सत्यमेव जयते

MANUAL ON SEWERAGE AND SEWAGE TREATMENT SYSTEMS

PART A: ENGINEERING - APPENDIX

THIRD EDITION - REVISED AND UPDATED

MINISTRY OF URBAN DEVELOPMENT, NEW DELHI

http://moud.gov.in

CENTRAL PUBLIC HEALTH AND ENVIRONMENTAL ENGINEERING ORGANIZATION

IN COLLABORATION WITH

JAPAN INTERNATIONAL COOPERATION AGENCY

NOVEMBER 2013

In keeping with the advancements in this sector, updates as and when found necessary will be hosted in the Ministry website: http://moud.gov.in/ and the reader is advised to refer to these also.

Copy Edited and Published under contract with JICA by
Creative Environmental Consultants, Chennai, www.cec.ind.in
in association with Water Today, Chennai, www.watertoday.org

APPENDICES

ABBREVIATIONS

AL	Aluminium	LT	Low Tension
ASP	Activated Sludge Process	M	Meter
Avg	Average	MBR	Membrane Bio Reactor
BIS	Bureau of Indian Standards	MBBR	Moving Bed Bio Reactor
BOD	Biochemical Oxygen Demand	ML	Million litres
BOD -T	Biochemical Oxygen Demand - Total	MLD	Million Litres Daily
BOD-S	Biochemical Oxygen Demand - Soluble	MLSS	Mixed Liquor Suspended Solids
CPCL	Chennai Petroleum Corporation Ltd	MPN	Most Probable Number
COD	Chemical Oxygen Demand	ORP	Oxidation Reduction Potential
COD -T	Chemical Oxygen Demand - Total	PAC	Poly Aluminium Chloride
COD-S	Chemical Oxygen Demand - Soluble	S	Slope
DEWAT	Decentralised Wastewater Treatment	SBR	Sequencing Batch Reactor
D O	Dissolved Oxygen	SD	Standard Deviation
E coli	Escherichia Coliform	ST	Sewage Treatment
Fe	Iron	STP	Sewage Treatment Plant
HRT	Hydraulic Retention Time	SVI	Sludge Volume Index
IIT	Indian Institute of Technology	TSS	Total Suspended Solids
KW	Kilowatt	V Valley	Vrishabhavathi valley

Appendix	Title of Appendix	Page
A	Symbols	A-1
AA	List of Indian Standards Relating to Sewerage and Sewage Treatment	A-2
A 1.1	The Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013	A-23
A 1.2	Time frame for fulfilment of responsibilities and certain activities and Implementing Agencies	A-38
A 2.1	Performance of Known Sewage Treatment Processes under Indian Conditions	A-40
A 2.2	Estimation of Future Population	A-47
A 3.1	Computation of Storm Runoff and Design of Storm Sewer	A-50
A 3.2 A	Nomogram for Manning's Formula for Gravity Sewers Flowing Full and Manning's n value of 0.013	A-56
A 3.2 B	Nomogram for Manning's Formula for Gravity Sewers Flowing Full and Manning's n value of 0.013	A-57
A 3.3	MS Excel for Manning Formula for Circular Gravity Pipes Flowing Full	A-58
A 3.4 A	Computations of Diameter, Slopes, Discharges in Gravity Sewers by using Appendix A 3.3	A-59
A 3.4 B	MS Excel for Manning Formula for Circular Gravity Pipes Flowing Full	A-60
A 3.5 A	Nomogram for Hazen Williams Formula for Mains Flowing Full and C value of 100	A-61
A 3.5 B	Nomogram for Hazen Williams Formula for Mains Flowing Full and C value of 100	A-62
A 3.6	Hazen Williams Formula for Circular Sewers Flowing Under Pressure	A-63
A 3.7	Design of sanitary sewer system	A-64
A 3.8	Illustrative Examples for Structural Design of Buried Conduits	A-67
A 3.9	Three Edge Bearing Tests for Pipe Strength	A-74
A 3.10	Relative Limitations on Use of Sewers Pipe Materials in Specific Locations	A-75
A 4.1	Computation of Friction Factor in Pumping Mains	A-78
A 4.2	Calculation of Kw needed for Pumping	A-80
A 4.3	Effects of Silting and Erosion Sewage Pumping Main Performance	A-81
A 4.4	Evaluating Options for Sizing the Sewage Pumping Main and Pump sets	A-85
A 5.1	Odour Control	A-86
A 5.2	Mass Diagram for Raw sewage flow pattern at the koyambedu stp, chennai	A-97
A 5.3	Laboratory	A-98
A 5.4	Minimum Laboratory Equipments Needed for Tests	A-103
A 5.5	Tests Recommended to be Carried Out on Units of Sewage Treatment Plants	A-105

