation	Diverted from stream
Brea	Agriculture	Irrigation	Diverted from stream
Chino	Agriculture	Irrigation	Used directly
Cloverdale	Agriculture	Irrigation	Used directly
Colfax	Agriculture	Irrigation	Used directly
Colton	Agriculture	Irrigation	Used directly
Corcoran	Agriculture	Irrigation	Used directly
Dixon	Agriculture	Irrigation	Used directly
Elsionore	Agriculture	Irrigation	Used directly
Exeter	Agriculture	Irrigation	Used directly
Fowler	Agriculture	Irrigation	Used directly
Fresno	Agriculture	Irrigation	Used directly
Hanford	Agriculture	Irrigation	Used directly
Hemet	Agriculture	Irrigation	Used directly
Indio	Agriculture	Irrigation	Used directly

Kingsburg	Agriculture	Irrigation	Used directly
Lemoore	Agriculture	Irrigation	Used directly
Livermore	Agriculture	Irrigation	Used directly
Lodi	Agriculture	Irrigation	Used directly
Madera	Agriculture	Irrigation	Used directly
Manteca	Agriculture	Irrigation	Used directly
Marysville	Agriculture	Irrigation	Used directly
Merced	Agriculture	Irrigation	Used directly
Modesto	Agriculture	Irrigation	Used directly
Ontario	Agriculture	Irrigation	Used directly
Orland	Agriculture	Irrigation	Used directly
Pasadena	Agriculture	Irrigation	Diverted from stream
Pomona	Agriculture	Irrigation	Used directly
Ripon	Agriculture	Irrigation	Used directly
Riverside	Agriculture	Irrigation	Used directly
SanBernardino	Agriculture	Irrigation	Diverted from stream
SanLouis Obispo	Agriculture	Irrigation	Used directly
Santa Maria	Agriculture	Irrigation	Used directly
Santa Paula	Agriculture	Irrigation	Used directly
Santa Rosa	Agriculture	Irrigation	Diverted from stream
Selma	Agriculture	Irrigation	Used directly
Sonoma	Agriculture	Irrigation	Used directly
St Helena	Agriculture	Irrigation	Used directly
Susanville	Agriculture	Irrigation	Used directly
Tracy	Agriculture	Irrigation	Diverted from stream
Tulare	Agriculture	Irrigation	Used directly
Turlock	Agriculture	Irrigation	Used directly

Ukiah	Agriculture	Irrigation	Used directly
Vacaville	Agriculture	Irrigation	Used directly
Visalia	Agriculture	Irrigation	Used directly
Wasco	Agriculture	Irrigation	[Creamery waste Used directly
Whittier	Agriculture	Irrigation	Used directly
Woodland	Agriculture	Irrigation	Used directly
Yreka	Agriculture	Irrigation	Used directly
COLORADO			
Burlington	Agriculture	Irrigation	Diverted from stream
Colorado Springs	Agriculture	Irrigation	Diverted from stream
~~Colorado~~ Denver	Agriculture	Irrigation	Diverted from stream
Greeley	Agriculture	Irrigation	Diverted from stream
Holyoke	Agriculture	Irrigation	Diverted from stream
IDAHO			
Glenns Ferry	Agriculture	Irrigation	Used directly
Meridian	Agriculture	Irrigation	Used directly
KANSAS			
Herington	Railroads	Boiler water	Used directly with softening
Liberal	Agriculture	Irrigation	Used directly
Scott City	Agriculture	Irrigation	Used directly
MARYLAND			
Baltimore	Steel mines	Cooling and quenching	[Treated and used directly
MONTANA			
Anaconda	Agriculture	Irrigation	Used directly
Helena	Agriculture	Irrigation	Used directly
WhiteSulphur Spring	Agriculture	Irrigation	Used directly

NEBRASKA			
Grand Island	Amusement	Skating	Used directly by pondin
Hastings	Agriculture	Irrigation	Diverted from stream
Imperial	Agriculture	Irrigation	Used directly
Kimball	Agriculture	Irrigation	Used directly
NEVEDA			
Goldfield	Mining	Processing Ore	Used directly
Reno	Agriculture	Irrigation	Diverted from stream
NEW JERSEY			
Vineland	Agriculture	Irrigation	Used directly
NEW MEXICO			
Cloris	Agriculture	Irrigation	Used directly
Hobbs	Agriculture	Irrigation	Used directly
Lordsburg	Agriculture	Irrigation	Used directly
Portales	Agriculture	Irrigation	Used directly
Raton	Agriculture	Irrigation	Diverted from stream
SantaFe	Agriculture	Irrigation	Used directly
OKLAHOMA			
Duncan	Oil	Cooling	Diverted from stream
Enid	Oil	Cooling	Diverted from stream
OREGON			
Ashland	Agriculture	Irrigation	Diverted from stream
Athena	Agriculture	Irrigation	Used directly (creamery wastes)
Burns	Agriculture	Irrigation	Used directly
Hillsboro	Agriculture	Irrigation	Used directly (cannary wastes)

Medford	Agriculture	Irrigation	Diverted from stream
Milton	Agriculture	Irrigation	Used directly (creamery wastes)
Milton	Agriculture	Irrigation	Used directly (Cannary wastes)
RHODE ISLAND			
Providence	City Incinerator	Cooling	Used directly
TEXAS			
Abilena	Agriculture	Irrigation	Used directly
Amarillo	Agriculture	Irrigation	Used directly
Baird	Agriculture	Irrigation	Used directly
Big spring	Oil	Cooling	Used directly
Brady	Agriculture	Irrigation	Used directly
Breckenridge	Agriculture	Irrigation	Used directly
Brownfield	Agriculture	Irrigation	Used directly
Canyon	Agriculture	Irrigation	Used directly
Carlsbad (State Sanitorium)	Agriculture	Irrigation	Used directly
Childress	Agriculture	Irrigation	Used directly
Coleman	Agriculture	Irrigation	Used directly
Corpus Christi	Oil	Cooling	Used directly
Dublin	Agriculture	Irrigation	Used directly
Falfurrias	Agriculture	Irrigation	Used directly
Georgetown	Agriculture	Irrigation	Used directly
Karnes City	Agriculture	Irrigation	Used directly
Karrville	Agriculture	Irrigation	Used directly
Kingsville	Agriculture	Irrigation	Used directly
Lubbock	Agriculture	Irrigation	Used directly
Midland	Agriculture	Irrigation	Used directly

Mission	Agriculture	Irrigation	Used directly
Munday	Agriculture	Irrigation	Used directly
Plainview	Agriculture	Irrigation	Used directly
Robstown	Agriculture	Irrigation	Used directly
Roscoe	Agriculture	Irrigation	Used directly
Rotan	Agriculture	Irrigation	Diverted from stream
San Angelo	Agriculture	Irrigation	Used directly
San Antonio	Agriculture	Irrigation	Used directly
San Marcos	Agriculture	Irrigation	Used directly
Snyder	Agriculture	Irrigation	Used directly
Stamford	Agriculture	Irrigation	Used directly
Stephenville	Agriculture	Irrigation	Used directly
Sweetwater	Agriculture	Irrigation	Used directly
Tahoka	Agriculture	Irrigation	Used directly
Uvalde	Agriculture	Irrigation	Used directly
UTAH			
Bringham			
Ogden	Agriculture	Irrigation	Diverted from stream
Richfield	Agriculture	Irrigation	Diverted from stream
Saltlake City	Agriculture	Irrigation	Diverted from stream
Saltlake City (Geneva Steel Co.)	Steel	Cooling	Diverted from stream
St George	Agricuature	Irrigation	Used directly
WASHINGTON			
Wallawalla	Agriculture	Irrigation	Used directly
WYOMING			
Cheyenne	Agriculture	Irrigation	Used directly
Cheyenne	Railroad	Boiler water	Proposed

from the reclaimed water achieved by the Tahoe process is shown below which gives average efficiencies since commencement of operation in March 1968. The percentage removal of different parameters of effluent is given below. ‡

The reclaimed water from Tahoe state is not used for doemestic purpose. In conformance with state Law, it is exported out of Tahoe basin. All effluents are impounded in a new man-made reservoir located in some 30 miles from treatment plant in Alpine County, California. The reservoir has capacity of about 3000 acreft. and since its initial filling has constantly maintained a very pleasing appearance, used for boating and swimming. During irrigation season, a portion of the water in the reservoir is released for irrigation of forage crops.

1.3.5 Reclamation as most economical method of disposal

In some areas, it is less expensive to reclaim and dispose of waste water in land than dispose of waste water to the ocean through outfalls. Although treatment costs may be higher for reclamation, but it is less expensive than the construction of additional trunk sewers, coastal sewage treatment and ocean outfall. As a result additional water supply is available through reclamation.

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‡ (i) BOD - 99.4 % (ii) COD - 96.4 % (iii) Phosph - 99.1 %
(iv)Suspended solids - 100 % (v) Colour - 100 %
(vi) Odour - 100 % (vii) Coliform Bacteria - 100 %
(viii) Turbidity - 99.9 % (ix) Viruses - 100 %.

Table No. 1.4

MÜnicipal Waste Treatment Plants with Discharge Applied to Land in 1962. after Eastman.

	States	Number of Plants,	Estimated population served.
1.	Arizona	22	2,96,875
2.	California	199	15,47,878
3.	Colorado	11	1,27,400
4.	Idaho	3	624
5.	Kansas	2	3,600
6.	Montana	7	4,680
7.	Nebraska	6	3,180
8.	Neveda	11	1,19,920
9.	New Mexico	21	1,86,410
10.	North Dakota	6	4,585
11.	Oklahoma	-	-
12.	Oregon	8	15,250
13.	South Dakota	-	-
14.	Texus	40	2,41,405
15.	Utah	4	8,345
16.	Washington	16	21,110
17.	Wyoming	5	12,475
18.	Total 17 Western States	361	25,93,737
19.	Total 33 other states	40	90,520

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1.3.6 Enhancement of the Environment

In the past the main objective of waste water reclamation was to develop an additional water supply and more recently, the economic disposal of waste water.However, the advantages of reclamation in enhancing environment are now being recognised. Reclamation by secondary treatment, sometimes tertiary treatment and reuse of waste water reduces the adverse impact on receiving waters caused by discharge of untreated or partially treated liquid waste.

The environmental improvement aspects of reclamation has great potential even in areas of abundant,inexpensive surface water supplies. The reduction in quantity and improvement in quality of waste discharges as a result of reclamation and reuse can reduce stream, lake, ocean and ground water pollution, regardless of whether additional supply is needed.

In addition in water deficit areas, the aesthetics of an area can be improved by use of reclaimed water for the irrigation of parks, green belts, golf course, and freeway landscaping.

1.3.7 Pisciculture

The reclaimed waste water for pisciculture has been used since long indirectly. This was done by discharge of effluents into rivers, lakes and estuaries. There are a lot of examples for using raw sewage, which has endangered the lives of the fishes. But Pisciculture by reclaimed waste water is a beneficial practice for disposal.

It has been estimated that treated sewage obtained from 1000 - 2000 persons [12] can be handled by one acre of pond, producing 1600 lbs of healthy carp, per year provided dilution and reaeration are adequate. The largest installation of fish ponds is at Munich where sewage from 700,000 persons is treated on about 550 acres in 30 ponds, and average return of fish flesh is reported to be 425 lbs per acre per year. A series of shallow tanks 0.60 to 1.22 metres are constructed, one overflowing into the next; the sercened and settled sewage, diluted 2 to 4 times is filled and fish introduced.

It has been reported [13] the controlled use of settled sewage for the culturing of carp around Calcutta. During dry weather once there was a great demand from the fishing owners for sewage, and for the sewage of Calcutta, carpoculture in that area was profitable.

It has been found that the discharge of the effluent from the Hyperi on sewage Treatment Plant in Los Angels, California, into the Santa Monica Bay has increased the fish population in the bay. Fish are known to be grown in the effluent from the Sewage Farm Madura, Tamilnadu, where raw sewage is used for growing grasses on land provided with under drains.

1.4 Present Practices in India

India's present population (according to 1971 census) is 547 millions out of which approximately 109 millions people are known to live in the urban areas constituting a mere 20 percent. The urban population is classified as that population which lives in towns having population above 5,000 and cities having population above 1,00,000 Out of 2430 towns and cities, only about 175 towns and cities are sewered which is about 7 percent of the total number of towns. In terms of population, about 33 million (i.e. 30 percent of urban population) is served with sewers which amounts to 6 percent of total population. About 30 years ago, the population served by sewers was 3 percent, from which one can judge the slow growth of sewerage system in the country.

Seventy percent of the urban population is known not to be served with sewers. The excreta from this population is collected without dilution and disposed of by trenching or dumping and occasionally composting with town refuse again by trenching.

The cities and towns, having sewerage facilities discharge their sewage into the nearest nullah(natural drain) which ultimately flows into a river or into sea. In a majority of cases sewage is discharged into these nullahs practically untreated. This results in heavy pollution of the river and hardship to downstream users. This has been occuring in many rivers in India. A notable example of this is the discharge of sewage and sullage from various towns; between Delhi and Agra.

Marine Disposals

Many towns and cities on the sea coasts are invariably discharging their wastes into the sea in an unorganised manner resulting in the destruction of fish and shell fish and creating foul conditions in that area. For the same reason most of the beaches around these areas are contaminated and give out foul odours. This situation is very apparent in the city of Bombay.

Sewage Farming

About 40 percent of the available sewage is disposed of on land. Out of these, however, it is a sad to record that about 50 percent of sewage disposed on land is irrigated without any treatment.

Table No.1.5 gives a clear picture of sewage disposal of some of the major cities of India [65].

Among major industries, waste water from Amul Dairy Farm, Anand, Gujrat, has been used on land for irrigation for several years by ridge and furrow method and varieties of dry crops like Maize, bajra, wheat and cash crops like tobaco, vegetables, orchards have been irrigated. [64)

Most of industries in Kanpur discharge their wastes in municipal sewers. Thus sewers receive a varying quality of industrial and domestic wastes.

Table No. 1.5

Current Practice of Municipal Waste Disposal in some of the major cities in India, after G.J. Mohanrao.

	City	Approx. Population	Present Practice of Sewage Disposal
1.	Greater Calcutta	75,00,000	Only a part of city is sewered and primary treatment provided. Part used for farming. Balance to River in untreated condition.
2.	Greater Bombay	55,00,000	Only 10 percent of city sewage is treated partly with secondary treatment. Balance goes untreated to sea and an odour problem exists in some areas.
3.	Delhi	24,00,000	Two modern plants with primary and secondary treatment.
4.	Madras	18,00,000	Part of sewage used for irrigation and a part goes direct to sea.
5.	Kanpur	15,00,000	No sewage treatment plant, part for irrigation.
6.	Hyderabad	13,00,000	Screens, grit, and balancing tank followed irrigation.
7.	Bangalore	12,50,000	No sewage treatment plant.

8.	Ahemadabad	12,50,000	Two modern sewage treatment plant. Also irrigation.
9.	Poona,	7,50,000	No treatment plant, Pumped for firming.
10.	Nagpur	7,00,000	
11.	Lucknow	6,75,000	
12.	Agra	5,50,000	
13.	Varanasi	5,00,000	
14.	Madurai	4,50,000	
15.	Allahabad	4,50,000	
16.	Amritsar	4,00,000	Secondary Treatment Plants Effluents used for farming.
17.	Indore	4,00,000	
18.	Jaipur	4,00,000	
19.	Sholapur	3,50,000	
20.	Patna	3,750000	

At present waste from the city is being utilised for irrigation after dilution with water from river Ganges. The night soil, from part of the town served by conservancy system, and garbage is collected at pail depot situated near the pumping station and washed into main sewer. Both sewage and raw water are pumped from outfall works to a distributory irrigating the sewage farms. The command area of distributary is about 7600 acres. The excess of waste water above the requirement of the farm flows through a by-pass channel to the river.

Secondary Treatment

Steel plant at Rourkela, Orissa, is one of the biggest industries in India. It adopts secondary treatment by a two stage-series of bifilteration plant for its waste disposal. The effluent from primary clarifier is taken to a distribution box, from which a constant amount of 700 m^3 per hour flows to primary biofilter, while the excess is mixed with recirculation and flows to a secondary biofilter. Ultimately the effluent is taken to final clarifier and then to chlorinator from where it is discharged to an open nullah which discharges to river Brahmani, about 100 m of downstream of Pickup Weir, the main intake weir. [65]

Oxidation Pond

There are many small towns using oxidation pond for treatment of the waste waters. Even among the larger cities like Ahmadabad had oxidation ponds treating about 13 million gallons per day of their domestic waste. The city of Nagpur treats part of its wastes through such ponds.

CHAPTER-II.

WASTE WATER AND ITS CHARACTERISTICS

2.1 Types of Waste Water

The types of waste water depending on its origin may be classified as of three types.

(i) Municipal Waste Water.

(ii) Industrial Waste Water.

(iii) Dairyfarm Waste Water.

2.1.1 Municipal Waste Water

The waste waters are the spent waters supplied to the community, and originate from domestic or residential establishments. The domestic waste water is the spent water from kitchen, bathroom, lavatory, toilet,and laundry. To the mineral in the water, supplied to the community, is added burden of human excrement, paper, soap, dirt, food wastes, and other substances, like cosmetics, medicines, oils and paints etc which may be available to a householder. However, perhaps the greatest source of the chemical compounds in the municipal waste water is the small industrial and chemical enterprizes, those discharge to various organic and inorganic compounds to the municipal sewage system. The approximate quantities of waste water have been given in tables II-1 and II-2 [14].

2.1.2 Industrial Waste Water

Large industrial organisations customarily discharge their non-domestic waste water to the water-resources as return flows separate from municipal effluent. These waste waters originate from various manufacturing process-units of the industry. Broadly industries require large volumes of water for cooling purposes steam generation, manufacture processes, and sanitation. The general uses of water in industry is given in table II.3.

Industrial needs for water are relatively uniform for any particular industry, but vary widely for different industries. Chemical and Metal Industries withdraw 25 to 30 times as much as rubber industry. Also the units within a industry use different quantities of water for their purposes. The quantities of water required by some important industries are given in Table II.4 [15].

2.1.3 Dairy Farm Waste Water

The dairy farm waste water consists of [16]

(i) Waste water from manufacturing and processing plants.

and(ii) Domestic waste water.

(i) Waste water from manufacturing and processing plants:

This includes wash water from milk cans, equipments, bottles, and floors. Also a portion of spilled milk, spoiled or soured milk, skimmed milk, whey and butter milk. The volume and composition of waste water depend on number of products made, the care with which the processes are conducted (to avoid leakage and spillage) and amount of water readily available for washing purposes. The waste

Table II.1

Sewage Volume per day per Person

	Type of Occupancy	Descriptive Use	Gal per person or occupant per day
1.	Dwellings, Residential	Residential clubs, Homes, Apartments	50 - 75
2.	Food serving Establishments	Sanitary Sewage	5
	Restaurants etc.	Kitchen waste	5 - 7.5
3.	Institutional Hospitals day(only)	Boarding (Usual types)	75 - 125
		Offices, Shops, Stores	150 - 250
		Industry, Schools and commercial	15 - 25
4.	Hotels	Overnight guests	50 - 60
5.	Motels	Overnight guests	25

Table II.2

Sewage flow from various type units

Item	Kind and Description				Flow of sewage there from Gals/Day
A.	*Kitchen sink,	Domestic,	Usual,	Average	40 - 100
B.	Clothes washer	Domestic	Usual,	Average	300 - 600
C.	Dish washer	Domestic	Usual,	Average	200 - 400
a.	Water closet	Domestic	Usual,	Average	100 - 300
b.	Bath Tub	Domestic	Usual,	Average	100 - 200
c.	Shower Bath	Domestic	Usual,	Average	100 - 200
d.	Bath Tub withShower	Domestic	Usual,	Average	100 - 200
e.	Lavatory	Domestic	Usual,	Average	50 - 100
a,b,e´	Combination of Tub(or shower) waterclosel and				
1.	Lavatory or complete bath room				250 - 600
2.	Combination, commercial sink and Tray				300 - 900
2.	Sink commercial				200 - 300
3.	Urinal, wall lip or stall				100 - 300
4.	Water closet - Commercial Tank				200 - 700
5.	Lavatory, Commercial				100 - 300
6.	Water closet, valve operated				400 - 900

* Obviously the kitchen sink will use more water without a dish-washer than it will with a dish-washer, herein presume a dish washer in the instance of lower use of water.

Table II.3

Uses of Waste In Industries

	General Class	Typical Uses
1.	Gooling Water	Surface condensers Heat exchangers Jet condensers
2.	Processing	Water entering product Supplementary use in manufacture of the product such as washing etc.
3.	Boiler feed	Steam generation
4.	Air conditioning	Humidfication, cooling and washing
5.	Fire Protection	General Fire Protection Sprinkling systems
6.	Sanitary	Showers, washrooms and toilet facilities
7.	Miscellaneous Uses	Clean-up water Lawn Sprinkling Gardening etc.

Table II.4

Quantity of Water Required for Some Industry

Industry	Quantity Required
Pulp and Paper Mills	
Paper board	14000 gals/ton of paper board
Straw board	26000 gals/ton of straw board
Sulfate pulp	6000 gals/ton of dry pulp
Steel Plant	
Finished steel	65000 gals/ton of steel
Fabricated steel	42000 gals/ton of steel
Ingot steel	18000 gals/ton of steel
Hot rolled steel	11000 to 15000 gals/ton of steel
Cold rolled steel	6000 gals/ton of steel
Pig iron	4000 gals/ton of steel
Petroleum	
Oil, refined	77000 gals/100 bbl of crude oil
Oil, Fischer Tropsh Synthesis	50000 gals/100 bbl of crude oil
Gasoline, natural	20 gals/gal of gaboline
Coal Carbonization	3500 gals/ton of coal carbonised
Cement	750 gals/ton of cement
Tannary	16000 gals/ton of hides
Cotton Textile	
Bleaching	25 to 38 gals/ yard
Dying	1000 to 2000 gals/100 lbs of goods
Finishing	10 to 15 gals/yard
Processing	3800 gals/100 lbs of goods
Rayon	
Cupprammonium yarn	160000 gals/ton of yarn
Dissolving pulp	190000 gals/ton of pulp
Viscose rayon	2000000 gals/ton of goods

-:-

water comes from the following units:

(a) Waste water from milk receiving station - Here milk cans are unloaded and emptied into a receiving tank after testing for physical fitness for their freshness. Cans which are turned some are segregated. The wash water consists of milk drippings, rinses, and washings.

(b) Waste water from pasteurisation plant - The waste water from this section consists of the washings of equipments and floor washings, spills and leaks.

(c) Waste water from manufacture of butter - Butter milk and wash water from washings and small quantities of butter are the main waste waters from this section.

(d) Waste water from manufacture of chease. - Waste waters from this process comprise mainly of whey washings from vats, drains, and washing from floor and other equipments.

(e) Waste water from the Casein Plant - Usually soured or spoiled milk is used for the manufacture of Casein by precipitating with a mineral acid. The wastewater from this plant usually contains whey of milk, the mineral acids and washings.

(f) Waste water from Washing plant - Bottles, and canes are thoroughly washed in this plant using the detergents, or caustic or washing soda. Hence the pH of this water is high.

(g) Waste water from softening plant and boiler house.

The waste water, from the water softening plants and also boiler blow-down usually are small in volume. The boiler blowdown contains suspended solids of minerals in the waste depending on the process used. It would be mildly acidic if both cations and anions exchange resins are used or highly acidic or highly saline if only cation exchange is used.

(ii) Domestic Waste Water :

The waste water, originates from toilets provided in the factory. If facilities are there it is sent to city sewer or septic tank, otherwise it is treated with the factory waste waters.

2.2 Parameters of Characterization

Characterization is essential for an effective and economical waste management programme. It helps in the choice of treatment methods, deciding extent of treatment and assessing beneficial uses of waste water.

The characteristics of municipal waste water depends on a number of factors. The major local factors which contribute to variation in domestic waste water characteristics are (i) daily per capita water use (ii) quality of water supply (iii) the condition and extent of sewerage system. Municipal waste water, which contains both domestic and industrial wastes, may differ from one place to another, depending on the type of industries and number of industrial establishments contributing to the municipal sewage. However, where volume of industrial wastes is 10 to 20 percent of the total flow, not much variation in the characteristics may be expected.

Unlike municipal waste water, the characteristics of industrial waste water depends on the quality of water supply, types of industries , and many others. Characteristics variations are found from different units of a particular industry and at different hours of a day. Due to holiday the characteristics also vary from Sunday to week days.

The characteristics of a waste water depends on a number of parameters. The important parameters are discussed below:

2.2.1 Temperature

It is an important parameter and varies from summar to winter. It indicates the solubility of oxygen and hence, biological activities in the waste water. A warm temperature indicates an increased bacterial activity but a lower dissolved oxygen content. On the other hand the waste water, that is cold, the biological life is dormant, though dissolved oxygen is high. Normally the temperature of domestic and municipal waste water is few degrees higher than the temperature of water supply. The temperature of Industrial waste water depends on the type of industry and different units utilizing water. For example the temperature of waste water from a cooling unit is much more than that of water supply.

2.2.2 Hydrogen ion concentration (pH)

Hydrogen ion concentration is a valuable parameter in the operation of biological processes. Due to presence of ammonia and phospherus the pH of fresh domestic waste water is slightly higher than the water used. But the pH of industrial waste water varies from industry to industry, depending on manufacturing processes:

2.2.3 Solids

Domestic waste water contains 99.9 percent water. Industrial waste water contains water in similar quantities depending on type of industry. However, the balance extraneous matter cannot be overlooked. Some of these solids are highly putrescible and cause nuisance if it is disposed in uncontrolled manner. The solids in waste water may be divided into suspended and dissolved solids which may be further classified as volatile and inert. It is the volatile or organic fraction which is putrefactive. The organic fractions in a domestic waste water originates mainly from kitchen and body wastes. The estimation of suspended matter is important from the standpoint of sedimentation processes, grit channels and primary sedimentation in waste water treatment. Dissolved inorganic fraction becomes important if waste water is applied on land for irrigation.

2.2.4 Nitrogen

The various forms in which Nitrogen occurs in nature are organic or protein nitrogen, free ammonia, nitrites and niterates. The principal nitrogenous compounds in domestic waste water are proteins, amino-acids and urea. The nitrogen content [17] in a dairy farm waste water is much higher than those usually found in a municipal waste water, and it varies from industry to industry. In a fertilizer industry it is reported [18] that 2 percent of urea and 0.5 to 1 percent of ammonia produced are carried out in waste water. Ammonia nitrogen in waste water is obtained due to bacterial decomposition of these organic sources. Nitrogen is an essential component of biological protoplasm. Hence this determination is important in assessing suitability of wastes to undergo biological treatment and as irrigant.

2.2.5 Phosphorus

Phosphorous is contributed to domestic waste water from breakdown of food materials, particularly liquids. Builders in synthetic detergents also contribute substantial amounts of phosphorus. In dairy farm waste water phosphorus content is higher than the municipal waste water. In other industrial waste water, phosphorus is present in a varying degree depending on the type of industry. Just as nitrogen phosphorus is also an essential nutrient for biological processes.

2.2.6 Chlorides

Concentration chlorides in waste water above the normal chloride content of water supply is used an index of strength of waste. Human excretion contain chlorides equal to the chlorides consumed with food and water . This amount is average about 8 gm of chloride per person per day. With an average per capita waste flow of 180 litres per day, this would result chloride content of Municipal waste water to be 45 mg/l higher than that of water consumed. The chloride content in industrial waste water depends on the type of industry.

2.2.7 Bio-Chemical Oxygen Demand.

'BOD' is the amount of oxygen used for a particular time and water temperature, in degrading putrescible organic matter. It is a measure of the concentration of decomposible organic matter in a particular sample of waste water. The BOD concept involves not only the amount of organic material which is decomposable by bacteria, but also the time rate at which it will decompose aerobically.

The concentration of decomposable organic matter in waste water is not directly measurable and is of little importance except it controls the demand for oxygen. On the other hand, the associated dissolved oxygen demand is of major importance and this is measured by BOD test. Decomposable organic matter may be reduced in concentration by a number of different processes in a treatment plant or in waste water. Since amount of associated oxygen demand, rather than the amount of organic matter, is the parameter of interest.

2.2.8 Chemical Oxygen Demand (COD)

The COD test has been devised to overcome the objection to BOD test, such as the time required for the test and uncertainty regarding the reaction rate constant. The COD test the organic matter is related to the oxygen required for its chemical oxidation. The test does not differentiate between biologically oxidizable and non-oxidizable material.

2.2.9 Toxic Metals and Compounds

Some heavy metals and compounds such as chromium copper, cyanide cadmium which are toxic, may find their way in municipal waste water through industrial discharges. These are common in industrial waste water. For use of waste water as irrigation water, the determination of these toxic metals is important.

2.3 Characteristics of Municipal Waste Water

The parameters involved in the characteristics have been discussed earlier. In addition to these parameters, the characteristics of waste water also depends on the volume of wastewater, quality and quantity of water consumed by the population of the locality. The data for five cities are given in table II.5 along with average values as reported for U.S.A. Except the data for Ahmedabad, which are for a purely residential area, the values ~~in table are for a purely residential area, the value~~

In the table II.5 are for municipal sewages which contain varying amounts of industrial wastes. The concentration of nutrients, N, P, K and Alkyl Benzene sulphonate (ABS) in some municipal waste water are given in table II.5 [19].

The BOD and solids concentration indicate the municipal sewage to be more concentrated when compared to those from U.S.A. This attributed mainly to a lower per capita water use. The nitrogen and phosphorus concentrations are what would be expected to be contributed from the decomposable organic matter in the sewages. The concentration of ABS in the sewages is not to the level which would cause extensive foaming.

Per Capita Daily Contribution of Sewage Constituents

Consumption of water per capita, and quality of water supply influence characteristic of sewage. Daily per capita contribution of suspended solids and BOD are two most useful parameters. Table II.7 [19] gives these values with per capita sewage flow. Average values for U.S.A. have been included for comparison.

On the basis of data contained in Table II.7 it can be stated that increase per capita water use, there is an increase in the BOD contribution up to a flow above which daily BOD contribution remains constant. This increase is due to abundant use of water which would flush down all wastes into the sewerage system. If water consumption will be low, there would be chances of waste organic matter

Table II.5

Characteristics of Municipal Waste Water from some Indian Cities

Parameters	USA[‡] average	Nagpur[●]	Ahemadabad[●]	Kanpur[●●]	Madras[●]	Delhi[●]
Temperature ^{o}C	NR	30	30	27	NR	NR
pH	NR	7.0	NR	7.0	7.4	7.5
TSS mg/l	295	292	206	560	530	354
TDS mg/l	530	963	1481	1000	1170	803
Chlorides mg/l	NR	40	352	114	259	147
BOD mg/l	180	334	186	255	352	203
COD mg/l	NR	NR	NR	532	NR	377

NR stands Not reported.

‡ G.M.Fair and J.C. Geyer 'Water supply and waste water disposal' N.Y.1954

● Yearly average of weekly to fortnightly grab samples

●● Average of two one day composite samples collected in winter and summer

Table II.6

Nitrogen, Phosphorus, Potassium, and Alkyl Benzene Sulphonate (ABS) Concentration in mg/L in municipal sewages (Average one day composites collected in three different seasons during 1970-71 by NEERI Labs.)

Place	N	PO_4	K	ABS
Delhi	28.48	13.70	41.0	0.65
Calcutta	40.60	5.50	15.9	0.08
Madras	59.20	25.30	19.2	0.70
Bombay	47.70	12.20	-	-
Hyderabad	37.00	14.70	26.0	-
Kanpur	73.00	2.50	6.8	1.64
Nagpur	58.30	7.0	41.6	1.16

Table II.7

Daily Per Capita Contribution of Sewage Constituents

Place	BOD g/capita/day	Suspended solids g/capita/day	Flow L/day
Bombay	44.6	-	122
Bombay	31.6	-	147
Ahmadabad	26.8	70	340
Ahmadabad	63.0	64	580
Kanpur	70	198	490
Kanpur	58.0	35	81
Jaipur	35.0	90	300
U.S.A.	54.0		

not finding its way to sewer. In India, where sewage flow is generally taken to be between 150 and 200 litres/capita/day, the daily BOD contribution of 40 to 45 g/capita may be expected. It has been reported by Sehgal [20] rate of progressin of BOD (at 20 °C) was higher in summar as compared to winter, due to higher population of micro-organisms present during summer because of higher temperature. The characteristic of Kanpur city is given in table II.8

2.3.1 Biological Characteristics

Raw sewage contains a variety living organisms. These can be divided under two categories, the pathogenic and the non pathogenic. It is reasonable to expect causative organisms for almost all diseases of man in raw sewage. Table II.9 [19] gives this information for sewage at Nagpur along with concentration of some indicator bacteria.

2.4 Characteristics of Industrial Waste Water

The characteristics of industrial wastes vary extensively according to type of industry. The presence of toxic substances, beyond tolerable limits of plants, makes it unsuitable for irrigation water if the waste is not properly treated. The characteristics of some industrial waste waters are given for reference in tables II.9a [20] and II.10 [21].

Table II.8

Characteristics of Waste Water from Kanpur City
[All value except pH in mg/l

	Determination	Winter		Summer
		Sunday	Weed day	Week day
1.	Temperature °C	-	23 - 28	32 - 34
2.	pH	6.6	7.4	6.8
3.	Total solids	1270	1910	1210
4.	Total suspended solids	558	706	417
5.	Volatile suspended solids	330	430	295
6.	Volatile dissolved solids	570	630	610
7.	Ammonia Nitrogen	22.2	20.0	10.5
8.	Organic Nitrogen	35.2	28.0	28.0
9.	Total phosphate	18.8	22.5	12.1
10.	Chlorides	84	82	146
11.	Chemical Oxygen Demand (COD)	397	539	526
12.	Biochemical Oxygen Demand BOD at 5 day 20 °C	230	270	240
13.	Chromium	Nil	Nil	Nil
14.	Copper	0.5	3.0	4.0
15.	Cyanide	Nil	Nil	Nil
16.	Lead	0.5	1.0	0.9
17.	Zinc	1.0	0.4	0.0
18.	Sulfide	1.0	1.0	0.5
19.	Tanin	13	24	26

Table II.9

Concentration of some Pathogenic and Indicator Organisms in Nagpur Municipal Sewage.

Organism	Concentration	Remarks
Ancylostoma duodenale	80-100/L	Concentration of ourresult of 3 months survey
Hymenole pisnana	0-30/L	
Trichuris trichura	0-5/L	
Ascaris lumbricoids	150-200/L	
Enterobious vermicularis	0-30/L	
Entamoeba histolytica	5-400/L	
Salamonella	175/100 ml	Average 16 samples collected over 4 months
Virus Plaque forming units	10^2-10^3/100 ml	Result of 10 months survey
Coliform	10^7-10^8/100 ml	Result of 5 months survey
Faecal Streptococci	10^7-10^8/100 ml	

Table II.9a

The Characteristics of Zinc Smelten Effluent
Debari, Rajasthan.

	Characteristics		
1.	Odour	-	Slightly acidic
2.	Colour	-	Very slightly reddish
3.	pH	-	2.4
4.	Turbidity	-	Slightly Turbid
5.	Total Dissolved solids	-	4100
6.	Total Nitrogen	-	7.5
7.	Total Chlorides	-	97
8.	Total Sulphates (SO_4)	-	650
9.	Total phosphates (PO_4)	-	492
10.	Total Calcium	-	430
11.	Total Magnesium	-	265
12.	Iron	-	40
13.	Zinc	-	150
14.	Copper	-	4.2
15.	Fluoride	-	110
16.	Silica	-	29.0
17.	Chemical Oxygen Demand	-	270

Table II.10

Physico-Chemical Characteristics of Distillary Waste and the Mixed Pulp and Paper Factor Waste.

	Factors	Types of Wastes	
		Distillary	Mixed Pulp and Paper
1.	Appearance	Reddish brown	Brown
2.	pH	4.8 - 5.9	7.8 - 9.2
3.	Dissolved Oxygen	Nil	4.0 - 5.1
4.	Total solids	3950 - 5210	512 - 587
5.	Dissolved solids	16000-20105	814 - 910
6.	Sulphide as		
	(i) Sulphur	96 - 210	Nil
	(ii) H_2S	12 - 19	Nil
7.	BOD (5 days - $20^{o}C$)	7167 - 10235	210-900
8.	Nitrogen Ammonical nitrogen	3.2 - 3.8	Nil
9.	Aldehyde	Nil	Nil
10.	Ketones	Nil	Nil
11.	Free Chlorine	Nil	Nil
12.	COD	12900 - 14850	479 - 1220
13.	Legnin	-	17.9 - 21.4

From the above characteristics of three different types of industries, it is evident that the different parameters of different industries vary to a considerable extent. For example BOD of paper and pulp industry is 210-900 mg/l whereas that for distillary industry is 7167 to 10,235, and COD for zinc smelter effluent is 27 mg/l whereas that for distillary industry goes up to 14850 mg/l. In the zinc smelter effluent, the toxic materials zinc and copper and iron with concentrations 150, 4.2 and 40 mg/l respectively render the waste water unsuitable for use in irrigation without being properly treated.

Hence it is clear that the characteristics of different types of waste water vary considerably and treatment required for an industrial waste water may be different depending on its effluent characteristics.

2.5 Characteristics of Dairy Farm Wastes

The characteristics of wastes of diairy farm depends on the size of the farm. As the wastes are rich in degradable organic matter, exert high oxygen demand. Table II.11 and II.12 [16] give the characteristics of a small and large dairy farms respectively.

It appears that the ddiry wastes are primarily rich in organic matter as seen in their BOD and COD. The BOD values varies according to size of the dairy farm. A plant processing 10,000 litre milk per day, discharges wastes 5 L/L of milk, will add a BOD load equivalent to a human population of 1100. Volatile solids constitute about 70 - 90 percent of total solids, in a dairy waste, and suspended solids also a good portion of total solids. However these solids do not settle easily. Oil and grease are relatively high in this wastes, ranges from 1.33 to 1.70 which is very similar to domestic wastes. The smaller value indicates most of the organic matters are biodegradable. The nitrogen, phosphorus and potassium content is much higher than those usually found in municipal waste water. It is believed that the major source of the nitrogen is from milk spilled or lost during processing. The high phosphorus and potassium content probably comes from the cleaning compounds used in the plants. Many of these compounds are high in phospherus or potassium or both.

The similarity of COD/BOD ratio of dairy wastes with that of sewage suggests the possibility of treating it along with sewage or by method similar to sewage treatment method.

Table II.11

Characteristics of combined wastes from a small size Dairy Farm.

Volume of milk processed = 12,800 L/d

Wastes = 3.6 L/L of milk

All in mg/l except pH

1.	pH	-	8.1
2.	Total solids	-	2730
3.	Volatile solids	-	2205
4.	Suspended solids	-	1810
5.	Volatile suspended solids	-	1660
6.	Alkalanity as $CaCo_3$	-	220
7.	Volatile Acid as (CH_3COOH)	-	20
8.	Chemical Oxygen Demand	-	4510
9.	Biochemical Oxygen Demand	-	3070
10.	COD : BOD	-	1.47
11.	BOD rate constant (K/day)	-	0.19
12.	Total Nitrogen as (N)		1080
13.	Total Phospherus as P	-	110
14.	Sulfate (SO_4)	-	45
15.	Fats	-	1390

CHAPTER-III

WATER USED FOR AGRICULTURAL USE

3.1 Quality Criteria

The concentration and composition of dissolved constituents in a water determine its quality for use in agriculture. Quality of water is important consideration for salinity or alkalinity conditions in an irrigated area.

The characteristics [22] of an irrigation water, that appear to be most important in determining its quality are as follows:

(i) total concentration of soluble salts

(ii) relative proportion of sodium to other cations

(iii) concentration of boron or other elements that may be toxic

(iv) under some conditions, bicarbonate concentration as related to the concentration of calcium and magnesium.