Appendix	Title of Appendix	Page

A 5.6 Example for Hydraulic Design of Mechanically Cleaned Bar Rack and Screen Chamber....A-106
A 5.7 Design Example For Grit Chamber With Proportional Flow Weir As Hydraulic Control Device....A-111
A 5.8 Design Example For Detritor....A-114
A 5.9 Calculating Size of Approach Channel for Parshall Plume....A-115
A 5.10 Detention Times of Clarifiers in STPs Evaluated by NEERI A-116
A 5.11 Illustrative Sizing of Clarifiers in Activated Sludge....A-117
A 5.12 Illustrative Design of conventional ASP aeration....A-119
A 5.13 Design Example of Facultative Aerated Lagoon....A-125
A 5.14 Design Example of Facultative Stabilization Pond....A-127
A 5.15 Design Example for Upflow Anaerobic Sludge Blanket Reactor....A-131
A 5.16 Design Example for Anaerobic Filter....A-132
A 6.1 Illustrative Computation of Sludge weights and volumes from ASP....A-133
A 6.2 Illustrative Calculation Of Sludge Weights....A-136
A 6.3 Friction Losses in Sludge Pipelines Under Gravity and Pumped Conditions....A-138
A 6.4 Design Example of Sludge Digesters....A-140
A 6.5 Design Example of Sludge Drying Beds....A-143
A 7.1 Table of Micro Nutrients to be added to biological systems per month till MLSS builds up to 3000 mg/l for continuous flow reactors....A-144
A 7.2 Table of Micro Nutrients to be added to biological systems per month till MLSS builds up to 3000 mg/l for batch flow reactors....A-145
A 7.3 Case Studies in Recycling and Reuse of Sewage....A-146
A 8.1 Design Example of Interceptor Tank....A-180
A 9.1 Design Example of Leach Pit....A-181
A 9.2 Soil Percolation Test....A-183
A 9.3 Example of Design of Mini-packaged Treatment Plant (On-site construction type)....A-184

References....A-186

APPENDIX - A
Symbols
(Retained as in 1993 edition of this manual and updated)

deg C	degrees centigrade	kwh	kilowatt hour
amp	ampere	l	litre
BOD_5	5 days BOD	lpm	litre per minute
cc	cubic centimetre	lps	litre per second
cm	centimetre	m	metre
CM	cement mortar	m^2	square metre
cumecs	cubic metre per second	m^3	cubic metre
d	day	meq	mill equivalent
eq or eqn	equation	min	minute
F/M	food to micro-organisms ratio	ml	millilitre
GI	galvanised iron	mld	million litres per day
gm	gram	mm	millimetre
h, hr	hour	mps	metre per second
ha	hectare	MWL	maximum water level
HSV	hydraulic subsidence value	ORP	oxidation reduction potential
IS	Indian standard	Pr	primary
kcal	kilo calorie	PSS	percent soluble sodium
kg	kilogram	rph	revolution per hour
kgf	kilogram force	rpm	revolution per minute
kL	kilo litre	S.S.T	secondary sedimentation tank
kLD	kilo litre per day	T	tonnes
km	kilometre	TF	trickling filter
kw	kilowatt	w	watt

APPENDIX.AA-List of Indian Standards Relating to Sewerage and Sewage Treatment

Also refer to (http://www.bis.org.in/) for further Standards under a particular subhead.

No	IS code	Indian Standard
1	SP 7	National Building Code of India 2005 (group 1 to 5)
2	SP 35	Handbook on Water Supply and Drainage with special emphasis on plumbing
3	IS 15883 : Part 1	Construction project management - Guidelines : Part 1 General
4	IS 269	Specification for ordinary and low heat portland cement
5	IS: 383	Specification for coarse and fine aggregates from natural sources for concrete
6	IS: 432	Specification for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement
7	IS: 1786	Specification for high strength deformed steel bars and wires for concrete reinforcement
8	IS 456	Code of practice for plan and reinforced concrete
9	IS 457	Code of practice for general construction of plain and reinforced concrete for dams and other massive structures
10	IS 460 : Part 1	Specification for test sieves part I wire cloth test sieves
11	IS 460 : Part 2	Specification test sieves part II Perforated plate test sieves
12	IS 460 : Part 3	Specification for test sieves : part III methods of examination of apertures of test sieves
13	IS: 2116	Specification for sand for masonry mortars
14	IS: 2250	Code of practice for preparation and use of masonry mortars
15	IS 962	Code of practice for architectural and building drawings
16	IS 1200 : Part 16	Code of practice for architectural and building drawings
17	IS 1200 : Part 19	Method of measurement of building and civil engineering works Part 19: water supply, plumbing and drains