3.1.1 Total Concentration of Soluble Salts

A large proportion of inorganic salts, is dissolved in water in ionic forms, which can conduct electric current. So the total concentration of soluble salts in irrigation waters can be adequately expressed in terms of electrical conductivity. The conductivity is useful, because it can be readily and precisely determined in micromhos per cm. Generally the soluble salts are expressed in ml/l

Table II.12

Characteristics of Waste from a Large Dairy

1.	Temperature	-	38 °C
2.	pH	-	10.1
3.	Colour	-	Milky white
4.	Alkalinity as $CaCo_3$ to pH 4.3	-	340
	pH 8.3	-	170
5.	Total solids	-	790
6.	Volatile solids	-	320
7.	Fixed solids	-	470
8.	Suspended solids	-	78
9.	Chlorides	-	35
10.	Biochemical Oxygen Demand	-	950

CHAPTER-III

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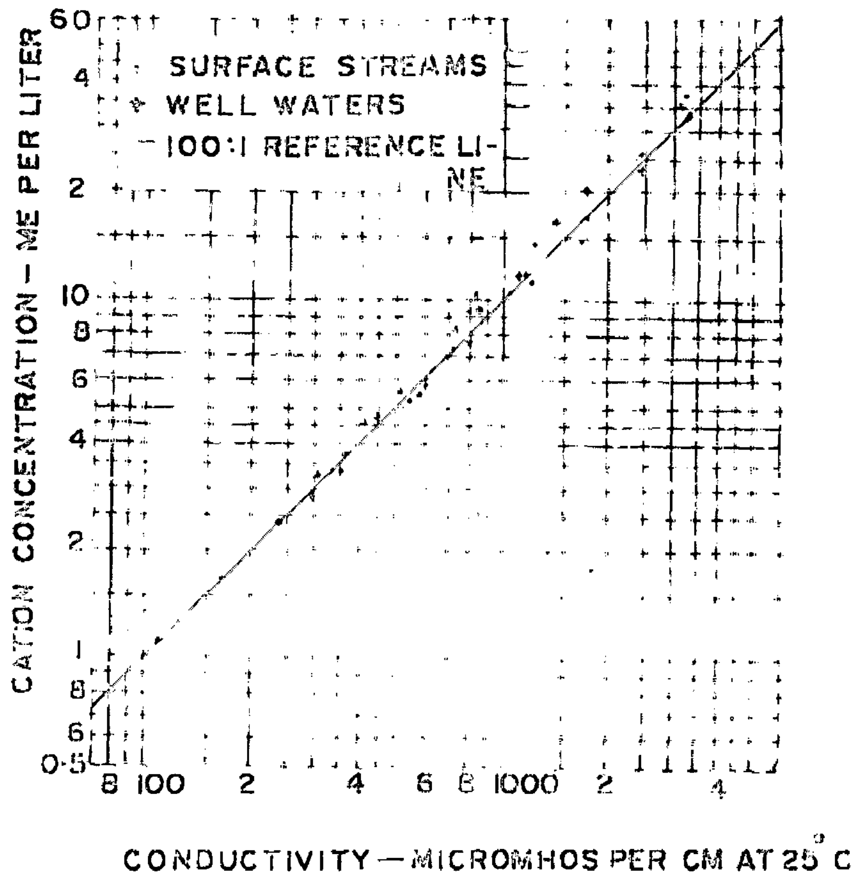
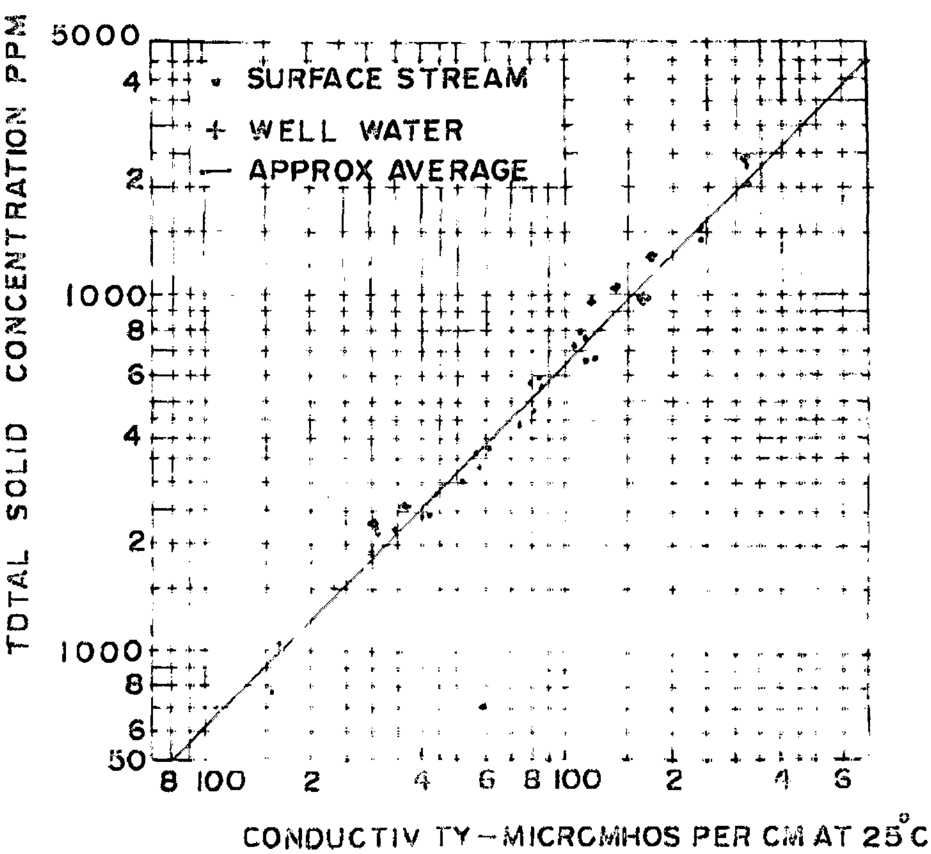


RELATION BETWEEN CATION CONCENTRATION AND ELECTRICAL CONDUCTIVITY

FIG.



RELATION BETWEEN TOTAL DISSOLVED SOLIDS AND ELECTRICA CONDUCTIVITY.

FIG.

(milli equivalent per litre). If C''_A be the concentration in ml/l of any soluble constituent, having molar concentration 'A', C'_A be the concentration in mg/l and M be the molecular weight, then

$$C''_A = C'_A \frac{Z_A}{M}$$ where Z_A is the valence of the substence A.

$$= Z_A[A] \times 10^3$$

The relations between total dissolved solids in ppm and electrical conductivity cation concentration and electrical conductivity at 25 °C are shown in Figures III.1 and III.2 prepared by U.S.Department of Agriculture.

According to Handbook No.60 of U.S.Department of Agriculture, nearly all irrigation waters that have been used successfully for a considerable time have conductivities of less than 2,250 micromhos per cm. Waters of high conductivity are used occasionally, but crop production, except in unusual situations has not been satisfactory. Saline soils are those in which the saturation extract is greater than 4,000 micro mhos per cm. In the absence of salt accumulation from ground water, the conductivity of the saturation extract of a soil is usually from 2 to 10 times the conductivity of applied irrigation water. This increase in salt concentration is the result of continual moisture extraction by plant roots and evaporation. Hence, the use of waters of moderate to high salt content may result in saline conditions, even where drainage is satisfactory.

In general, waters with conductivity values below 750 micromhos per cm are satisfactory for irrigation in so far as salt content is concerned, although salt-sensitive crops may be adversely affected by use of irrigation waters in the conductivity range of 250 to 750 micromhos per cm. Waters in range of 750 to 2250 micromhos per cm are widely used and satisfactory crop growth is obtained, under good management and favourable drainage condition, but saline condition will develop if leaching and drainage are inadequate. Use of waters with conductivity values above 2250 micromhos per cm is exception and very few instances can be cited where such waters have been used successfully. Only more salt tolerant crops can be grown with such waters when subsoil drainage is good.

3.1.2 Relative Proportion of Sodium to Other Cations

The soluble inorganic constituents of irrigation water react with soils as ions rather than in molecules. The principal cations are calcium, magnesium, and sodium. Also small quantities of potassium is ordinarily present. The principal anions are carbonates, bicarbonates, sulfate and chloride, with fluoride and nitrate occuring in low concentration. The concentration and relative proportion of these cations and anions determine to a large extent the character of water. Calcium plus magnesium in excess of sodium is characteristic of hard water and the converse, with sodium in excess, a soft water. A hard water will tend the soil open and permeable and in good tilth, while use of a soft water produces undesirable soil conditions such as poor tilth low permeability and alkaline. Hence if proportion of sodium is high, the alkali hazard is high and conversely, if calcium and magnesium predominate the hazard is low. Scofield and Headley [23] summarised the results in a series of alkali reclamation experiments with statement. 'Hard water makes soft land and soft water makes hard land'.

Because when sodium content of an irrigation water is high compared to calcium and Magnesium content, the sodium will be absorbed by the soil and will replace the calcium and magnesium which are there. As the exchangeable sodium increases in the soil, the soil becomes more alkaline and adverse physical and chemical conditions develop which prevent plant growth.

The sodium or alkali hazard of an irrigation water is conveniently measured by the SAR or sodium adsorption - ratio, where

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{++}] + [Mg^{++}]}{2}}}$$

in which concentrations are in milli equivalents per litre. Irrigation waters of low mineral content may be used with SAR values to about 26, whereas if the mineral content is high, the SAR values must be lower than about 10.

Potassium is usually present only in low concentrations. It is an essential plant nutrient, and is there-

-fore desirable. Its reaction to soil is similar to that of sodium, but usually less pronounced.

Among the anions, the carbonates and sulfate form sparingly suitable salts with calcium. These salts, lime stone and gypsum, are desirable soil constituents. The chlorides are soluble and characterise many saline water and soils. Nitrate seldom appears in natural water in more than traces. It is one of the major plant nutrients and is limiting in most of the arid region. Waste water effluents often contain substantial quantities of nitrates and therefore valuable for this reason.

3.1.3 Concentration of Boron or Other Elements that may be Toxic

Among all elements, Boron is important from view of quality of irrigation use. Boron in low concentration is a normal constituent of most natural waters and occasionally it occurs in such quantities as to be injurious to crop plant. It is essential to plant growth, but is exceedingly toxic when concentrations only slightly above optimum. Eaton (1944) [22] found many plants made normal growth in sand cultures with a trace of Boron (0.03 to 0.04 ppm) and that injury often occured in cultures containing 1 ppm. Generally boron, in concentrations less than 0.5 ppm is thought to be safe for use of any crop concentrations in excess of one ppm, boron will cause easily recognised injury to more sensitive plants, while more than 3 to 4 ppm is about the top limit for use of most tolerant crops.

Nitrite, sulfide, and ammonia are found in poorly aerated waters and in low concentrations, and are not particularly objectionable in irrigation water. Iron, aluminium and phosphate are ordinarily present in traces in the middle alkaline water. Water of high pH i.e. about pH 9 are usually unsuitable for irrigation.

3.1.4 Bicarbonate Concentration

In waters containing high concentration of bicarbonate ion, there is tendency for calcium plus magnesium to precipitate as carbonates as the soil solution becomes more concentrated. The reaction does not go for completion under ordinary circumstances, but so far as it does proceed, the concentration of calcium and magnesium are reduced and relative proportion of sodium is increased.

$$\% \text{ Na} = \frac{Na^{+} \times 100}{Ca^{++} + Mg^{++} + Na^{+}}$$

when ionic constituents are milliequivalents per litre.

Hence it is clear that deleferious effects of sodium in water are not only dependent on the amount of sodium applied, but also on the amount of other cations present.

3.2 Classification of Irrigation Water

Broadly the classification of irrigation water may be from following three points of view :

(i) Salinity hazard

(ii) Sodium hazard

(iii) Effect of Boron

3.2.1 Salinity hazard

Depending on the conductivity, water may be put to four different classes:

(i) Low Salinity water

(ii) Medium Salinity water

(iii) High Salinity water

(iv) Very high Salinity water

(i) Low salinity water (C1) - Irrigation waters having conductivities less than 250 micromhos per cm belong to this group. This can be used for irrigation with most crops on most soils with little likehood that soil salinity will develop. Some leaching is required, but this occurred under normal irrigation practices, except for the soils extremely low permeable.

(ii) Medium salinity water (C2) - From conductivities 250 to 750 micro mhos per cm, all the waters belong to this class. This can be used if a moderate amount of leaching occurs. Plants modrate salt tolerance can be grown in most cases, without special practices for salinity control.

(iii) High salinity water (C3) - All the waters having conductivities less than 2250 micro mhos per cm and more than 750 micro mhos per cm belong to this group. Ordinarily this water cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerant should be selected.

(iv) Very high salinity water (C4) - Waters having more than conductivities 2250 micromhos per cm belong to this class and is not suitable for irrigation under ordinary conditions, but may be used occasionally under special circumstances. The soil must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching and very salt tolerant crops shauld be selected.

3.2.2 Sodium Hazard

The establishment of water quality classes from sodium hazards is more complicated than for salinity hazard. The problem may be approached from the point of view of probable extent to which soil will adsorb sodium from water applied. Classification of irrigation water with respect to sodium adsorption ratio (SAR) is based on primarily on the effect of exchangeable sodium on physical condition of soil. Sodium sensitive plants may,however, suffer injury as a result of sodium accumulation in plant tissues when exchangeable sodium values are lower than thoses effective in causing deteriotion to physical condition of soil.

(i) Low sodium water (S1) - This can be used for irrigation in all most all soils with little danger of development

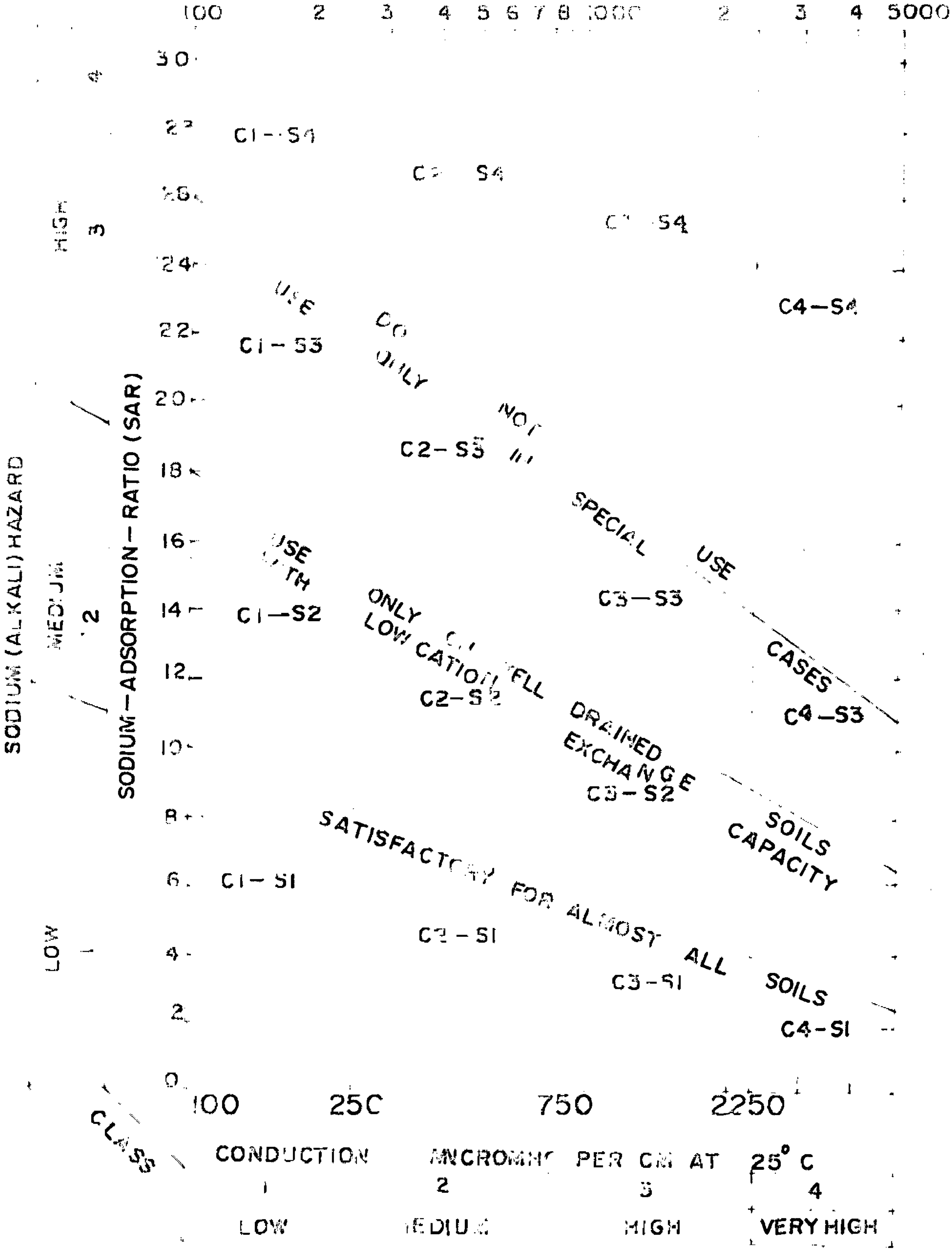


DIAGRAM FOR CLASSIFICATION OF IRRIGATION WATER of harmful level, of exchangeable sodium. However, sodium sensitive crops such as stone fruit, and avacodos may accumulate injurious concentrations of sodium.

(ii) Medium sodium water - It represents an appreciable sodium hazard in fine textured soils having high catione exchange capacity, especially under low leaching conditions, unless gypsum is present in the soil. This may be used on coarse grained organic soil with good permeability.

(iii) High sodium water (S3) - This may produce harmful levels of exchangeable sodium in most soils and will require special soil management like good drainage, high leaching, and organic matter conditions.

(iv) Very high sodium water (S4) - This is generally unsatisfactory for irrigation except low and perhaps medium salinity where solution of calcium from soils or use of gypsum or other ammendment may make the use of these waters feasible.

Figure III.3 is a diagram from Handbook No.60 for classification of irrigation waters based on the salinity and sodium adsorption ratio.

3.2.3 Effect of Boron

As discussed earlier, Boron is essential to normal growth of all plants, but quantity required is very small. A deficiency of boron produces striking symptoms in many plant species. Boron is very toxic to certain plants and concentration that will injure these sensitive plants is often approximately that required for normal growth of very tolerant plants. For instance, Lemons show definite injury when irrigated with water containing 1 ppm of boron, while Alfa-alfa will make maximum growth with 1 to 2 ppm of boron. Scofield [23] has classified irrigation water in five classes as excellent, good, permissible doubtful and unsuitable according to concentrations of boron for three types of plants, i.e. sensitive, semitolerant and tolerant.

3.3 Permissible Limits of Concentration

In appraising the quality of an irrigation water first consideration should be given to salinity and alkali hazards by ref. to Fig. given by U.S.Department of Agriculture. Also due considerations should be given to the independent characteristics, boron or other toxic elements, and bicarbonates, any one of which may change the rating. Even good irrigation water is used, there are many other factors for crop failures. Of great importance among these is permeability of soil. Saline condition will develop even with good irrigation water in a poorly drained soils and conversely fairly saline waters are used successfully on well drained soils. Other factors of importance are quantity of water used, method of irrigation, rainfall, climate, soil management practices, and crop species. In using the limits suggested below average conditions are assumed. Scofield has given the following table No.III.1

Table III.1

	Class of Water	Total concentration as Conductance at 25 °C $K \times 10^5$	Total concentration as Dissolved solid in ppm	% Na	Born in ppm, Crop group: Sensitive	Born in ppm, Crop group: Semi-tolerant	Born in ppm, Crop group: Tolerant
1.	Excellent, less-than	25	175	20	0.33	0.67	1.00
2.	Good	25-75	175-525	20-40	0.33-0.67	0.67-1.33	1.00-2.00
3.	Permissible	75-200	525-1400	40-60	0.67-1.00	1.33-2.00	2.00-3.00
4.	Doubtful	200-300	1400-2100	60-80	1.00-1.25	2.00-2.50	3.00-3.75
5.	Unsuitable	300	2100	80	1.25	2.50	3.75

Table III.1

Table III.2

Relative Tolerance of Crop Plants to Boron

Sensitive	Semitolerant	Tolerant
Lemon	Limabean	Carrot
Grape fruit	Sweet potato	Lettuce
Avocado	Bell pepper	Cabbage
Orange	Tomato	Turnip
Thornless black berry	Pumpkin	Onion
Apricot	Oat	Broad bean
Peach	Milo	Gladiolus
Cherry	Corn	Alfa-alfa
Persimmon	Wheat	Garden beet
Kadota fig	Barley	Mangel
Grape (Sultanina and Malaga)	Olive	Sugar beet
Apple	Ragged Robin rose	Palm (phoenix Canariensis)
Pear	Field pea	Date Palm
Plum	Radish	Aspa ragus
American elm	Sweet pea	Athel (Tamarix aphylla)
Navy beam	Pima cotton	
Jerusalem-artichoke	Acala cotton	
Pererian(English) Walnut	Potato	
Black Walnut	Sunflower (native)	
Pecan		

In each group the plants first named are considered as being more sensitive and the last named more tolerant.

in his report 'Salinity on Irrigation' for the different types of water required for agricultural purposes. Table No. III.2 gives some of the plants according to their tolerance to boron.

3.4 Tolerance limits for Irrigation Prescribed by Indian Standards Institute.

Indian Standards Institute [24] has framed the standards for the quality of water suitable for irrigation which is given in table No.III.3. These standards may not be taken as the specification for the water suitable for irrigation, but are guide to different authorities.

The methods of test, to find out the tolerance limits have been given in IS 3025-1964 [25].

3.5 Methods of Application

There are different methods by which agricultural crops are being irrigated. These methods are used according to characteristics of soil and irrigation water, quantity of water available, and types of crops etc. The principal methods are as follows:

(i) Spray Irrigation

(ii) Broad Surface Irrigation

(iii) Ridge and Furrow Irrigation

(iv) Flood Irrigation.

(v) Sub Surface Irrigation.

Table III.3

Tolerance Limits for Inland Surface Water for Irrigation as IS-2296-1974.

	Characteristics	Tolerance Limit
(i)	pH	5.5 to 9.0
(ii)	Electrical conductance at 25 °C Maxm.	3000×10^{-6} mhos/cm
(iii)	Total dissolved solids (inorganic), mg/l Max.	2100
(iv)	Sulfates (as SO_4) mg/l(maxm.)	1000
(v)	Chlorides (as Cl) mg/l(maxm.)	600
(vi)	Boron (as B) mg/l,(maxm.)	2.0
(vii)	Percent sodium (Max.)	600
(viii)	Alpha emitters MC/ml (max.)	10^{-9}
(ix)	Beta emitters MC/ml (max.)	10^{-8}

Note- In agricultural practice, it is usual to express concentration of ions in terms of milli-equivalents per litre (meq/l) instead of milligrams per litre. T

The following conversion factor shall be used to convert values from one system to another.

Sulphates (as SO_4) : 1 meq/l = 48.03 mg/l

Chlorides (as Cl) : 1 meq/l = 35.46 mg/l

Boron (as B) : 1 meq/l = 3.61 mg/l

3.5.1 Spray Irrigation

The most successful method of using reclaimed waste water for irrigation is spray system, because the effluent is distributed uniformly over the land to be irrigated. Wind sometimes disturbs the uniformity of coverage, however for evenly distribution of irrigation water, this method may be treated as one of the best methods.

In this method large revolving spray nozzles, attached to movable pipelines, distributes water over the land to be irrigated. By this technique, crops are wetted as by rain; frequent application of small quantities of reclaimed water is used, rather than frequent heavy flooding. There are no chance of percolation losses, as the distributing system is comprised of underground piping.

The cover crop on the disposal area is very important part of spray irrigation system. Skulte [26] has found that the best absorption of effluent and the least runoff, is obtained from well established pastures or from fields covered with dense grasses and clover. However the choice of crop depends on geographical location, type of soil, and characteristics of waste water.

3.5.2 Broad Surface Irrigation

For broad surface or trench irrigation, the main carriers usually are concrete lined ditches. The minor distributing systems require carefully laid out earth channels, with concrete lining only where soil is especially permeable. It is desired to distribute the effluent uniformly over the land being irrigated. If slopes are adequate (2 percent), the effluent is flowed over the land from the ridge distributors in the form of ditches or pipes having side outlets. Where slopes are flat, the effluent is carried from the distributries in furrows. Cross ditches are provided to collect it.

In order to avoid pools of effluents, and consequent irregular growth of plants, the grading of land surface and furrowing should be carried out accurately.

3.5.3 Ridge and Furrow System

A ridge and furrow system is generally used for vegetable crops. As name implies, the system involves a series of parallel ridges and furrows.

Ridges are generally 0.90 to 1.22m apart and 20 to 25 cm high, with furrows 25 cm to 30 cm wide and nearly 30 to 40 metres length. If nature of soil requires, an under drain is laid under the centre of each ridge. Effluent is applied along the furrows and seeps laterally through the ground.

In this method effluent does not come in contact with crops.

3.5.4 Flood Irrigation

Flood irrigation consists of level fields surrounded by banks or low dykes. The area is alternatively flooded with the effluent and is rested. This method assures reaeration of the soil. Under drains are used to carry off the effluent and to prevent groundwater from rising above a certain level. This method at times combine with ridge and furrow irrigation the area is broken up into series of beds lying between furrows of approximately equal surface.

3.5.5. Sub Surface Irrigation

Sub surface Irrigation involves distribution of waste water effluent by open joint tile pipe, laid below the soil surface. A new type of pipe has been developed for the purpose by Stein [26] which serves both irrigation and drainage.

CHAPTER-IV

WASTE WATER AS IRRIGATION WATER

4.1 Fertilizer Value of Waste Water

The elements, essential to plant growth, those may be added in form of fertilizer, are nitrogen, phosphorous and potassium. Nitrogen promotes the growth of foliage and stem, phosphoric acid stimulates root growth, hastens ripening and increases the resistance against diseases, potassium encourages vigorous growth, develops the woody part of the stem and the pulp of the fruit and is needed for the formation of chlorophyl. There are also many many other elements, needed in small amounts for a wide varities of plants and crops, are usually found in sufficient quantities in average soil. They [27] include calcium, magnesium, sulfer, iron, manganese, zinc, boron, aluminium, arsenic, cobalt, chromium and lead. However, nitrogen, phosphorus and potassium are heavily drawn up, as the plants grow, for which soil which is constantly cropped, is depleted rapidly in absence of careful soil culture and conditioning. The elements hydrogen, oxygen, and carbon, essential to plant growth, are secured from air and water, are not subjected to depletion and need not be added to soil in fertilizer form. Waste waters contain these valuable plant foods in solution which may render more valuable for crops than other irrigation supplies. It has [28] been estimated that a million gallons of average domestic waste water from plain subsidence may add as much fertility to soil as two tons of ordinary barn manure, provided the water is used widely. It has been computed [29] that 300 million gallons of sewage will yield approximately 42 tons of nitrogen, 8 tons of phospheric acid and 25 tons of potassium. The cost of chemical fertilizers to deliver the same manurial benefits is calculated to be somewhat more than Rs.100,000 in 1965.

For evaluating agricultural values a series of analysis was conducted by Dye covering major chemical considerations in application of municipal waste water to soil and plants. Table IV.1 indicates the results, including agricultural evaluations of various constituents.

4.2 Pathogenic Criteria of Waste Water

Rudolfs [30], Falk, and Ragotzkie of Department of Sanitation, College of Agriculture, Rutgers University U.S.A. have extensively investigated the public health aspects of vegetable grown in microbially contaminated soil They showed that bacteria, protozoa, and helminths, present in waste water, do not penetrate healthy unbroken surfaces of vegetables and they concluded that vegetables to be eaten raw can be grown without health hazard in soils that have been irrigated with sewage effluent in years prior to the season in which the vegetables are grown. Rudolphs, et al.[30] also concluded that application of waste water by surface flooding or overhead spray should be stopped one month before harvest to ensure safety from bacterial disease transmission. Dunlop [31] and Wang have recovered bacteria of the genus Sal monella from a large number of samples of irrigation-water — sewage plant effluent mixtures.

The number of coliforms to be found in waste water are enormous. Chambers [31] noted that, 'while various physical and biological waste treatment processes remove significant numbers of bacteria from waste water, this still leaves many to be killed'.

Water borne diseases like cholera, typhoid, and dysentery caused by the pathogenic organisms like cholera vibro, shigella, Entamoeba, and diseases caused by helmiths, such as Ascaris, Anacylostonia, etc may be caused by contamination of the farm produced by using waste water in irrigation. The viruses of infective hepatites and poliomelytis may be found in facal discharges. If this polluted waste water is put on land without any pretreatment, vegetables grown on land and eaten raw are likely to be contaminated and may spread diseases. Also farmers working on these farms and cattle grazing on these land are exposed to danger.

In Europe [32] and other parts of the world out side U.S.A. more recent epidemics of typhoid and parasitic worm infections (particularly Ascaris) have been reported as caused by application of human wastes to food crops.

Table IV.1

Two-Year Results of Tueson Sewage Effluent Analysis Including Agricultural Evaluations.

Constituents	Amount in ppm	Agricultural Value
Total solids	800 - 1200	Good
Suspended solids	10 - 40	-
Total N	16 - 20	Good
Total P_2O_5	15 - 30	Good
Mg	10 - 16	Good
Total Fe	4 - 8	-
Cl	60 - 90	Good
pH	7.3 - 7.5	Satisfactory
Alkalinity	180 - 280	Insignificamt
SO_4	120 - 180	Good
HCO_3	220 - 342	-
CO_3	0	Good
Hardness	175 - 250	Medium
Ca+Mg	55 - 70	-
Ca+Mg	30 - 35[a]	Poor to fair
Na+K	90 - 160	Satisfactory to doubtful
Na	45 - 55[a]	Satisfactory to doubtful
Na/Ca	2.5[b]	Satisfactory

a - Percentage of bases

b - Ratio.

Table IV.2

Disease Condition of Sewage Farm Workers

Diseases observed at time of study	Test Group	Control Group
Gastro-intenstinal	45.6	13.0
Respiratory	19.6	4.3
Anamia	50.3	23.6
Skin condition	22.3	4.0

Table - Results of Stool Examination of Sewage Farm Workers For Worm Infection etc.

	Test Group Nos.	Test Group %	Control Group* Nos.	Control Group* %
Total Examined in 5 sewage farms	1178		3429	
Total Positive	937	79.5	978	29

* Farm workers in similar areas, but where sewage is not used as an irrigant.

In India, a survey on the status of sewage farm workers had been done by central Public Health Engineering Research Institute and the results have been shown in table IV-2 .

4.3 Plant Responses to waste water

A variety of crops ranging from orchards and vineyards to forage grains and raw crops have been irrigated with waste water in several countries through out the world. As need for disposal areas increases and water supply is more fully used, the acreage irrigated with waste water may increase. A great deal has been written about successfully growing crops using waste water for its fertilization value. But in addition to it, there will be problems for its management and toxicity to crops, irrigated.

A farmer using waste water as the sole source of irrigation water loses control over the timing of fertilizer applications. The nutrients are applied with each irrigation instead of a few specific fertilizer additions, as would be normally practiced. Leaching will remove some of the excess nitrates, but the effluent leaching water normally adds more nitrogen than it removes. The end result is high soil and correspondingly high plant nitrogen level. The known hazards that may rise out of using sole source of irrigation with waste water have been discussed by Dwight C Bair [33] and Milton B. Fryer. They may be as followings.

4.3.1 <u>Decreased Yield</u>

In some cases marketable produce can be reduced if excessive levels of nitrogen from whatever source are applied to crop., especially if crop is perenial. The total tons of yield may not necessarily decrease, but the effective date of maturation may be delayed, and the fruit size may be decreased or quality may be otherwise affected.

For example, the overall maximum marketable yields of Dixon Cling peaches occurs when trees are fertilized ~~in the~~ with 0.34 kg to 0.68 kg of nitrogen per tree. Higher rates as well as lower rates, result in reduced yield . These reduced yields are directed result of smaller fruit sizes. It has been observed that if each acrefoot of waste water containing 50 lbs (23 kg) of nitrogen is applied in an orchard where trees have been placed at 20 ft (6M)apart, the gross application of nitrogen would be 0.5 lb per tree per acreft of irrigation water. Most of the crops require more than three acreft of irrigation water. Hence due to application of sufficient nitrogen, yield is decreased.

Grapes are variety dependent in their response to nitrogen fertilization. The response is 20 fold difference in fruit set between Malbec, one of the most sensitive, and Pinot Noir, one of the least affected. In addition, irrigation with low concentrations of nitrogen in the water could be a problem on grapes because grapes accumulate toxic levels of nitrates in their tissue of there is a drainage problem.

Sugar beets and potatos are adversely affected by excess nitrogen, which generally means more than 224 kg per hactare. The over fertilized beets are bigger but the percentage of sugar content decreases. Potatoes that are overfertilized with nitrogen have fewer and smaller tubers with a lower starch content. In both crops it is the excess vegetable growth that causes the decreased yield.

4.3.2 Decreased Crop Quality

Due to excessive rates of nitrogen many crop quality is decreased. It has been observed that both Navel and Valencia oranges, when grown in certain soils and fertilized during the summer with more than 168 kg of nitrogen per hactare produce grainy pulpy oranges with less juice than normal. Over fertilized valencias also regreen when ripe, an esthetic displeasure, making the fruit unsuitable for fresh fruit markets. Any fertilization of valencia oranges in the summer can reduce the quality. The use of wastewater all year-round could be damaging to the fruit quality by supplying nitrogen in the summer season.

Apples have colour development problems associated with overfertilization. The red varieties, like delicious, donot develop a full red colour when more nitrogen is applied. The problem is more acute if trees are fertilized after June.

4.3.3 Production Complications

Production complications arise due to excessive vegetative growth that occurs from over fertilization. For example excess growth due to more than 224 kg per hectare shades the fruits of melons and squash, keeping the moisture content high around the fruit. Such high moisture causes fruit rot.

Tomatoes are affected by excessive growth from over fertilization and over watering. The vines produce more fruits of smaller sizes in some varities.

4.3.4 Toxicity to plant consumer

Many of the compounds that plants take up from soil solution are more toxic to the plant consumer than to plant itself. Nitrate (NO_3) is one of these compounds. Many plants take up nitrate in excess of the plants' needs Weeds are the examples of these plants.

4.3.5 Toxicity to Plants

In addition to nitrate, waste water contains many other constituents in toxic concentrations. Approximately 300 mg/l of total dissolved solids are added to water by one municipal use. The use of these saltier waters on salt sensitive plants like citrus can cause decreased yields or even death. The salt problems can be aggravated by salt accumulation resulting from poor drainage.

Content of Boron is one of the major elements that harms plants. Waste water commonly contains 0.60 mg/l, boron. Concentration greater than 0.5 mg/l boron in the irrigation water can cause injury to citrus. Table No. III-2 gives tolerants to boron of some of the plants. Boron is not readily leached in some soils, so it builds up toxic level if applied overtime with irrigation water.

Chloride ion, commonly comprises one third of total dissolved salts in municipal waste water. It is also present in varying quantities in other types of waste water. This can reduce the growth of many plants even one third. Chloride in excess of 1 percent of the dry weight of apricot or peach leaves causes marginal leaf necrosis. Sodium often is associated with chloride in waste waters and it causes leaf tip burn, when its concentration range becomes 0.2 percent to 0.7 percent of dry weight of Plum leaves. Excluding this the adverse effect of development of salinity in the soil has been described earlier.

Bicarbonate ion in the waste water may aggravate effect of sodium in soil, especially if the ionic concentration of bicarbonate in the soil solution is greater than that of calcium and magnesium. The bicarbonate ion also plays an important role in the regulation of soil pH, which is important for rootgrowth. It can induce iron chlorosis, a serious plant nutrition problem if the soil pH becomes high - above pH 8.0. Phosphate, like nitrogen is essential for plant growth and available in waste water in plenty. But as most of the phosphates from waste water are adsorbed on clays as water percolates through the soil. So generally phosphate may not be considered as dangerous to crops. Excessive application of soil phosphate however, may cause deficiencies of copper and zinc, which are important micro-nutrients.

4.3.6 Heavy Metals

The heavy metals like, arsenic, lead, copper etc. are harmful to plants. The solubility of these heavy metals varies with pH. Some plants, like clovers, and grasses, will take up heavy metals as molybdenum, and may be concentrated enough in the plant to be toxic to the animal that eats the plant, even though the plant may be healthy. If these heavy metals have reached to toxic level in soil solution, they are difficult to remove. Many heavy metals are not removed by leaching, because of their affinity to soil.

4.3.7 Damages from Heavy Metals

Lead, a heavy metal, present in the waste water is not generally toxic to plant, but quite toxic to plant consumer. Lead applied to forage foliage having concentration 50 ppm to 100 ppm is toxic to horses. Soluble lead can cause fatal brain damage to animals with gastric traits with acid stomachs such as man, horses.

Copper is quite toxic to crops. Copper accumulates in the soil and becomes toxic to trees when the irrigation water has got concentration of over 50 mg/l. The toxic effect of copper is usually leaf burn.

These are some of the major plant responses to waste water. In many cases, dilution of waste water is necessary to prevent fertilization of crops when it is not desired.

4.4. Problems with Waste Water Irrigation

Apart from these some other problems also arise due to waste water irrigation. Waste water undergoes decomposition in the soil and offensive grass like hydrogen sulphide, methane are liberated. These cause bad odour around the farm. Excessive application also results in breeding of flies and mosquitoes odour nuisance and multiplication of intenstine parasite.

The presence of higher suspended solids in waste water may give rise to soil sickness. Excluding this there is every possibility of sludge deposit in the drains for which crop will fail.

4.5 Tolerance Limits for Industrial Effluent Discharged on Land for Irrigation

The industrial effluents vary a lot according to type of industry. In almost all the effluents contain toxic elements which are harmful to plants and plant consumers. Indian Standards Institution has given following table [34] showing maximum limits of the constituents of waste water to be discharged on land for irrigation.

Table IV.3

(i)	pH	5.5 to 9.0
(ii)	TDS (inorganic), mg/l Max.	2100
(iii)	Sulphate (SO_4), mg/l Max.	1000
(iv)	Chlorides as Cl, mg/l Max.	600
(v)	Percent Sodium, Max.	60
(vi)	Biochemical Oxygen Demand (5 day at 20 ^{o}C), mg/l Max.	500
(vii)	Oils and grease	30
(viii)	Boron (as B), mg/l Max.	2

Ref. ISI - 3307 — 1965

4.6 Treatment Required to Waste Water

It is quite clear from above discussions that, fresh waste water should not be encouraged for irrigation in view of its various adverse effects. From the stand point of health, safety, and quality, the guidelines enumerated by Krishnaswami [31] in 1971 may indeed serve as models - not only does he propose guidelines, but also goes so far as to propose standards. A portion of the total guidelines, and standard sections are reproduced here.

1.0 Irrigation with raw waste water.

1.1 Raw waste waters should not be used for irrigation of any type, any where.

2.0 Irrigation with renovated waste water.

2.1 Waste waters to be reused for irrigation should be treated by physiochemical and/or biological processes and always disinfected effectively to produce a quality designated by the control agency.

2.2 The renovated waste water should not exceed total coliform density MPN 100 per 100 ml.

2.3 The renovated waste water should not fecal coliform density of 20 organisms (MPN) per 100 ml at any time.

2.4 The demonstration of the presence of any pathogenic organisms in more than one consecutive sample of renovated waste water should be cause for rejection of the effluent unless it is redisinfected to point where absence of pathogens can be demonstrated.