No	IS code	Indian Standard
18	IS 1343	Code of practice for prestressed concrete
19	IS 1554 : Part 1	PVC insulated (heavy duty) electric cables: Part 1 For working voltage up to and including 1100 volts
20	IS 1554 : Part 2	PVC insulated (heavy duty) electric cables: Part 2 For working voltage form 3.3 KV up to and including 11 KV.
21	IS 1607	Methods for test sieving
22	IS 2064	Code of practice for selections, installation and maintenance of sanitary appliances
23	IS 2212	Code of practice for brickworks
24	IS 2431	Steel wheel barrows (single wheel type) Specification for steel wheel barrows (single
25	IS 3370 : Part 1	Code of practice for concrete structures for the storage of liquids; part 1 General requirements
26	IS 3370 : Part 2	Code of practice for concrete structures for the storage of liquids: Part II reinforced concrete structures.
27	IS 3370 : Part 3	Code of practice for concrete structures for the storage of liquids: Part II Prestressed Concretes Structures.
28	IS 3370 : Part 4	Code of practices of concrete structures for the storage of liquids: Part IV Design tables.
29	IS 3764	Safety code for excavation work.
30	IS 3861	Method of measurement of plinth, carpet and rentable area of buildings
31	IS 4081	Safety code for blasting and related drilling operations.
32	IS 4682 : Part 1	Code of practice of for lining of vessels and equipment for chemical processes Part I Rubber lining.
33	IS 1200 : Part 16	Part 2 Glass Enamel lining
34	IS 4682 : Part 3	Part 3 Lead lining
35	IS 4682 : Part 4	Part 4 Lining with Sheet Thermoplastics

No	IS code	Indian Standard
36	IS 4682 : Part 5	Part 5 Epoxide resin lining
37	IS 4682 : Part 6	Part 6 Phenolic resin lining
38	IS 4682 : Part 7	Part 7 Corrosion and heat resistant metals
39	IS 4682 : Part 8	Part 8 Precious metal
40	IS 4682 : Part 9	Part 9 Titanium
41	IS 4682 : Part 10	Part 10 Brick and tile
42	IS 4854 : Part 1	Glossary of terms for valves and their parts: Part 1 Screw down stop check and gate valve and their parts.
43	IS 4854 : Part 2	Glossary of terms for valves and their parts: Part 2 Plug valves and cocks and their parts.
44	IS 4854 : Part 3	Glossary of terms for valves and their parts: Part 3 Butterfly valves
45	IS 4885	Specification for sewer bricks
46	IS 4926	Ready mixed concrete - Code of Practice
47	IS 5421	Glossary of terms relating to test sieves and test sieving
48	IS 5742 : Part 1	Terms and symbols for sieve bottoms: Part 1 Woven and welded wire screens
49	IS 5742 : Part 2	Terms and symbols for sieve bottoms: Part II Perforated Plates.
50	IS 7331	Code of practice for inspection and maintenance of cross-drainage works
51	IS 7357	Code of practice for structural design of surge tanks
52	IS 7784 : Part 1	Code of practice for design and of cross drainage work : Part 1 General features
53	IS 7784 : Part 2 : Sec 1	Code of practice for design of cross drainage works: Part 2 Specific requirements section 1 Aqueducts.
54	IS 7784 : Part 2 : Sec 2	Code of practice for design of cross drainage works: Part 2 specific requirements section 2 Super passages.
55	IS 7784 : Part 2 : Sec 3	Code of practice for design of cross drainage works : Part 2 Specific requirements section 3 Canal syphons