2.5 Periodic assays for enteroviruses should be renovated waste water.

2.6 The chemical characteristic with respect to concentration of chemicals toxic to man and animals should conform to maximum limit established for drinking water.supply sources and farm stead water supplies respectively.

2.7 The chemical characteristics with respect to effects should conform to requirements established by agricultural control agency.

Hence it is essential to examine the characteristics of waste waters and treat it accordingly so that it can be useful forirrigation water. Now a question may be raised as whether a complete treatment is necessary to have above qualities as insurance against health hazards or not. It appears that there are two alternatives that may be adopted in agriculture with reclaimed waste water as irrigation water.

(i) Waste water could be subjected to secondary treatment and thorough disinfection and sometimes teriary treatment to remove excess toxic materials that may be harmful to plants and the reclaimed waste water may be used for irrigation of unrestricted agricultural crops.

(ii) Or The waste water may be given minimum treatment possible and the reclaimed waste water may be utilized for irrigation of restricted crops only from the economical point of view.

4.6.1 Unrestricted Irrigation

Due to agricultural considerations, there are certain difficulties for use of irrigation in restricted crops only. In restricted irrigation any desired vegetables and other agricultural crops cannot be cultivated according to one's will and pleasure. Rotation of crops is not possible if too heavy restrictions are imposed. Hence unrestricted irrigation is the solution of these problems. For unrestricted irrigation there is no doubt to reclaim waste water by means of high degree of treatment and disinfection for insurance against health hazards and to overcome toxicity problems. Specially it is a great problem to industrial waste water where many toxic materials having concentrations more than tolerance limits of certain plants may be found. It is technologically feasible to reclaim to required standards by adopting various treatment processes. If such treatment is provided, there is limited health risks from unrestricted irrigation with reclaimed waste water as the effluent approaches the bacteriological quality characteristics of drinking water.

It is needless to emphasize that the unrestricted irrigation with reclaimed waste water is a better practice provided economical condition is favourable. It is not possible on part of many countries including India to have unrestricted irrigation after extensive waste treatment and disinfection. Hence second alternative may be thought of.

4.6.2 Restricted Irrigation

The restricted irrigation with reclaimed waste water, nature of crops, and irrigation practices etc. The most important factor that needs serious consideration in the planning of utilization of treated or partially treated waste water for irrigation is the degree of contamination of that water with pathogenic organisms.

The characteristics of the reclaimed waste water depend on the raw waste water of the locality and treatment processes adopted for the reclamation. As waste water is treated through different processes of primary and secondary treatment plant, its characteristic changes.(36)

4.6.3 B.O.D. removal by settling

The fraction of B.O.D. removed [35] upon the settling of municipal waste water or industrial waste water is comparatively in-significant to settleable solids. The proportion of this fraction to B.O.D. of waste water is affected not only by settleability of suspended organic matter, but also by relative amount of organic matter in the solution. Hence removal of B.O.D. by primary sedimentation varies over a wider range than does removal of suspended matter.

The fertilizer value of waste water also changes which may be as follows. The table has been given by Reinhold [36] for average sewage effluent in Berlin.

Table IV.4

All values in mg/litre

Sewage	Total Nitrogen	Total Potash as K_2O	Total Phosphorus as P_2O_5
1. Raw untreated	66.2	42.1	22.6
2. Primary treated	73.3	43.2	23.5
3. Secondary treated	17.2	37.0	17.6
4. Drainage water from Farm field	12.7	20.0	8.4

For smaller localities, sometimes septic tank and oxidation tanks are provided for the treatment of waste water. The characteristic of such a reclaimed waste water from septic tank which has been followed by an oxidation pond has been studied by Viraraghavan et al.[37] at T.B. sanaterium at Tamberam, Madras and found it is very suitable in removal of pathogins.

Santee Project, in San Diego County, California utilizes a modified activated sludge process followed by retention in oxidation ponds and chlorination prior to percolation. Then the water flows in a limited underground path prior to dilution with natural ground water and emerges into a set of artificial recreational lakes.

The use of oxidation pond-effluent for irrigation is suitable and there is no important difference between irrigation in with oxidation pond effluent and conventional irrigation.

In many places throughout the world primary effluent is used for irrigation. An example of the U.S. experience is that of the Talbert Water District in Orange County, Calif. Due to lack of fresh water resources and contamination in the ground water aquifer from salt water intrusion, the Talbert-water District began supplying the primary treated effluent in the amount of approximately 250 hametre per year to local farmers for irrigation of alfa-alfa and sugar beets, and for pre-irrigation of tomatoes, chili, peppers, and lima beans. The project was discontinued in 1964 because of odour and other problems.

It is obvious that primary treatment effluents will have some odour problems due to incomplete oxidation. Before coming to conclusion about the extent of treatment reqd. suitability of waste water for agricultural crops may be studied.

4.7 Suitability of Waste Water

The suitability of waste water after partial treatment is to be considered in order to use the same for irrigation. In Chapter III, the quality criteria of irrigation water have been discussed. The table IV.5 shows the essential features of some analysis of municipal waste water. It is not possible to make a close comparison between the composition of input water and waste water effluent. In most cases the municipal waste water is variable in composition. It is evident, however, that the effluents are more concentrated than the input waters by atleast twofold. It is also apparent that the concentration of boron, bicarbonates and sodium in many effluents are disproportionately high. Boron contamination in all effluents are found except Pasadena and San Bernardino plants. These latter two may be classified as good to permissible, according to limits discussed in Chapter III. The facts that relatively high concentrations of boron are found in other seven sets of samples, would render them questionable for irrigation use, such waters may possibly be used if diluted with sufficient quantity of good water.

Among the contaminants boron is very common and harmful to plants. In municipal waste water boron comes from laundry wastes and sometimes from solution containing borax which is used for washing citrus fruits in the packing houses. When these waste solutions are emptied to municipal sewer, the municipal waste water contains boron to larger extent. It is a better method to provide separate disposal system of these solutions.to make the reclaimed waste water suitable for irrigation.

The inorganic salts, those are toxic to plants are aluminium, lead arsenate, chromium in some forms, cobalt, copper, manganese, mercury, thalium and zinc. Very often industrial waste waters according to type of industry contain these salts to a varying degree. Great care should be given in selection of plants and treatment processes when reclaimed waste water of these industries will be used for irrigation. Perhaps these reclaimed waste water can often be used if diluted sufficiently with good water.

Table IV.5

Analysis of Effluents from Sewage Treatment Plants in Southern California.

Description	Method of treatment and disposal	Conductance $Kx10^5$ at 25 °C.	Baron in ppm	%Na
1. Los Angels County Sanitation District Sewage Treatment Plant, Harbor city discharge 15-20cfs.	Imhofftanks followed by treatment by activated sludge process, effluent chlorinated and discharged to Nigger Slough	133	0.46	61
		186	0.76	70
		203	1.03	79
2. City of Whittier Sewage treatment Plant, disch 1.6cfs	Imhofftanks, sprinkling filters and secondary tank, effluent used for irrigation on sewerfarms, Sulphur discharged into creeks.	72.3	0.29	40
		88.9	0.33	52
		96.8	1.49	49
3. Pasadena Sewage treatment plant, discharge 12-14cfs.	Fine Screening followed by treatment by activated sludge process. Effluent chlorinated and discharged to Riottondo.	70.3	0.45	59
		77.3	0.35	55
		82.2	0.50	65
4. City Pomona Sewage treatment plant. Disch 1.5 cfs. approximately.	Imhofftanks followed by treatment by activated sludge process, effluent is chlorinated and used for irrigation.	66.7	0.28	48
		70.3	2.84	52
		83.4	1.25	64
5. Orange country cities joint outfall sewers system, disch. 7 cfs	Prechlorination and fine screening Effluent disch. to ocean	261	1.88	76
		395	3.52	83
		570	5.74	85

contd..

6. City of Corona Sew Treatment Plant, discharge approx. 0.8 cfs.	Imhofftank, Sprinkling filters sand beds. Effluent discharged into gravel beds in Temescal Creek wash.	102 128	0.80 1.31	29 70
7. City of Riveside Sew. Disposal Fa?, disch. approx. 3.6 cfs.	Settling in earthen basins and land disposal. Used for for irm.of sew. farms and surplus disposed on land.	88.2	2.80	31
8. City of SanBernardio Sewage treatment Plant; discharge 4.7 - 6.3 cfs.	Prechlorination Imhofftanks, Sprinkling filler and final clarifier Effluent chlorinated Discharged into Warm Creek and diverted by Riverside Water Co. Canal.	64.3 72.8 85.6	0.16 0.21 0.15	48 43 56
9. City of Redlands Sewage disposal plant, discharge approx. 1.2 cfs.	Imhofftanks, followed by disposal on sand beds on northside of Santa Ana River Wash.	91.5 99.7	10.64 4.76	67 66

'Agricultural Uses of Reclaimed Sewage ' by W.V. Wilcox. Vol.20, No.1. Sew. Wks Jr. 1948.

CHAPTER V

TREATMENT OF WASTEWATER

The primary objectives in the treatment of wastewater for its use for agricultural purposes are as follows :

1. To eliminate the infections organisms harmful to human health by destroying them.
ii. To prevent the development of nuisance and soilsickness in the agricultural land by transferming putrescible organic materials into stable compounds and microbial c
iii. To make it suitable so that agricultural productions may not be decreased due to application of excess fertilizers or toxic materials above tolerante limits of plants.

5.1 Conventional Treatment

Both primary and secondary treatments belong to conventional treatment of wastewater. Primary treatment includes preliminary treatment i.e. screening and grit removals sedimentation to remove a portion of suspended solids and BOD, and sludge disposal (38).

Secondary treatment includes biological oxidation utilizing either trickling filters or activated sludge units with final sedimentation for separation of biological floc.

5.1.1 Preliminary Treatment.

One of the primary objectives in all systems of treatment is to lower the organic content of wastewater, i.e. lower its BOD Various devices have been tried to accomplish the necessary reduction in organic content. In the preliminary treatment, removal of insoluble materials may be accomplished by passing wastewater through screens of various mesh grit removal using grit chambers or detritus tanks, and by skimming of floating materials in baffled tanks.

In India (39) with hot climatic conditions the greasy and oily materials do not congeal easily and are difficult to skimmed out. Their amounts are also small in municipal waste water, for which skimming tanks are not provided. But they are useful for industrial towns due to industrial waste disposal in municipal sewer and at hill stations like , Simla, Nainital, Mussorie etc where the oily materials congeal well.

5.1.2 Sedimentation

Suspended solids too fine to be removed by screens and too heavy to be removed by flatation, are taken out of waste water by allowing it to remain quiscent in large holding tanks. This operation is called "sedimentation" when the impurities are separated from the suspending fluids by action of natural forces alone, i.e., by gravitation and natural aggregation of settling particles, the operation is called 'plain sedimentation when chemical or other substances are added to induce or hasten aggregation and settling of finely divided suspended matter, colloidal substances, and large molecules, the operation is called 'coagulation' when chemicals are added to throw dissolved impurities out of solution, the operation is described as 'chemical precipitation'.

At waste treatment plants sedimentation tanks of continuous flow design are most commonly employed. They are either rectangular or circular in plan and the flow of waste water through them is horizontal, radial or vertical. Screened wastewater enters these tanks from one end through specially designed inlet, flows through at a very slow velocity and leaves of smoothly over specially devised outlet weirs. The conditions in the tanks remain practically quiscent and the heavier suspended solids (mostly organic type) settle out and are removed as sludge from time to time or even continuously. The classified wastewater carrying mostly colloids and dissolvedsolids passes out as effluent which may either be disposed of or treated further as per requirements.

Coagulation means gathering together of a number of smaller particles into bigger and heavier masses. The coagulation and rapid settling is due to

(i) The formation of a gelatinous floc that is largely insoluble and which enmeshes or absorbs to its sticky surface, the suspended solids in wastewater and is heavy enough to settle rapidly.

(ii) The dissociation of the chemicals into high valent ions which neutralize the electrical charges on the collidal particles, thus causing them to coagulate and settle.

A number of chemicals used in this process. Among them the common are salts of iron, i.e., ferrous and ferric chlorides and sulphates as they form heavy floc to settle rapidly. Aluminium salts, commonly used in water, are not so suitable for wastewater.

Now a days many experiments are being conducted in order to know the particular chemical which is very useful for particular type of waste in whole water. S.K. Chang (40) et al found that primary treatment plants when supplemented with addition of iron salts as coagulant, would provide significant removal of phosphorous and BOD and SS. In steel Industry (41) where iron oxides are in suspension alum may be a good coagulant . At present polymers (pollyelectrolytes) (42) play an important role as coagulant in treatment of municipal wastewater. They are good as they remove BOD , SS to a great extent, with less sludge.

5.1.3 Disposal of Sludge

Sludge from a wastewater treatment plant is semiliquid mass formed out of solids removed in various treatment processes. Its disposal is a difficult task because of its large volume and high putrescibility. Its characteristics depend on the characteristic of parent wastewater and treatment Process through which they originate. They may be as

i. Sludge from primary settling tanks.

ii. Sludge produced from chemical precipitation

iii. Trickling filter humns

iv. Activated sludge.

Though there lie a lot of problems for their disposal. still primarily they are disposed of by any methods given below -

i. Lagooning .

ii. Incineration

iii. Land filling

iv. Disposal into sea.

Now a days experiments show that pyrolysis (43) is the best means for sludge disposal. Pyrolysis or destructive distillation, is a process for conversion of organic waste in which solar energy may be recycled. Organic compounds exposed to temperature 1000°F - 2000°F (535°C - 1090°C) in the absence of oxygen decomposed to form three major product streams, gases, oil and char. The relative fractions of these operating conditions include residue time and tempera ure . By this the volume is reduced to 90% or more, and odour , chemical pollutants and pathogens are eliminated.

It is doubtedless that further research on disposal systems will be very helpful in eliminating the problems of disposal.

5.2 Secondary Treatment

Secondary trea ment of wastewaters containing biodegradable organic matters usually requires a choice between the trickling filter process and the activated sludge process. Both the processes have got merits and demerits and are useful to a varying extent.

5.2.1 Trickling Filter Process

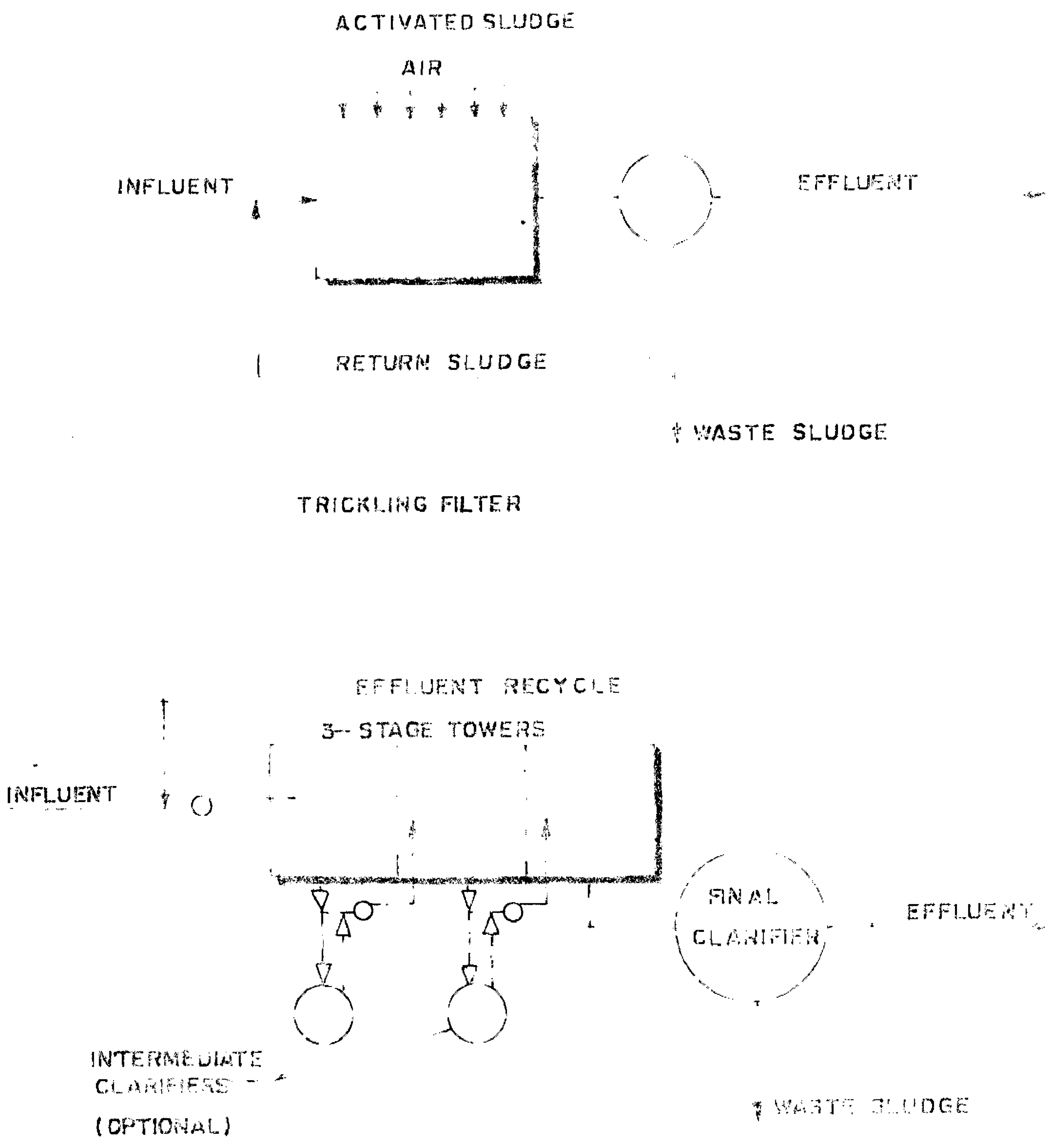
A trickling filter is a bed of coarse rough impervious materials (the contact media)over which wastewater is sprayed either from stationary or moving nozzles so arranged that the spray covers the entire area. The wastewater then trickles down through the filter incontact with the air and the aerobic bacterial stabilize it.

The most important features of trickling filter construction are (i) the nature and the depth of contact media (the filtering material)

(ii) The under drainage and ventilation system.

(iii) The system of applying wastewater to the bed.

According to the requirement and characteristics of the wastewater, the high rate trickling filters or the low rate trickling filters are chosen . Although the low rate trickling filters give a highly stabilized effluent and an easily digestible sludge, they require large volumes of aggregates to serve as contac t media and vast areas of land for their construction which make them very costly. Experiments are bein carried out to optimise the process with less expenditure. The quality of the effluent may be upgraded (44) by reduction of phosphorus, BOD and suspended solids to a considerable extent by addition of alum before final clarifier. There is no doubt that, in future by the experimental study the effluent can be upgraded to a high degree in this process.



TREATMENT PROCESS FLOW DIAGRAM

FIG.

5.2.2 Activated Sludge Treatment

When wastewater is vigorously aerated finely suspended materials and colloidal substances tend to- gather into floculles. When the wastewater thus floculated is permitted to stand quiescent, this floc quickly settles and forms a very thin mud or sludge at the bottom of the tank. Under this principle activated sludge process works. Here after giving primary treatment to raw wastewater, for short duration, activated sludge treatment is provided Proper amount of activated sludge trea ed effluent making recycle with primary treated effluent, put to aeration units. These units transfer oxygen to wastewater and keep the return sludge floc aerobic, also circulate floc through waste water and increase the contact opportunity between floc and waste water. These units may be of diffus d air or mechanical aeration or of both. Thus being aerated, the mixed liquor for 6 to 8 hours, sedimentation of aerated effluent is provided to separate activated sludge from mixed liquor. During recent years, the activated sludge treatment has come into wide use, due to its high efficiencies. Experiement on this process shows that addition of activated carbon (45) to aerating mixed liquor , improves organic removals. As this process is used recently to a greater extent, a number of experiments are being carried out by different researche to maximise its efficiency. In a new modification of the activated sludge process (46) called "Bardenpho" process, James L. Bernard removed between 90% and 95% of the nitrogen and simultaneously precipitated between between 90% and 97% of the phosphates entering in the feed without addition of chemicals.

5.2.3 Choice Between Activated Sludge and Trickling Filter Process.

Typical comparisons between these two processes yield concepts concerning trickling filters that they require more land area, are more costly to construct, may cause fly nuisance and odour problems and are less sensitive to shock loads. Activated sludge processes however, are credited with the ability to produce a higher quality effluent, but as there is more difficulties in their operations, they are unstable and unreliable.

Basically both the processes are aerobic (47) in nature and removal of organic compounds from solution occurs as a result of microbial metabolic activities. Carbon compounds are both incorporated into cellular tissue and are oxidised to metabolic endproducts. The trickling filter process relies on microbial growth on media surfaces, while the activated sludge process requires the formulation of foloculated growth of microorganisms held in suspension in an aeration basin. Besides this oxygen is supplied by mechanical or diffused air aeration to the activated sludge process.

In order to select a particular process, the desired treatment objectives may be determined. Factors such as (a) concentration of effluent BOD , (b) a nitrified or non nitrified effluent, (c) Sludge disposal problem (d) reaction to shcok loads i.e. process reliability are to be considered. Both trickling filter and activated sludge processes respond in a different manner according to high rate process or low rate process. For example high rate activated sludge and high rate trickling filter processes, produce high sludge and non nitridied effluent, whereas both processes when in low rate, produce low sludge and nitrified effluent.

Economic factors that influence the decision making process, can be divided between construction and maintenance costs. The construction cost of one process mainly depends on varying land prices, increased use of plastic and red wood media for trickling filters, and innumerable other factors. In general operating cost of trickling filter is less than that of activated sludge process. Another factor contributing to the economic considerations is the power requirement to impart dissolved oxygen into waste water. Power requirements to aerate activated sludge with mechanical or diffused air aerators are, in general, larger than the power requirements to overcome loss of head through trickling filter.

The operational problems are encountered more with the activated sludge process. Although there are a number of disadvantages for using activated sludge process, the significan advantages exist too when skilled operators are available. Most importantly, the solids level can be controlled in the aeration basin to enable a given plant to operate at a constant food to microorganism ratio (F/M). For example, if the strength of the incoming wastes increases, the solids level in the aeration basin could be increased to maintain a constant food to micro-organism ratio which is impossible in the trickling filter process. As there is no fear of clogging effect like trickling filter process during recent years ac-tivated sludge process has come into wide use.

5.3 Septic Tanks

These are settling tanks for wastewater having a long detention period and wherein the settled sludge is allowed to accumulate and get digested. The cover of the tank avoids smell and sight nuisance, and helps in maintaining better anaerobic conditions. As the tanks are settling cum digestion tanks, they need space for (i) settling of incoming wastewater, (ii) digestion of settled sludge (iii) storage of digested sludge till it is taken out of further disposal.

The effluent is offensive and potentially dangerous surface irrigation is not suitable though Batana and papaya trees are reported to give good yield with septic tank effluent

But subsurface irrigation is quite suitable in porous soils where ground water table is low and large areas of land available for irrigation.

5.4 Imhoff Tank

In 1907 , Karl Imhoff, Germany's foremost waste-water Engineer in his days, has invented this tank to avoid inherent difficulties of the their septic tanks. In those days of waste water treatment, settling of suspended solids and digestion of settled sludge were carried out in one and same unit. The septic action (anaerobic decomposition of settled organic materials) in open tanks resulted in ugly sight and offensive odours at the plant site. In order to avoid all these, Karl Imhoff invented these tanks comprising a large settling tanks and a number of inter-connected hoppers below so that two processes (sedimentation and digestion) can be segregated in two different units.

The diagestion compartment consists of a number of hoppers connected at the top by the bottom of rectangular settling compartment above. The settled solids enter these hoppers through the slot, remain stored for a long period of 1 to $1\frac{1}{2}$ months depending on the temperature of the sludge, and get digested.

The settling tank above has vertical sides and 45° to 60° to horizontal inclined bottom. The solids settling in the upper compartment can, therefore easily slidedown and pass into digestion compartment below through the slot opening.

The effluents from the Imhoff tanks are similar to that from primary settling tanks i.e. containing about 35 to 40% suspended solids and 65 to 80 % BOD. This may be used in irrigation either with or without secondary treatment depending on its characteristics.

5.5 Oxidation Pond

These are ponds of regular and controlled shape, depth and marginal area; specially designed and constructed for treatment of wastewater. Growth of certain type algae is promoted in these ponds so as to obtain oxygen (resulting from their photosynthetic processes), which is further utilised in the aerobic stabilization of putresible organic material in wastewater.

Since the major function of the pond is the stabilization of organic material, they are like the units of secondary treatment. The efficiency of the pond depends on the physical, chemical and biological factors in the environment.

Physical factors

Important physical factors affecting oxidation pond (48) are temperature, light, and specific gravity. For every microorganism, there is a definite range of temperature in which it is able to carry out its metabolic activities. If the variation of tempera ure of the environment exceeds the rangeof temperature tolerance of the organism, the death of the organism may result. As applied to biological phenomena, it indicates approximately a doubling of the rate of activities of microorganism, with each 10°C rise in temperature. Hence for maximum rate of activities, the pond is to be maintained as high temperature as possible without exceeding tolerance limit of desired population.

The effect of light on pond is the effect of photosynthesis. As photosynthesis is desired as a method of oxygen sypply, light must be provided at desired intensity.

Chemical Factors

The important chemical factors in oxidation pond are nutrition factor and pH effect. The nutritional effects of a specific organic compound depend to a large extent. On the concentration of compound and on the characteristics of the organism. When nutrients become limiting the growth and metabolic rate will be the functions of its availability.

The pH range of fresh water has a profound effect on the compositionof microbial population. All organisms have pH tolerance range in which pH value has little effect of metabolic activities of organism wide and sudden variation of pH has an adverse effect on organisms.

Taking all these factors into consideration a good designed and maintained oxidation pond will give high quality effeluent. The BOD removal may be 75 to 95 % which is quite comparable with other conventional units of treatment coliform bacteria also get removed upto 99.9% due to long detention period.

The conditions suitable for adoption of such ponds are

(i) Flat land - so that they may be easily constructed

(ii) Clayey and impervious soils which will prevent percolation of wasbe water under ground.

(iii) Bright sunshine throughout the year for growth of algae.

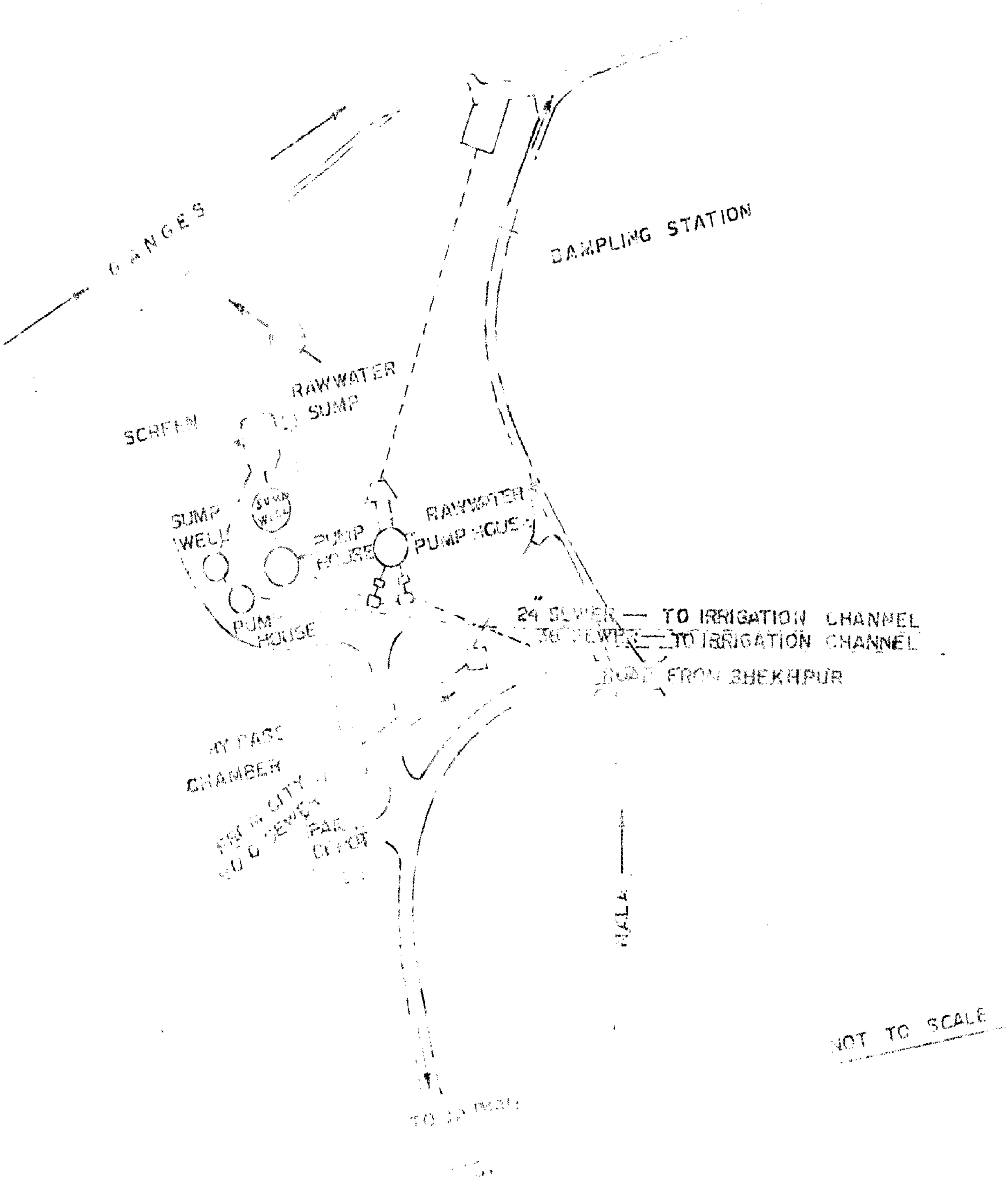
(iv) Warm climate- so that activity of bacteria and efficiency of BOD remova is high.

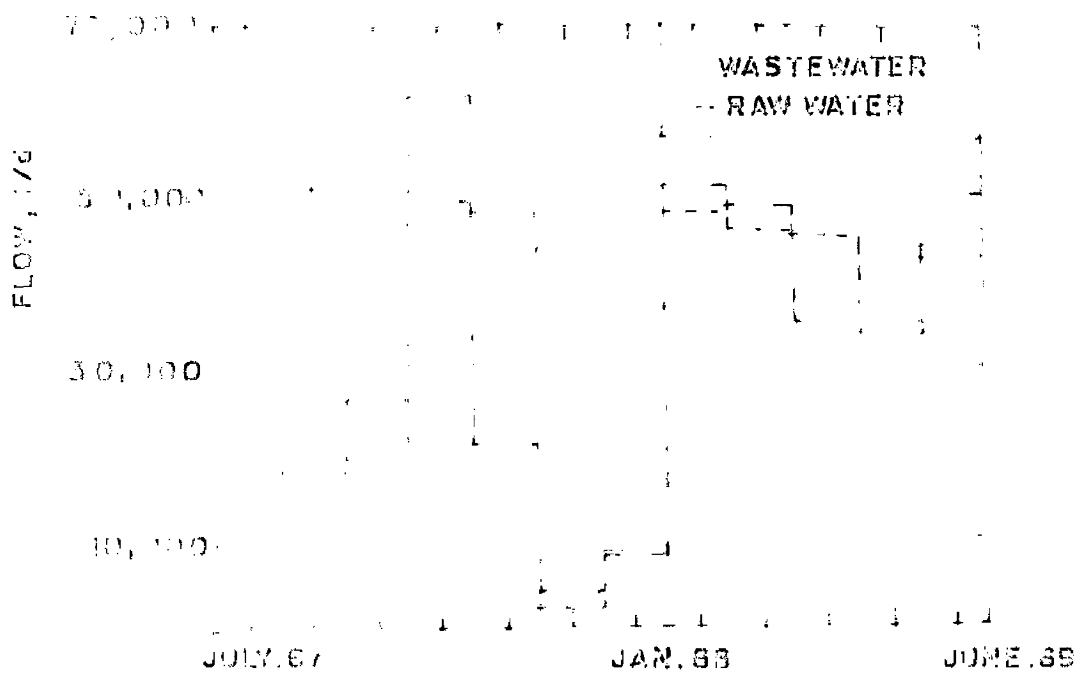
(v) Low rainfall since it disturbs the working of pond.

Taking all these conditions into account, India may b(a country, suitable for treatment of its wastewater by oxidation pond, which is no doubt a cheaper method. The effluent may be used for irrigation directly. It has been found that wastewater treated by septic tank and then oxidation pond is as good as any irrigation water.

5.6 Dilution

In this method, the waste water is diluted with sufficient quantities of fresh water and then applied for irrigation. By dilution it is sure that pathogens are not destroyed or removed, but their numbers per litre are reduced. For example if a waste water of 100,000 cu metre per minute containing bacteria concentration 1100 number per ml is combined with a flow of freshwater 900,000 cu metre per minute with bac teria 100 number per ml gives a bacterial concentration 200 number per ml only which is twice than that


GANGES
SAMPLING STATION
RAWWATER
SUMP
SUMP
WELL
PUMP
HOUSE
RAWWATER
PUMP HOUSE
PUMP
HOUSE
24" SEWER — TO IRRIGATION CHANNEL
— TO IRRIGATION CHANNEL
FROM SHEKHPUR
CHAMBER
NALA
NOT TO SCALE



VOLUME OF RAW AND WASTE WATER PUMPED TO IRRIGATION CHANNEL IN 1967–68 present infresh water. Hence constant addition of fresh-water which is relatively free of bacteria , to a waste water will result in reduction in numbers of bacteria per milli-litres. Similarly the nutrients like nitrogen, phosphorus which are abundantly present and the toxic materials like boron, which are harmful to plants, are reduced per litre by dilution with fresh water. However, the quantity of dilution may be decided according to characteristics of wastewater.

There are many cities in India, where the wastewater is used after dilution only in the agricultural fields. For example, in Kanpur city, the wastewater (both industrial and municipal) from the city is being utilised for irrigation after dilution with water from river Ganges. A site plan at Jajman is shown in Fig. V-1 . The night soil, from the part of the city served by conservancy system is collected also at the pail depot near the pumping station and washed into main sewer . Both waste water and raw water are pumped from the outfall works, to a distributory irrigating the agricultural field. The command area of the distributory is about 3076 hactares . Figure V-2 shows the volume of raw and wastewater pumped to the distributory in the year 1967-69. The excess of waste above the requirement of the form flows through a bypass channel to the river.

5.7 Disinfection of Wastewater

Pathogens of all kinds and classes are removed in a varying degree, during different treatment processes

Pathogens also die away and are destroyed in significant numbers in the course of treatment. Still then, many are left which are harmful to human beings. Hence either bacteria or viruses or amoebic cysts whatever present are desirable to be destroyed before water is used for unrestricted irrigation. Of course for restricted irrigation some allowances may be made depending on the crops and farms, to use it.Fortunately there are disinfectants which can do this.

The wastewater can be disinfected in a number of ways. But most practical one is use of chemicals.

5.7.1 Chemical Disinfectants

There are a number of chemicals, which are disinfect the wastewater. For example -

(i) Oxidising chemicals-Chlorine, Bromine, Ozone etc

(ii) Metal ions-Silver ions which can disinfect only bacteria.

(iii) Alkali and Acids-Pathogenic bacteria do not last long in highly alkaline and acidic waters.

(iv) Surface Active chemicals- Cationic detergents.

5.7.2 Disinfection by Chlorine.

Among all the disinfectants perhaps most commonly used chemical is chlorine due to its high oxidising capacity and cheap availability and many other properties.

(i) Destruction of disease producing organisms.

There is no doubt that disease producing organisms in wastewater can be destroyed by chlorine, provided the concentration and time of contact are adequate. However, the efficiencies of chlorine is markedly interfered with by the presence of organic matter, particularly if it is proteinaceous in nature. Hence high concentrations of chlorine like 5 to 25 ppm or even higher, may be necessary for thorough disinfection. In addition a higher residual content (0.2 to 0.5 ppm) may be present to obtain good disinfection.

Some idea as the rate of destruction of bacteria in wastewater can be have from following data reported (49) for destruction of E. coli by Chlorination. If 100 per cent chlorination represents complet satisfaction of chlorine demand of wastewater, then,

40% chlorination killed	58.6% E. coli	in 7.5 minutes
50% chlorination killed	70.0% E. coli	in 7.5 minutes
60% chlorination killed	83.5% E. coli	in 7.5 minutes
100% chlorination killed	99.1% E.coli	in 7.5 minutes

(ii) Reduction in BOD

The addition of chlorine for disinfection of wastewater may reduce BOD of wastewater due to two reasons. Oxidation of organic matter by chlorine and secondly the addition of chlorine reduces the microbial population and this would certainly be expected to bring about the reduction of oxygen required in microbial metabolism immediately following chlorination. But as soon as residual chlorine disappears, any surviving organisms may be expected to develop rapidly.

(iii) Controlling Odours

There are two points to control odours, i.e. (a) preventing their development, (b) eliminating odours after they are produced . Bacterially produced odours are commonly attributed to hydrogen sulfide and other protein decomposition products. Hydrogen sulfide may arise either from decomposition of proteins or from the reduction of mineral sulfur compounds, neither of these processes results in appreciable accumulation of Hydrogen sulfide except under anaerobic conditions. Hence maintenance of aerobic condition is necessary for reduction of odours, for which chlorination may control odours.

There are several other factors for which chlorine is used in wide in disinfection of wastewater. Probable amounts of chlorine required in different types of effluent are given below .

TABLE V-1

Probable amounts of chlorine Required to rproduce a chlorine Residual of 0.5 mg per litre after 15 minutes in sewage and sewage effluents as per Fair and Geyer.

Type of Sewage effluent	Probable amou of chlorine mg/l.
Raw sewage, depending on strength and staliness	6 -24
Settled Sewage, depending on strength and Staliness	3- 18
Chemically precipitated sewage,depending on str.	3 -12
Trickling filter effluent,depending on performance	3 - 9
Ac-tivated sludge effluent,depending on performance	3 - 9
Intermittent sand filter effluent, depending on performance	1 - 6

5.8 Typical Examples of Wastewater Irrigation

The two largest california communities whose wastewater is applied to land for irrigation of agricultural crops are Bakersfield, central california (about 17,000 acreft (2125 hameter) per year and population served 90,000) and Fresno (about 30,000 ac reft per year and 16,5000 population served).

In 1939 (50) a 9.0 mgd primary treatment plant was constructed in Bakersfield, but in 1952, an earthquake reduced effective capacity of the plant to 4.0 mgd. In the same year, a 16 mgd primary plant (plant No.2) was constructed two miles to the south. Bakersfield continued to dispose of effluent from both plants on adjacent land, The characteristics of the effluents from Plant No.1 and (3.5 mgd) and Plant No.2 (9.5 mgd) have been combined for a typical irrigation blend. One ac refoot of this effluent applied to the land is equivalent to adding 760 lbs of 10-10-10 (N-P-K) fertilizer. The crops alfa-alfa, barley, corn, cotton and pasture grass are irrigated by the effluent usually by surface irrigation.

Bakersfield leases 2,500 ac res to a grower for $ 40,000 annually and the grower maintains ditches and controls the tailwater from irrigation. Uptil now there is no problem except nitrogen in the effluent overfertilizes the cotton, causing excessive plant growth at the expense of crop yield current plans are to consolidate plant 1 and 2 and an activated sludge plant of 17.7 mgd is being designed the effluent of which will be used in same agricultural field.

At Fresno, about 40% of the wastewater receives secondary biological treatment by trickling filter and rest was treated by primary treatment plant at the time of 1965. The treated wastewaters were used for growing alfa-alfa, cattle pasture, corn, cotton, small grains and sugar beets.