No	IS code	Indian Standard
56	IS 7784 : Part 2 : Sec 4	Code of practice for design of cross drainage works : Part 2 Specific requirements section 4 Level Crossings
57	IS 7784 : Part 2 : Sec 5	Code of practice for design of cross drainage works : Part 2 Specific requirements section 5 Syphon aqueducts
58	IS 7861 : Part 1	Code of practice for extreme weather concreting part 1 Recommended practice for hot weather concreting
59	IS 7861 : Part 2	Code of practice for extreme weather concerting: Part II Recommended practice for cold weather concreting.
60	IS 7969	Safety code for handling and storage of building materials
61	IS 9913	Code of practice for construction of cross drainage works
62	IS 10262	Recommended guidelines for concrete mix design proportioning
63	IS 10483	Code for designating perforation of industrial plate sieves (Identical with ISO/DIS 7806)
64	IS 11389	Methods of test for performance of concrete vibrators; immersion type
65	IS 11993	Code of practice tor use of screed board concrete vibrators.
66	IS 12119	General requirements for pan mixers for concrete
67	IS 12440	Specification for precast concrete stone masonry blocks
68	IS: 1077	Specification for common burnt clay building bricks
69	IS: 3495	Methods of tests of burnt clay building bricks
70	IS 12468	General requirements for vibrators for mass concreting : immersion type
71	IS 12592	Precast concrete manhole covers and frames
72	IS 5329	Code of practice for sanitary pipe work above ground for buildings
		Pipes and Fittings
73	IS 782	Specification for Caulking lead
74	IS 5382	Specification for Rubber sealing rings for gas mains, water mains and sewers
75	IS 6837	Specification for Three wheel type pipe cutter

No	IS code	Indian Standard
76	IS 6843	Technical supply conditions for pipe cutters
77	IS 6881	Specification for Link type pipe cutters
78	IS 10883	Specification for Single wheel type pipe cutters
79	IS 11906	Recommendations for cement-mortar lining for cast-iron, mild steel and ductile-iron pipes and fittings for transportation of water
80	IS 12820	Dimensional requirements for rubber gaskets for mechanical joints and bush joints for use with cast iron pipes water, gas and sewage. Dimensional Requirements of Rubber Gaskets for Mechanical Joints and Push-on Joints for Use with Cast Iron Pipes and Fit
		Concrete
81	IS 458	Precast Concrete Pipes (with and without reinforcement)
82	IS 783	Code of practice for laying of concrete pipes
83	IS 784	Prestressed concrete pipes (including fittings)
84	IS 1916	Steel cylinder pipe with concrete lining and coating
85	IS 3597	Methods of test for concrete pipes
86	IS 7322	Specials for steel cylinder reinforced concrete pipes
87	IS: 516	Methods of tests for strength of concrete
		Asbestos Cement
88	IS 6908	Asbestos cement pipes and fittings for sewerage and drainage
89	IS 5531	Cast iron specials for asbestos cement pressure pipes for water, Gas and Sewage
90	IS 5913	Methods of test for asbestos cement products
91	IS 6530	Code of practice for laying of asbestos cement pressure pipes
92	IS 8794	Cast iron detachable joints for use with asbestos cement pressure pipe
93	IS 9627	Specification for asbestos cement pressure pipes (light duty)

No	IS code	Indian Standard
94	IS 10232	Dimensional requirement for rubber sealing rings for cast iron detachable joints in asbestos cement piping
95	IS 10299	Cast Iron saddle pieces for service connection from asbestos cement pressure pipes
96	IS 11769 : Part 1	Guidelines for safe use of products containing asbestos: Part 1 Asbestos cement products
97	IS 12987	Guidelines for safe use of products containing asbestos- Cast Iron detachable joints for use with asbestos cement pressure pipes (light duty)
98	IS 12988	Dimensional requirements for rubber sealing rings for CID joints in asbestos cement piping for light duty AC pipes
		Cast Iron pipes
99	IS 1729	Cast iron rain water pipes and fittings. Cast iron/Ductile iron Drainage Pipes and Pipe Fittings for over ground non pressure pipeline socket and spigot series.
100	IS 1536	Centrifugally cast (spun) iron pressure pipe for water, gas and sewage
101	IS 1537	vertically cast iron pressure pipes for water, gas and sewage
102	IS 1538	Cast iron Fittings for pressure pipes for water, gas and sewerage
103	IS 1879	Malleable cast iron pipe fittings
104	IS 3114	Code for practice for laying of cast iron pipes
105	IS 3989	Centrifugally cast (spun) iron spigot and socket soil, waste and ventilating pipes, fittings and accessories
106	IS 12592	Horizontally cast iron double flanged pipes for water, gas and sewage
107	IS 8329	Centrifugally cast (spun) ductile iron pressure pipes for water gas and sewage
108	IS 11606	Methods of sampling of cast iron pipes and fittings.
109	IS 12288	Code of practice for use and laying of ductile iron pipes
		Steel