Texas also uses significant amount of wastewater for irrigation. The most notable texas communities using wastewater irrigation are Abilene (approximately 1,000 acreft per year from population of 95000), Ludbock (approximately 12000 acrefoot per year from population of 1,09,000) and San Antonio (population served 5,81,000 and out of wastewater flow of 80,000 acre foot per year, a part is used for irrigation). After treatment from these cities is used for crops as cattle and horse pasture, alfa-alfa, corn, small grains, and cotton. Abilena provides primary sedimentation plus oxidation ponds, ludbock provides secondary treatment by trickling filters and San Antonio has secondary treatment by activated sludge effluent stored in a lake, prior to diversion for irrigation purposes. In each of the above cases the crop irrigation with treated wastewater effluent started before World War II. No human food crops are grown on lands to which wastewater is applied.

5.9 Treatment of Waste Water by Groundwater Recharge

The treatment of wastewater by artificially recharging to groundwater and then reusing for irrigation, seems to be a costlier process. But often the wastewater contains such impurities those are toxic to plants and are not removed through conventional treatment. Groundwater recharge may be a solution of such situation in order to utilize it in unrestricted irrigation in water scarcity areas.

Now a days an increasing interest is in applying conventionally treated wastewater for ground water recharge which is an effective and economical way for reclaiming water in stead of its disposal in streams and lakes. After percolating downwards through the soil to the water table and moving laterally as ground water for some distance, the wastewater has lost its suspended solids, biodegradable materials, microorganisms almost all of its phosphorus, and most of its nitrogen. Thus the reclaimed water has manifold utilities such as it is suitable for recreational lakes, unrestricted irrigation of fruit and vegetable crops, and with additional treatment of necessary municipal and industrial uses. If soil and hydrogeological conditions are favourable, the cost of renovating wastewater by ground water recharge is a fraction of that comparable tertiary inplant treatment.

5.9.1 Aquifer Recharge Methods

The two main methods of adding recharge water to an aquifer are

(a) direct injection through wells into aquifer

(b) percolation to the aquifer from surface spreading basin

The test injection well (51) on long Island, U.S.A. is 150 meter deep and was drilled in 90 cm diameter. A 18 m long 16" dia(40 cm) stainless steel screen was placed near the bottom of well and annular space around it was filled with graded sand. The top of the screen was fastened to an 46 cm dia fibre glass pipe which extend to the surface, the annular space around it being filled with cement grout. With such arrangements the water can be injected directly to aquifer below the water table.

In surface spreading operations wastewater is admitted to shallow ponds or spreading basins from which it percolates through the soil to join the ground water table. This type of recharge is used at Whitter Norrows, Holland etc.

Another method of aquifer recharge by surface spreading is the over irrigation of restricted crops with waste waters replenishment of ground water after percolation through soil.

5.9.2 Soil Characteristics.

The main characteristics of soil effecting the efficiency of basins are size of soil particles i.e. unfformity coefficient and effective size, permeability and con tituents of soil.

All groundwater replenishment will be effected by the percolation capacity of the formations receiving the effluents. Coarse formations do not clog so readily as fine formations. In very coarse formations, the development of slimes may be necessary to reduce travel of bacteria. Formations of fine gravel, clay and sand tend to clog more readily. Therefore, in such formations a high degree of pretreatment is necessary to accomplish the spreading of suff icient quantities.

Observations (52) made during test through Hanford Soil at Lodi are indicative of the expected changes in dissolved salts as work water percolates through soil. Inthese tests, calcium , Magnesium and sodium ion concentrations remained relatively constant to a depth of 4.0 metre . Potassium ions decreased by 50 % during percolation, the greater proportion of the removal occurs below 2.10 metre Ammonia was completely removed within 1.22 meter of the ions, chlorides remain unchanged, sulfates and bicarbonates increased roughly 30% , presumably due to oxidation of organic sulpher and carbon, and nitrates increased greatly because of organic and ammonia nitrogen which was available for oxidation.

5.9.3 Chemical Reaction with Soil and Groundwater

It is possible that the reactions may occur between rechavge water and either the minerals in soils or the dissolved matter in ground water or both.

Where organic matters are oxidised, the carboneous portion produces carbondioxide, which in water forms carbonate and lowers pH. The solubility of calcium, Magnesium and Aluminium are affected by the pH and therefore pH changes may cause leaching or deposition of salts of these metals. The oxidation reduction potential is also affected by biological reactions. The solubility of some materials, including iron, magnese and copper are related to oxidation reduction potential of the system.

Studies in Israel have shown low solubility salts can be leached from layers of dune sand, and that some of the leached salts may tend to redeposit elsewhere. It is believed that future changes in permeability may occur, increased permeability in zones from which material is leached, but decreased in the zones which become clogged by redepositio Sulfides, which may be produced by anaerobic decomposition will combine with heavy metals to form insoluble metallic sulfides, in this way tending to reduce permeability, or even to cause practically complete blockage,

5.9.4 Quality of Water for Recharge

The required quality of water for any aquifer recharge project will depend not only on the method of recharge to be used, but also on proposed use of water to be taken from aquifer.

When water is to be percolated intermittantly from spreading basins into ground water through an unsaturated zone of aedequate depth, the process of natural treatment are brought into play. Many basisn may be favourably placed in such circumstances that they can be used safely to accept wastewater which has subjected to only primary treatment.

At Whitter Narrows plant, which is operating since 1962 and Flushing Meadows experimental site, the water is admitted to basins is municipal wastewater which has undergone primary and secondary treatment. In Israel many spreading basins receive effluent from oxidation lagoon treatment of wastewater.

However, degree of treatment before spreading affects the rates of infiltration. In general highly treated effluents can be infiltrated both at a greater rate and for longer periods before serious clogging occurs.

Where water is injected directly into an aquifer through deepwells, removal of bacteria in slower than the percolation from basins and stabilization of organic material occurs at a negligible rate. In western U.S.A. direct injection is frequently used to form a barrier against seawater intrusion.

5.9.5 Spreading Basin Operation

Spreading basins on dune sand in Holland using Rhine water and basins at Los Angels where municipal waste water is first coagulated and filtered can be operated on a continuous basis. But where wastewater with a lesser degree of preliminary treatment is used, there is usually enough organic matter present to cause progressive clogging of the soil, so that the rate of infiltration gradually decreases. However, after a resting period, during which soil surfaces of basins are dried out, infiltration rates increases sufficiently for reloading of basins on intermittant loading schedule.

However maintaining high infiltration rate for long period, clogging (53) takes place due to chemical, biological and physical factors. Chemical clogging is caused by chemical interaction between dissolved salts in the water and the soil resultingin decreased pore diameter and consequently lower permeability. Chemical clogging seldom occurs unless sodium content of wastewater is high. Biological clogging occurs when bacterial growth or its byproducts reduce the pore diameter. Biological clogging is associated frequentl with anaerobic conditions and usually occurs at soil surface Physical clogging is result of suspended solids blocking the pores.

Effluents from activated sludge plants and lagoon treatment may be successful for the infiltration cycle to adopt a period of from three to six days wet, followed by a period of from six to twelve days dry.

5.9.6 Infiltration Rate

However rates of infiltration depends on soil type as discussed earlier and management of basin. The rates of infiltration cited in literatures vary from about 3 cm per day to 1 million gallons per acre per day (approximately 4 ft per day). The more common range of infiltration is from 0.3 ft per day to 2 ft per day.

5.9.7 Collection Fascilities

The facilities for collecting reclaimed water may be either natural, such as streams and springs or artificial. Germany and Pensylvania state University systems are artificial, such as

(a) The horizontal tube drains paralleling to recharge basins in the dunes of Holland.

(b) Interception trench of santee system U.S.A.

(c) Wells pumping from recharge aquifer in Whittier Narrows project U.S.A.

The design of a system of recharge areas with wells or other collection facilities should be based on avoidance of high water table mounds beneath the recharge areas, so that watertable does not back up to the soil surface with resulting reduction in infiltration rates. Also high water tables should be avoided to maintain sufficient aerobic percolation and to allow rapid drainage of the soil profile during a dryup. The system should also be designed to yield sufficient times and distance of travel, as the water moves below the water table from the recharge area to collection facility to obtain high quality of reclaimed water (54).

As a guide to the order of magnitude of height of aerobic percolation zone, and desirable underground travel distance and time, the height may be atleast several feet, the distance of underground travel several hundreds of feet and the detention time several months. Modification of these magnitude may be desirable, depending on soil and hydrogeologic conditions, the quality of wastewater and desired quality of renovated water.

5.9.8 Example of G.W. Recharge .

There are many examples abroad specially in U.S.A. Holland and Israel where wastewater is being reclaimed. But reclaimation for agricultural purpose very few examples may be cited. One of the recent examples is in the west of Phoenix, Arizona. Due to consumptive use of agricultural land of Salt river valley, the groundwater was dropping at the rate of 3 meter per year . In order to avoid it, a pilot project in the salt river bed west of Phoenix, Arizona was performed and municipal wastewater was recharged by spreading at the river bed where hydrogeological conditions were favourable. It was demonstrated that 24,000 ha of agricultural land which was more than required could be irrigated by renovated water.

Large scale reuse of the effluent for irrigation and recreation requires treatment beyond conventional activat process, specifically the requirements for unrestricted irrigation and unrestricted recreation should be met. According to Arizona standards this requirement s to produce BOD and suspended solids contents of less than 10 mg/litre and if necessary, disinfection to keep fecal coliform density below 200 / 100 ml.

Use of effluent for large scale irrigation would also make it desirable to remove some of the nitrogen to avoid undesirable effects on crop quality and on the harvesting schedules. It was found that complete removal of BOD, suspended solids and fecal coliforms were obtained and nitrogen and phosphorus were reduced to a considerable extent.

CHAPTER VI

ANALYSIS OF ROORKEE MUNICIPAL WASTE WATER AND UNIVERSITY DAIRY FARM WASTE - WATER.

6.1 Roorkee Municipality

Roorkee municipal area covers whole of Roorkee town except the area occupied by University of Roorkee and cantonment. The population according to census 1931, 1941, 1951 and 1961 of the Roorkee Municipal area was 13,944, 17,344; and 24,535; 33,618. The increasing rate of population can be well visualised in these three decades. Hence the expected population, for which Roorkee sewer has been designed, is about 60,000 in 1991 on the assumptions of the above rate of increase in population.

6.1.1 Topography.

Ganga canal divides the town in two areas one on the west side i.e. right bank side occupies nearly two-third of municipal area and is more thickly populated than the eastern side.

6.1.2 Quantity of Municipal waste-water.

The sewer receives wastes frombath, latrines, kitchens etc., but no provision has been made for storm water. The rate of water supply to municipal area is 135 litres per head per day. It has been assumed that 75% of water reaches the sewers. At present volume of waste water flowing per day is nearly 136 cu meters.

6.1.3 Treatment practice

No primary or secondary treatment is being given to waste water. At present only screening is being done before discharging the effluent to nearby river Solani.

6.1.4 Sampling and Testing Procedures

Composite samples of wastewater for physical, chemical and bacteriological analysis were collected from the municipal sumpwell in accordance with standard methods [5

The bacteriological examination consisted of determining total counts and MPN coliform. In conducting the tests nutrient agar and MacConkey broth were used for total counts and MPN coliform respectively.

6.1.5 Results

Physical Characteristics

i.	Temperature at time of collection	20°C
ii.	Temp . at Laboratory	18°C
iii.	pH at Laboratory	7.4
iv.	Total solids	1810 mg/litre
v.	Suspended solid	1450 mg/litre
vi.	Volatile solids	440 mg/lit.
vii.	Fixed solids	1370 mg/litre

Chemical Characteristics

i.	BOD	450 mg/litre
ii.	COD	675 mg/litre

iii.	Nitrogen	55.5 mg/litre
iv.	Phosphorous	15.0 mg/litre
v.	Hardness ($CaCO_3$)	257 mg/litre
vi.	Alkalinity ($CaCO_3$)	261 mg/litre

Bacteriological Characteristics

i.	Total counts	Numerous
ii.	MPN Coliform	$24x10^{3+}$ / 100 ml.

6.1.6 Sewage Farm

There is a plan to dilute the raw wastewater by pumping fresh ground water and use the effluent for irrigation. The purposed irrigation rate is 112 cu meter per hectare . The total discharge per day being nearly 6136 cu meters the area of the farm required is 55 hectares . Including rest and rotation and for distribution channels, the total area of farm has been worked out to be 80 hactares, but 60 hactares have been proposed at present. Now already 40 hectares have been occupied and pumping station, sumpwell etc have been constructed with total cost of 6.1 lakh rupees. No sooner the rising main which is under repair how , will be alright than the effluent will be used for agricultural purpose.

6.2 University Dairy Farm

University of Roorkee has a small diary mainly for its employees. The total quantity of milk, being handled in this farm is about 1000 litres per day. The tribution of milk is the primary function of the farm. ever sometimes a very small quantities of milk is used manufacture of cheese.

.1 Diary farm waste

The wastes from the dairy farm is mainly from processing unit i.e. due to washings of cans after distution of milk. The cans are cleaned with hot water neatly this unit.

The waste flow is very little. The wastewater of the ry farm flows to the low land at the northern side of the ry farm.

.2 Sampling and Testing Procedures

Sample was collected from the dairy farm processing t at 10.30 a.m. The waste was mainly washings of cans af tribution of milk.

Physical, chemical and bacteriological tests were e as per standard methods [53]. In bacteriological tes total count and MPN coliform. Nutrient agar, and Conkey broth were used respec tively.

.3 Results

sical characteristics.

Temperature at time of collection	22°C
Temperature at laboratory	19°C
pH at laboratory	7.0

iv.	Total solids	2110 mg/l.
v.	Suspended solids	2090 mg/l
vi.	Volatile solids	450 mg/ l
vii.	Fixed solids	1660 mg/l

Chemical Characteristics

i.	BOD	2750 mg/l
ii.	COD	4240 mg/l
iii.	Phosphorus	Traces
iv.	Hardness ($CaCO_3$)	580 mg/l
v.	Alkalinity ($CaCO_3$)	135 mg/l

Bactriological characteristics

i.	Total Count	Numerous
iii.	MPN Coliforms	2400^+ / 100 ml

The results show that dairyfram waste has high BOD and COD values, but less nutrients. As the ratio of COD and BOD is similar to that of municipal waste, the similar treatment method may be adopted for dairy farm waste also.

CHAPTER VII

DISCUSSION

In a country like India, which is deficit in basic foods and chemical fertilizers, the importance of reuse of wastewater for agricultural purposes is needless to explain. Also in a country, where rivers are in spate for 3 months, and particularly dry for 3 to 6 months, the utilization of wastewater for irrigation is most logical answer.

In any discussion of the quality of effluent used for irrigation it is necessary to consider the effects of its constituents on the plant, the soil and on the consumers of the products grown. The deleterious effects of salts on plant growth can result from: (a) direct physical effects of salts in preventing water uptake by plants i.e., osmotic effects, (b) direct chemical effects upon metabolic reactions of plants i.e., physiological effects, and (c) indirect effects through changes in soil structure, permeability and aeration.

Use of raw wastewater both municipal and industrial effluents for directly irrigating edible and non-edible crops is potentially dangerous and can be possible for the outbreak of epidemics and other skin diseases.

7.1 Quality of Wastewater

Because of the many variable factors involved, the classification of effluents for use in irrigation cannot be very rigid. These factors include quality and quantity of the effluent, type of soil and land area available for irrigation, tolerance capacities of plants climatic conditions such as temperature, humidity and rainfall and the relationship between the constituents of the effluent and soil structure. The basic characteristics of an irrigation water has been dealt in Chapter III.

7.2 Factors Limiting the use for Irrigation

The problems of raw wastewater to be used in irrigation have been discussed earlier. In brief if the quantity of waste discharged is large, the soil texture unsuitable and the area for disposal limited, very critical conditions develop. The effluent may contain excessive quantities of inorganic salts, organic matter and pathogenic organisms. Invariably the industrial wastes contain large amounts of dissolved salts which municipal waste contains large quantities of putrescible organic matter. When such effluents are used on agricultural land, the soils, plants and consumers will be certainly adversely affected. The BOD value of raw municipal waste may be nearly 500 mg / litre and that from industries, tho-ugh varies a lot, may be as high as 2000 to 2500 mg/lit. Application of such effluents will render soil unsuitable for crop-production.

Very often the outbreak of enteric bacterial diseases have been attributed to the consumption of food stuffs which were grown under raw municipal wastewater irrigation. On the other hand the effluent irrigation has been in practice in South Africa, France, and in this country for more than 75 years (56) and in many places no epidemics among human and cattle have been directly traced out . It does not mean that raw wastewater can be used indiscriminantly without taking necessary precautions. Hence treatment of wastewater is pre-requisite prior to use the same for irrigation.

7.3 Treatment Necessary

In theory, the wastewater can be reclaimed to any desired quality, however economics play the important role for its treatment . From all points of view, including public health hazards which is the most important aspect, the following alternatives may be considered for utilizing effluent for agricultural uses.

1. Complete treatment and thorough disinfection and reuse for unrestricted crops.
2. Partial treatment, groundwater recharge, withdrawal and reuse for unrestricted crops.
3. Partial treatment and reuse for restricted crops.

The serial 1 and 2 requires heavy investments and they are not possible in near future in India. Hence serial 3 may be considered from all angles. Before consideration of pros and conss of this alternative, the standards followed by different countries may be discussed briefly.

7.4 Standards of Different Countries

Although no recent comprehensive compilation of information of standards for use of wastewater for irrigation of crops are available, the use of wastewater is generally accepted philosophy that all wastewaters should receive primary or greater treatment. Also in general, only complete treated and disinfected wastewater is permitted to be used on vegetable grown for human consumptions.

California is the leader of using reclaimed wastewater for several purposes including for irrigation. In 1949, the California Legislature recognised the importance of reclaimed wastewater as an additional source of water and added section 230 to California watercode, which authorised the California Department of water Resources to investigate the reclamation and use of the wastewater. Subsequently section 230 has been ammended. Here the treatment practice, for irrigation is primary treatment often followed by ponding so that water can be stored until needed by one third and the rest two third make secondary treatment or secondary followed by ponding.

The use of primary effluent for irrigation of foodcrops which are processed prior to use is a move towards a more liberalised use of reclaimed wastewater. For public health protection, a significant restraint has been placed on its use. Primary effluent may be used only for surface irrigation of such foodcrops and for purpose of standard surface irrigation has been defined as, "means, other than spraying such that contact betwe n the edible portion of any food crops and reclaimed waste water is prevented". The definition would essentially limit the use of primary effluent to ridge and furrow irrigation of processed food crops where precautions are taken to avoid ponded tailwater at the lower end of the field, where direct contact is prevented. Appendix 'A' gives the standards made by California Government for municipal wastewater irrigation (57). Of course no restrictions are placed on use of complete treated, well oxidised and reliable disinfected wastewater essentially conforming with public health service drinking water standard. It is true that no state or local regulations body would object to any irrigation use of such completely rennovated wastewater. It appears that California's regulations provide adequate protections to public, since their adoption in 1933, there have been no reported disease outbreaks resulting from crop irrigation withtreated effluent.

Similarly Government of Israel has iss ued a number of regulation for utilization of municipal wastewaters in irrigation. Appendix 'B' gives some of such regulations drawn up by Government of Israel (58). It seems like California's regulations, regulations of Israel minimise not only potential health hazards of the public, but also of the animals.

The state Arizona (59) has also drawn up some regulations and here secondary treatment is the minimum for all wastewater discharges. Some of regulations of Arizona are given in Appendix 'C'.

In Uttar Pradesh, a sewage utilization Committee was set up in 1945 (60) to consider reuse of municipal wastewater for irrigation. The committee after considerations of all facts, recommended following methods for purification and utilization of sewage in Uttar Pradesh.

"The sewage should first of all be screened of all the floating matter and freed from grit in a grit chamber. It should then be subjected to sedimentation and digest in a tank (plain sedimentation) which will yield a semisolid sludge at the bottom and partially clarified effluent. The partially treated effluent may be diluted with water as and when necessary and utilized on land over as large as an area as possible by carrying it into pucca or Kutcha channels and the sludge alongwith the floating matter should be utilized for making compost with town refuse. The period of retention of sewage in sedimentation tank should be determined according to local conditions such as nature and strength of sewage, the soil and temperature . Similarly the amount of dilution with water would be determined by nature and strength of sewage and local soil and crop requirements".

7.5 Economic Aspect

Economics play an important role in planning of any wastewater treatment system. Complete treatment costs tremendous amounts of money in both capital outlay and in maintenance particularly when skilled and trained labourers are scarce and costly. Hence it is economical to have partial treatment, which will depend on the climatic conditions, characteristics of effluent, type of soil, type of crops and method of irrigation.

The treatment plants constructed in this country vary from simplest (the septic tanks) to most complex (the activated sludge process with sludge digestion and water reclamation). The plants which requires least amount of mechanisation for its operation and most suitable for climatic conditions of this country is oxidation pond. Also the oxidation ponds seem to be ideal in this country because of the high ambient temperatures and availability of plenty sunshine in most of the parts of the country. The efficiency of removal of pathogens of oxidation ponds also is comparable to conventional treatment process.

Another simple treatment is the oxidation ditch, originally developed in Holland . More recently aerated lagoons are also coming to pictures. The cost of treatment through different processes given in Table No. VII-1 has been estimated in 1973 (63) by CPHERI , Nagpur.

Table VII - 1

Relative Costs of waste treatment plants in India for population ranging from 5000 to 200, 000 (0.15 to 6 mgd).

Sl	Process	Cost per capita for construction of plant including land cost Rs.	Capital cost plus capitalised running cost per capita. Rs.	Total annual expenditure per capital to defr all running cos including repayment of loan Rs.
1.	Waste stabilization Pond	8.80 -15.70	10.60-27.20	0.93 - 2.30
2.	Aerated lagoon	12.00 -19.00	32.20-55.80	2.80- 4.86
3.	Oxidation ditch	14.00 -21.00	43.75-79.60	3.80- 6.06
4.	Conventional treatment	25.00 -75.00	40.88-152.00	3.55-13.22

Though conventional treatment costs more than anyother method, in many cities, due to problem of land and other factors like quantity and quality of wastewater. conventional treatment becomes the only choice among all the methods.

7.6 Types of Crops

In order to make the partial treatment attractive and feasible for restricted irrigation, there should be sufficient numbers of crops to be grown, so that proper crop rotation will be possible The crops those may be used in restricted irrigation in India are given below.

1. Food crops those are taken after processing, rice, wheat, barley, maize and sweet corn etc.
2. Fruit trees - Citrus, banana, nut
3. Nursery plants and flowers
4. Oil seed crops - Castor, groundnut, linseed
5. Fibre crops - Cotton and jute
6. Other commercial crops and species - Sugarcane, tobacco, pepper, chillies, and ginger crops for seed purposes.

Vegetables like potato which are taken after processing may be grown.

7.7 Operation of Treatment Plant

As the crops, to be grown in restricted irrigation are in plenty, the partial treatment may be considered suitable. However properly operating treatment processes are also quite effective in reducing the quantities of waste matters, excessive nutrients, BOD, and COD to a larger extent, current waste treatment plant operations are based on primarily steady state relationships, and rule of thumb control by plant personnel. In order to avoid this type of control, some automatic control may be attempted using model technique

7.8 Precautions to be Taken

Further, certain precautions that can be taken to minimise the hazards to some extent by imposing restrictions, As seen earlier, advanced countries have framed legislations for use of wastewater in irrigation, in India, restrictions or ordinances may be put by appropriate state Government

Authorities prohibiting the untreated wastewater on land with the help of Indian Standard Institution.

7.9 Indian Standards Institution

Indian Standards Institution (61) is a quasi-government organisation working in active partnership and close collaboration between Industry and the Government. This institution was set up in 1947 to fulfil a vital role in the industrial development in the country. In its working, ISI draws upon the experience and know-how of not only manufacturers and consumers, but also technologists and official agencies.

Realising the importance of conservation of water resources of the country, chemical Division council of ISI set up a water sectional committee, CDC 26 , in 1957. Consequently in 1959 , an independent panel for River Water and Trade Effluents, CDC 26 : P4 was set up to laydown reasonable standards of purity of waters consistent with their uses. At early stage on prevention of pollution of water CDC 26 made a recommendation that all the state governments may establish research units and effluent boards of the pattern developed in U.P. and also the recommendation was conveyed to the Government of India. At the same time the committee also realised that it is not possible to cover in all India level standard variable aspects like dilution ratio which, no doubt, have their own significance. Therefore, it has been laid down clearly in the standard that the limits prescribed are intended to guide State Government and the local Authorities in enforcing rules. When standard was laid down it was also recognised that the industries in India did not have much experience in the treatment of effluents, the public health authorities too have not been following any systematic rules in controlling pollution. The standard was therefore published with the provision that it will be reviewed after a period of about three years in the light of the experience gained in the meantime.

The standards of effluent suitable for irrigation have been given in Table No. IV-3 . ISI has also charted out the treatment methods of tannery wastes, fibre manufacture waste and food processing waste etc. For treatment and drafting of proper legislations, useful help can be taken from the work that has already been done in those advanced countries

7.10 Existing Facilities at Roorkee

The present proposal for utilizing municipal wastewater of Roorkee for irrigation is no doubt a better planning in these days of food scarcity. But minimum primary treatment or oxidation pond treatment should be provided to the raw wastewater before diluting the same for using in the agricultural land for restricted crops. When water is not required for irrigation, the effluent may be discharged to river solani.

University Dairy waste, which is very meagre, should be collected in a tank and then should be allowed to flow to the agricultural fields which are adjacent to dairy farm.

7.11 Public Attitude

Why will the people object to use the wastewater which has been reclaimed upto the standard to use in irrigation? However in California, a survey was conducted in order to know the publ c attitude (62) towards the use of reclaimed wastewater for different purposes. The report has been given in Table No. VII-2 . Reclaimed water was then defined as water suitable for use as a result of purification of community or municipal waste. The result shows that the greatest percent t oppo sed to use relcaimed wastewater for drinking and food preparation. But for utilizing in irrigation the per cent was low in California. It was observed there that education factor played important role in percentage of opposition. Hence it is believed as a country will advance in education, the percentage of opposition towards use of reclaimed wastewater will be less and less.

Table VII- 2

Percentage of Respondents opposed to use of Reclaimed water after Bruvold (62)

Sl. No.	Use	Total number of respondents=972
1	Drinking water	56.4
2	Food preparation in restaurants	56.0
3	Cooking in the home	54.5
4	Preparation of canned vegetables	54.1
5	Bathing in the home	38.7
6	Swimming	23.7
7	Pumping down special wells	23.2
8.	Home laundry	22.8
9	Commercial laundry	21.9
10	Irrigation of dairy pasture	14.1
11	Irrigation of vegetable crops	14.0
12	Spreading on sandy areas	13.3
13	Vineyard irrigation	12.9
14	Orchard irrigation	10.1
15	Hay or alfa-alfa irrigation	7.5
16	Pleasure boating	7.3
17	Commercial air conditioning	6.5
18	Electronic plant Process water	4.9
19	Home toilet flushing	3.8
20	Golf course hazard lakes	3.1
21	Residential lawn irrigation	2.7
22	Irrigation of recreation parks	2.6
23	Golf course irrigation	1.6
24	Irrigation of freeway green belts	1.2
25	Road construction	0.8

CHAPTER VIII

CONCLUSIONS

In west the trend in wastewater reclammation seems to be towards higher value uses such as planned groundwater recharge, and recreational lakes. The costs of advanced treatment techniques for complete rennovations of wastewater for the highest quality uses are becoming more attractive day by day as compared with development of a freshwater supply.

In India complete rennovation of wastewater for using higher values cannot be thought of at present. The following recommendations are made for the time being for use of waste water for agricultural purposes.

1. Raw wastewater should not be used for irrigating any type of crops, edible or non-edible, either for use human or for animals.
2. All state governments according to the local conditions and, with the help of ISI, should fix the standards of the effluent giving the threshold concentration of constituents of wastewater to be used for irrigation.
3. For industrial effluents, every problem is unique and deserves special attention taking considerations of local conditions. But for municipal wastewater it seems , where land is available wastewater may be treated through oxidation pond which is possible within very nominal cost. The land required for

oxidation pond is almost less than 10% of the area of the farm, to be irrigated. Both from points of view of public health interest and also for proper utilization of wastewater, the use of oxidation pond for its treatment is recommended prior to utilize on agricultural land.

4. Many cities in India are situated near the confluence of the rivers for which land becomes a problem. In those places, the waste water may be treated through conventional treatments and may be discharged into streams, from which the same can be picked up in downstream and utilized for irrigation. Raw wastewater should be strictly prohibited to be discharged into streams. Care should be taken not to allow the streams to be polluted to a point where its composition makes it unfit for the uses (i) as raw water for public water supply and for bathing ghats (ii) for pisciculture (iii) for irrigation.

5. Partially or completely treated wastewater without disinfection should not be used for crops, the products of which are eaten raw. Such effluents may be used for forage crops, vegetables which are eaten after cooked, non-edible commercial crops, and orchards the fruits of which are borne well above the ground-level . In case of orchards no fruit is to be harvested that has come in contact with irrigating water or the ground.

6. Fodder crops may be irrigated, provided grazing of domestic animals like cows and sheep, are prohibited to graze on irrigation area until it is completely dry.

7. The effluent should be handled or controlled in such manner so as to prevent ponding, mosquieto breeding or the creation of nuisance.

8. Irrigation of lawns with partially treated effluent should not be permitted.

9. Spray irrigation should not be carried out for such crops where irrigation water has a chance to come in contact with fruit.

10. Precautions to be taken before irrigation are :

(a) The areas to be irrigated shall be clearly designated with signs, warnings in clear and visible letters that the wastewater irrigation is being carried out.

(b) The pipe network for irrigation should be completely disconnec ted from regular water supply network.

(c) All necessary steps should be taken to prevent odour nuisance which may reach residential areas or other public areas.

(d) All necessary steps should be taken not to allow the effluent to drain into otherland where contamination of food crops or water supply may occur.

In the west, the historical nomenclatures are going to be changed. For example the terms sludge, sewage and sewage treatment plant are being substituted by the words solids, used water and water reclammation plant. The philosophy lies behind it, is that the water used once is also beneficial and can be recycled again and again in stead of wasting it. But for India, it is high time to consider seriously, the effects of the application of the effluents on land for agricultural use which is a ladder step, and device suitable measures to check pollution of groundwater and natural water course. It is suggested that a seminar having participation of engineers, agriculture experts, agronomists, health authorities, representatives of municipalities both central and state governments, representatives of various industries and Indian Standards Institution, be held to focus attention on such a problem of national importance.

APPENDIX 'A'

California Administrative Code.

Definition- Reclaimed Wastewater.

Art. 2. Reclaimed wastewater means waters, originating from sewage or otherwastes, which have been treated or otherwise purified so as to enable direct beneficial reuse or to allow reuse that would not otherwise occur.

Primary effluent - Primary effluent from a sewage treatment process which provides partial removal of sewage solids by physical methods so that it does not contain more than 1 ml per litre of settleable solids as determined by an approved laboratory method.

Art. 3. Irrigation of Produce.

8041 Spray Irrigation - Reclaimed wastewater used for spray irrigation of produce shall be at all times an adequately disinfected filtered wastewater. The wastewater shall be considered adequately disinfected if the median most probable number of coliform organisms in samples collected from the irrigation piping does not exceed two and two tenths per 100 ml . The median value shall be determined from bacteriological results of last 7 days for which analysis have been completed.

8042 - Surface Irrigation .(a) Reclaimed wastewater used for surface irrigation of produce shall be at all times an adequately disinfected oxidised wastewater. The wastewater shall be considered adequately disinfected if at some point in the treatment process the median most probable number of coliform organism does not exceed two and two - tenth per 100 ml. The median value shall be determined from the bac teriologic results of the last 7 days for which analysis have been completed.

(b) Orchards and Vineyards may be surface irrigated with reclaimed wastewater that has the quality atleast equivalent to that of primary effluent provided that no fruit is harves-ted that has come in contact with the irrigating water or the ground.

Art 4 Irrigation of Fodder, Fiber, Seed and Processed Food Crops.

8043 Fodder, Fiber, Seed - Reclaimed wastewater used for the surface or spray irrigation of fodder, fiber and seed crops shall have the quality atleast equivalent to that of primary effluent.

8044 - Food crops - (a) Reclaimed wastewater used for surface irrigation of food for human consuption which will be processe sufficiently by physical or chemical methods to destroy pathogenic organism shall have the quality at least equivalent to that of primary effluent.

(b) Relcaimed wastewater used for the spray irrigation of food for human consupption which will be processed suffici-ently by physical or chemical disinfected oxidised wastewater. The wastewater shall be considered adequately disinfected if at some point in the treatment process the most probable number of coliform organism of samples collected does not exceed median of 23 per 100 ml. The median value shall be determined from the bacteriological result of the last 7 days for which analysis have been completed.

8045 Pasture for Milking animals - Reclaimed wastewater used for the irrigation of pasture to which milking cows or goats have access, shall have the quality and samplinf control program as specified in Article 5 , section 8046.

Article 5 Landscape Irrigation.

8046 . Reclaimed Wastewater used for the irrigation of golf course, cementaries, lawns, parks, playgrounds, freeway land scapes, and landscapes in other areas where public access shall be at all times an adequate disinfected oxidised waste-water. The wastewater shall be considered adequately disinfected if at the same point in the treatment process the median most probable number of coliform organisms does not exceed 23 per 100 ml of sample. The median value will be determined from the bacteriological results of the last 7 days for which analysis have been complted.

APPENDIX B

Special Conditions for Utilization of Sewage Issued by the Ministry of Health, Israel.

In accordance with the authority granted under paragraph 7 of the "Trades and Industries Ordinance (Regulations)" the following conditions for the utilization of liquid wastes or sewage in agriculture are established.

(i) Definitions.

The 'road' is a road liable to be used by motor vehicles . The "spray irrigation" is the irrigation by spraying in which there is no direct contact betwe n the liquid sprayed and the plants or trees irrigated. The "Director" is the Director-General of the Ministry of Health or any official authorised by him in writing to carry out these conditions under the trades and Industries ordinance. The 'irrigation' includes spray irrigation. The "secondary sewage Treatment plant" is the sewage treatment plant based on biological treatment processes. The 'effluent' is the sewage purified by an aerobic secondary sewage treatment plant approved by the Director and Operated in such a manner as to be satisfactory to him.

(ii) Irrigation with Sewage

The sewage means all liquid wastes containing suspended and dissolved material, human, animal or vegetable matter as well as chemicals in solution.

(iii) Conditions under which irrigation with effluent is allowed.

The sewage is not to be used for irrigation. The irrigation with the effluent is allowed on the crops:

a. Water melons, nuts, ground-nuts, sweet potatoes, Okra, bananas, citrus fruit, olives, egg plant, melons, trees for landscapping, flowers, marrows, date trees and potatoes,

b. Crops for industrial use and not used for human consumption.

c. Nursery trees.

d. Fodder crops for harvesting and not for grazing, and

e. Fodder crops for grazing of cows or sheep on condition that the animals do not graze on irrigation areas until it is completely dry.

(iv) Deciduous fruit trees.

Inspite of conditions on paragraph (iii) above, the Director may allow low-level spray irrigation of deciduous fruit trees with effluent if the following three conditions are fulfilled to his complete satisfaction:

a. Spray irrigation be so carried out as to prevent effluent from coming in contact with fruit.

b. that spray irrigation cease two weeks before fruit is harvested, and

c. that the wind-fall not be marketed.

(vii) Ridge and Furrow Irrigation

Ridge and furrow irrigation with effluent may be carried out if the distance to residential areas is greater than 100 m and the distance to roads is greater than 25 metres.

(viii) Use of effluent in fish ponds.

Effluent should not be used for breeding fish except under the following conditions :

a. Effluent shall not be used in ponds for storing fish before marketing or in tanks used for their transport.

b. Should snails be found, the owner or operator of fish pond shall notify the nearest health office.

c. In the case of snails which serve as vectors of schistosomieasis being found in the pond, the owner or operator shall carry out all instructions given by the director including the drying out of the pond.

(v) Irrigation of Lawns with Effluent

Effluent shall not be used to irrigate lawns unless the following conditions are met :

(a) The sewage to be used for irrigation be trea ed in oxidation ponds, in series, having a minimum detention period of 20 days or treated in a biological treatment plant and disinfected with chlorine.

(b) After being treated as above, the sewage shall meet the bacteriological standard determined by the Director (proposed standard : Coliform MPN of 100/100 milli litres or less in four out of five samples).

(c) The irrigation to be carried out only when the lawns are closed to public.

(vi) Precautions to be taken before irrigation.

Before irrigation with the effluent is carried out, the following precautions shall be taken :

(a) The areas to be irrigated shall be clearly designated with signs, warning in clear and visible letters that sewage irrigation is being carried out.

(b) The pipe network for sewage irrigation be complete disconnected from regular water supply network.

(c) All necessary steps betaken to prevent mosquito, or fly breeding in the area to be irrigated.

(d) All necessary steps be taken to prevent dissemination of odours which may reach residential areas, or other areas in which public is likely to be present.

(e) No spray irrigation with the effluent to be carried out within a distance of 200 m from a residential area or

(vii) Ridge and Furrow Irrigation

Ridge and furrow irrigation with effluent may be carried out if the distance to residential areas is greater than 100 m and the distance to roads is greater than 25 metres.

(viii) Use of effluent in fish ponds.

Effluent should not be used for breeding fish except under the following conditions :

a. Effluent shall not be used in ponds for storing fish before marketing or in tanks used for their transport.

b. Should snails be found, the owner or operator of fish pond shall notify the nearest health office.

c. In the case of snails which serve as vectors of schistosomieasis being found in the pond, the owner or operator shall carry out all instructions given by the director including the drying out of the pond.

APPENDIX C

On August 17, 1962 the State board of Health adopted a regulation governing the use of sewage effluent for irrigation purposes. The regulation is short and consists of two parts, which read as follows:

"Regulation 1 - Treatment required - all sewage or industrial waste effluents usedfor irrigation purposes shall be treated, discharged or disposed of in such a manner that will conform with the requirements of the department".

"Regulation 2 - Approval required = no sewage of industrial waste treatment effluent shall be used for irrigation purposes without written approval from the department. Direct disposal of sewage or industrial waste treatment effluent for irrigation of crops to be used for human consumption or for watering cattle is prohibited."

The regulation prohibited the direct disposal of effluent for irrigation of crops for human consumption. However conditions for unrestricted use in the policy statement are given as follows .

"Complete treatment including chlorination sufficient to give a 0.5 ppm residual after 30 minutes contact time, and discharge of the effluent to an irri-ation canal or ditch having a minimum dilution of ten to one".

Section II of the policy statement is entitled "Condition required where crops not intended for human consumption are to be grown".

Complete treatment provided

1. a. The BOD of the effluent shall not exceed 25 ppm

b. The effluent may be applied directly to the land.

c. Grazing of animals will be allowed, except for dairy cattle.

d. The effluent shall be handled and controlled in a manner so as to prevent po ding , mosquito breeding, or the creation of nuisance.

e. The effluent shall be withdrawn in such a manner that it does not interfere with the sewage treatment plant process.

f. The effluent shall not be permitted to drain on to other lands where contamination of food crops or water supplies may occur.

2. Primary treatment only provided -

a. No grazing of animals shall be allowed.

b. Crops are to be cut and removed before use.

c. No effluent shall be applied to the land, for a period of atleast two weeks prior to harvesting.

d. The effluent shall be handled and controlled in a manner so as to prevent ponding, mosquito bre ding, or the creation of a nuisance.

e. The effluent shall be withdrawn in such a manner that it does not interfere with the sewage plant process.

f. The effluent shall not be permitted to drain into other land where contamination of food crops or water supplies may occur."

'Primary treatment effluent permissible for irrigation of certain instances' is no longer valid since the state has subsequently adopted standards requiring secondary treatment as a minimum for all waste discharges.

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