No	IS code	Indian Standard
110	IS 3589	Electrically welded steel pipes for water, gas and sewage (150 to 2000 mm nominal size)
111	IS 5504	Specification for Spiral welded pipes
112	IS 5822	Code of practice for laying of electrically welded steel pipes for water supply
113	IS 6392	Steel pipe flanges
114	IS 8062 : Part 2	Code of Practice for Cathodic Protection of Steel Structures - Part II : Underground Pipelines
		Stoneware
115	IS 651	Glazed stoneware pipe and fittings - Specification
116	IS 3006	Chemical resistant glazed stoneware pipes and fitting
117	IS 4127	Code of practice for laying of glazed stoneware pipes
		Plastic (Please also refer no 357 and 358)
118	IS 4984	High density polyethylene pipes for potable water supplies, sewage and industrial effluents
119	IS 7634 : Part 1	Code of practice for plastic pipe work for potable water supplies-Choice of materials and general recommendations
120	IS 7634 : Part 2	Code of practice for plastics pipe work for potable water supplies-Laying and jointing of polyethylene (PE) pipes.
121	IS 7634 : Part 3	Plastics Pipe Selection, Handling, Storage and Installation for Potable Water Supplies - Code of Practice : Part 3 - Laying and Jointing of UPVC Pipes
122	IS 8008 : Part 1	Specification for injection moulded HDPE fittings for potable water supplies: Part 1 General requirements
123	IS 8008 : Part 2	Specification for injection moulded HDPE fittings for potable water supplies: Part 2 Specific requirements for 90 degrees bends.
124	IS 8008 : Part 3	Specification for injection moulded HDPE fittings for potable water supplies: Part 3 Specific requirements for 90 degrees tees.

No	IS code	Indian Standard
125	IS 8008 : Part 4	Specification for injection moulded HDPE fittings for potable water supplies: Part 4 Specific requirements for reducers.
126	IS 8008 : Part 5	Specification for injection moulded HDPE fittings for potable water supplies: Part 5 Specific requirements for ferrule reducers.
127	IS 8008 : Part 6	Specification for injection moulded HDPE fittings for potable water supplies: Part 6 Specific requirements for pipe ends.
128	IS 8008 : Part 7	Specification for injection moulded HDPE fittings for potable water supplies: Part 7 Specific requirements for sandwich flanges
129	IS 8008 : Part 8	Injection Moulded/Machined High Density Polyethylene (HDPE) Fittings for Potable Water Supplies - : Part 8 Specific Requirements for Reducing Tees
130	IS 8008 : Part 9	Injection Moulded/Machined High Density Polyethylene (HDPE) Fittings for Potable Water Supplies - : Part 9 Specific Requirements for Ends Caps
131	IS 8360 : Part 1	Fabricated high density polyethylene (HDPE) fittings for potable water supplies: Part 1 General requirements
132	IS 8360 : Part 2	Specification for Fabricated high density polyethylene (HDPE) fittings for potable water supplies: Part 2 Specific requirements for 90 degree tees.
133	IS 8360 : Part 3	Specification for Fabricated high density polyethylene (HDPE) fittings for potable water supplies: Part 3 Specific requirements for 90 degree bends.
134	IS 12709	Specification to glass fibre reinforced plastics (GRP) pipes for use for water supply
135	IS 14402	GRP pipes joints and fittings for use sewerage, industrial waste and water (other than potable)
136	IS 15328	Unplasticized Non-Pressure Polyvinyl Chloride (PVC -U) Pipes for use in Underground Drainage and Sewerage Systems
137	IS: 9271	Unplasticized Polyvinyl Chloride (UPVC) Single Wall Corrugated Pipes for Drainage
		Pitch Impregnated Fibre
138	IS 11925	Specification for pitch-impregnated fibre pipes and fittings for drainage purposes
		Public Health & Sanitation

No	IS code	Indian Standard
		Waste water handling equipment
139	IS 5600	Pumps - Sewage and Drainage - Specification
140	IS 6279	Specification for Equipment for grit removal devices
141	IS 6280	Specification for Sewage screens
142	IS 7232	Method for imhoff cone test.
143	IS 8413 : Part 1	Requirements for biological treatment equipment part 1 trickling filters
144	IS 8413 : Part 2	Requirements for biological treatment equipment part 2 activated sludge process and its modifications
145	IS 9110	Specification for Hand operated augers for cleaning water closets, pipes and sewers.
146	IS 9213	Specification for BOD Bottle
147	IS 10037 : Part 1	Requirements for sludge dewatering equipment Part 1 Sludge drying beds-sand, gravel and under drains.
148	IS 10037 : Part 2	Requirements for sludge dewatering equipment Part 2 vacuum filtration equipment
149	IS 10037 : Part 3	Requirements for sludge dewatering equipment Part 3 Centrifugal equipment (Solid bowl type)
150	IS 10261	Requirements for settling tank (clarifier equipment) for waste wafer
151	IS 10552	Specification for buckets to be used in power driven buckets type sewer cleaning machine
152	IS 10553 : Part 1	Requirements for chlorination equipment: Part I General guidelines for chlorination plants including handling, storage and safety of chlorine cylinders and drums
153	IS 10553 : Part 2	Requirements for chlorination equipment: Part 2 Vacuum feed type chlorinators
154	IS 10553 : Part 4	Requirements for chlorination equipment: Part 4 Gravity feed type gaseous chlorinators

No	IS code	Indian Standard
155	IS 10553 : Part 5	Requirements of chlorination equipment: Part 5 Bleaching powder solution feeder displacement type chlorinator
156	IS 10595	Requirements for power driven bucket-type sewer cleaning machine
157	IS 11117	Requirements for power driven rodding machine for sewers.
158	IS 11387	Requirements for high pressure jetting machine for sewer cleaning.
159	IS 11397	Specification for attachment tools for power driven rodding machine for sewers.
		Code of Practice
160	IS 1172	Code of basic requirements for water supply, drainage and sanitation
161	IS 2527	Code of practice for fixing rainwater gutters and downpipes for roof drainage
162	IS 1742	Code of practice for Building drainage
163	IS 2470 : Part 1	Code of practice for installation of septic tanks; Part 1 Design, criteria and construction
164	IS 2470 : Part 2	Code of practice for installation of septic tanks : Part 2 secondary treatment and disposal of septic tank effluent
165	IS 9872	Precast concrete septic tanks
166	IS 4111 : Part 1	Code of practice for ancillary structures in sewerage system -Manholes
167	IS 4111 : Part 2	Code of practice for ancillary structures in sewerage system -Flushing tanks
168	IS 4111 : Part 3	Code of practice for ancillary structures in sewerage system Inverted syphon
169	IS 4111 : Part 4	Code of practice for ancillary structures in sewerage system-Pumping stations and pumping mains (rising main).
170	IS 4111 : Part 5	Code of practice for ancillary structures in sewerage system-Tidal outfalls
171	IS 5455	Specification for cast-iron steps for manholes
172	IS 210	Specification for grey iron castings

No	IS code	Indian Standard
173	IS 5329	Code of practice for sanitary pipe work above ground for buildings
174	IS 5611	Code of practice for waste stabilization ponds (facultative type)
175	IS 6295	Code of practice for water supply and drainage in high attitudes and/or sub-zero temperature regions (first revision)
176	IS 6924	Code of practice for the construction of refuse chutes in multi-storeyed buildings
177	IS 7740	Code of practice for construction and maintenance of road gullies
178	IS 9872	Specifications for precast concrete septic tanks.
179	IS 12251	Code of practice for drainage of building basements
180	IS 12314	Code of practice for sanitation with leaching pits for rural communities.
181	IS 11972	Code of practice for safety precautions to be taken when entering a sewerage system
		Solid wastes
		Code of practice
182	S 10447	Guidelines for utilization and disposal of solid waste from integrated steel plants.
183	IS 12647	Guidelines for collection equipments. Solid Waste Management System - Collection Equipment
184	IS 12662 : Part 1	Guidelines for use of vehicles for collection of municipal solid wastes : Part 1 Selection of vehicles
185	IS 12662 : Part 2	Vehicles for Collection of Municipal Solid Wastes - Part 2 : Guidelines for Maintenance
		Methods of testing
186	IS 9234	Methods for preparation of solid waste sample for chemical and microbiological analysis.
187	IS 9235	Methods for physical analysis and determination of moisture in solid wastes (excluding industrial wastes)
188	IS 10158	Method of analysis of solid wastes (Excluding industrial wastes)

No	IS code	Indian Standard
		Glossary of Terms-Water Pollution
189	IS 7022 : Part 1	Glossary of terms relating to water, sewage and industrial effluent part 1
190	IS 7022 : Part 2	Glossary of terms relating to water, sewage and industrial effluent part 2
191	IS 10446	Glossary of terms for water supply and sanitation.
		Methods of sampling and analysis- Sewage and industrial effluents
192	IS 6582	Bio-assay methods for evaluating acute toxicity of industrial effluents and waste waters.
193	IS 6582 : Part 2	Bio-assay methods for evaluating acute toxicity of industrial effluents and wastewaters : Part 2 Using Toxicity Factor to Zebra Fish
		Methods of sampling and analysis- wastewater
194	IS 1622	Methods of sampling and microbiological examination of water
195	IS 3025 : Part 1	Methods of sampling and test (physical and chemical) for water and wastewater-Sampling
196	IS 3025 : Part 2	Methods of Sampling and Test (Physical and Chemical) for water and Wastewater - Part 2 : Determination of 33 Elements by Inductively Coupled Plasma Atomic Emission Spectroscopy
197	IS 3025 : Part 3	Methods of Sampling and Test (Physical and Chemical) for water and Wastewater - Part 3 : Precision and Accuracy
198	IS 3025 : Part 4	Methods of Sampling and Test (Physical and Chemical) for water and Wastewater - Part 4 : Colour
199	IS 3025 : Part 5	Methods of sampling and test (physical and chemical) for water and wastewater-Odour
200	IS 3025 : Part 6	Methods of sampling and test (physical and chemical) for water and wastewater-Odour threshold
201	IS 3025 : Part 7	Methods of sampling and test (physical and chemical) for water and wastewater-Taste threshold
202	IS 3025 : Part 8	Methods of sampling and test (physical and chemical) for water and wastewater-Taste rating
203	IS 3025 : Part 9	Methods of sampling and test (physical and chemical) for water and wastewater-Temperature
204	IS 3025 : Part 10	Methods of sampling and test (physical and chemical) for water and wastewater-Turbidity

No	IS code	Indian Standard
205	IS 3025 : Part 11	Methods of sampling and test (physical and chemical) for water and wastewater-PH Value
206	IS 3025 : Part 14	Methods of sampling and test (physical and chemical) for water and wastewater-Specific conductance (Wheatstone bridge, conductance cell)
207	IS 3025 : Part 15	Methods of sampling and test (physical and chemical) for water and wastewater-Total residue (total solids- dissolved and suspended)
208	IS 3025 : Part 16	Methods of sampling and test (physical and chemical) for water and wastewater-Filterable residue (Total Dissolved solids)
209	IS 3025 : Part 17	Methods of sampling and test (physical and chemical) for water and wastewater-Non-filterable residue (total suspended solid)
210	IS 3025 : Part 18	Methods of sampling and test (physical and chemical) for water and wastewater-Volatile and fixed residue (total filterable and non filterable)
211	IS 3025 : Part 19	Methods of sampling and test (physical and chemical) for water and wastewater-Settle able matter
212	IS 3025 : Part 20	Methods of sampling and test (physical and chemical) for water and wastewater-Volatile and fixed residue (total filterable and non filterable)
213	IS 3025 : Part 21	Methods of sampling and test (physical and chemical) for water and wastewater-Total hardness
214	IS 3025 : Part 22	Methods of sampling and test (physical and chemical) for water and wastewater-Acidity
215	IS 3025 : Part 23	Methods of sampling and test (physical and chemical) for water and wastewater-Alkalinity
216	IS 3025 : Part 24	Methods of sampling and test (physical and chemical) for water and wastewater-Sulphates
217	IS 3025 : Part 25	Methods of sampling and test (physical and chemical) for water and wastewater-Chlorine, demand
218	IS 3025 : Part 26	Methods of sampling and test (physical and chemical) for water and wastewater-Chlorine, residual
219	IS 3025 : Part 27	Methods of sampling and test (physical and chemical) for water and wastewater-Cyanide
220	IS 3025 : Part 28	Methods of sampling and test (physical and chemical) for water and wastewater-Sulphite
221	IS 3025 : Part 29	Methods of sampling and test (physical and chemical) for water and wastewater-Sulphide

No	IS code	Indian Standard
222	IS 3025 : Part 30	Methods of sampling and test (physical and chemical) for water and wastewater-Bromide
223	IS 3025 : Part 31	Methods of sampling and test (physical and chemical) for water and wastewater-Phosphorous
224	IS 3025 : Part 32	Methods of sampling and test (physical and chemical) for water and wastewater-Chloride
225	IS 3025 : Part 33	Methods of sampling and test (physical and chemical) for water and wastewater-Iodide
226	IS 3025 : Part 34	Methods of sampling and test (physical and chemical) for water and wastewater-Nitrogen
227	IS 3025 : Part 35	Methods of sampling and test (physical and chemical) for water and wastewater-Silica
228	IS 3025 : Part 36	Methods of sampling and test (physical and chemical) for water and wastewater-Ozone, residual
229	IS 3025 : Part 37	Methods of sampling and test (physical and chemical) for water and wastewater-Arsenic
230	IS 3025 : Part 38	Methods of sampling and test (physical and chemical) for water and wastewater-Dissolved oxygen
231	IS 3550	Methods of test for routine control for water used in industry.
		Treatment and Disposal of industries effluents
232	IS 7967	Criteria for controlling pollution of marine coastal areas.
233	IS 8032	Guide for treatment and disposal of distillery effluents.
234	IS 8073	Guide for treatment and disposal of steel plant effluents
235	IS 8682	Guide for treatment of effluents of dairy industry
236	IS 9427	Code of practice for operation and maintenance of deionizing columns
237	IS 9508	Guide for treatment and disposal of effluents of cotton and synthetic textile industry.
238	IS 9509	Guide for treatment and disposal of effluents of viscose rayon industry

No	IS code	Indian Standard
239	IS 9841	Guide for treatment and disposal of effluents of fertilizer industry.
240	IS 10044	Guide for treatment and disposal of effluents of petroleum refining industry.
241	IS 10495	Guide for treatment and disposal of effluents of wool processing industry
		Chemical hazards
		General
242	IS 1446	Classification of dangerous goods.
243	IS 4155	Glossary of terms relating to chemical and radiation hazards and hazardous chemicals
		Code of Safety
244	IS 4209	Code of safety in Chemical laboratories
245	IS 4262	Sulphuric acid- Code of safety
246	IS 4263	Code of safety for Chlorine
247	IS 4264	Code of safety for Caustic soda
248	IS 4312	Code of safety for Lead and its compounds
249	IS 4544	Ammonia- Code of safety
250	IS 4560	Code of safety for Nitric Acid
251	IS 4644	Code of safety for Benzene, toluene and xylene
252	IS 4906	Code of safety for Radiochemical laboratory
253	IS 5184	Code of safety for Hydrofluoric Acid
254	IS 5208	Code of safety for Acetic acid
255	IS 5311	Acetic anhydride Code of safety for Carbon Tetrachloride
256	IS 5685	Carbon Tetrachloride Code of safety for Carbon Disulphide (Carbon Bisulphide)

No	IS code	Indian Standard
257	IS 5931	Code of safety for Handling of cryogenic liquids
258	IS 6156	Code of safety for Chlorosulphonic acid
259	IS 6164	Code of safety for Hydrochloric acid
260	IS 6269	Code of safety for Ethylene oxide
261	IS 6270	Code of safety for Phenol
262	IS 6818	Code of safety for Phosphoric acid
263	IS 6819	Code of safety for Calcium carbide
264	IS 6955	Code of safety for Bromine
265	IS 6954	Code of safety for Caustic potash
266	IS 7415	Code of safety for Aniline
267	IS 7420	Code of safety for phthalic anhydride
268	IS 7444	Code of safety for Methanol
269	IS 7445	Code of safety for Acetone
270	IS 7812	Code of safety for Mercury
271	IS 8185	Code of safety for Phosgene
272	IS 8388	Code of safety for Nitrobenzene
273	IS 9052	Code of safety for Aluminium chloride, anhydrous
274	IS 9053	Code of safety for M-dinitrobenzene
275	IS 9277	Code of safety for Monochlorobenzene
276	IS 9278	Code of safety for Zinc phosphide
277	IS 9279	Code of safety for Aluminium phosphide
278	IS 9744	Code of safety for thionyl chloride
279	IS 9785	Code of safety for Aluminium alkyls
280	IS 9786	Code of safety for Vinyl chloride monomer (VCM)

No	IS code	Indian Standard
281	IS 9787	Code of safety for Phosphoryl chloride
282	IS 10870	Code of safety for Hexane
283	IS 10872	Code of safety for Malathion
284	IS 10920	Code of safety for Phosphorus Trichloride
285	IS 11141	Code of safety for Acrylonitrile
286	IS 12033	Code of safety for Dinitro Toluene (DNT)
287	IS 12034	Code of safety for Methyl bromide
288	IS 12035	Code of safety in Microbiological Laboratories
289	IS 12141	Code of safety for methyl ethyl ketone
290	IS 12142	Code of safety for 1.1.1 trichloro ethane
291	IS 12143	Code of safety for tetrachloroethane
		Sanitary Appliances & Valves
292	IS 771 : Part 1	Specification for glazed fire clay sanitary appliances: part 1 General requirements.
293	IS 771 : Part 2	Specification for glazed fire-clay sanitary appliances : part 2 specific requirements of kitchen and laboratory sinks
294	IS 771 : Part 3 : Sec 1	Specification for glazed fire-clay sanitary appliances part 3 specific requirements of urinals section 1 slab urinals
295	IS 771 : Part 3 : Sec 2	Specification for glazed fire-clay sanitary appliances part 3 specific requirements of urinals section 2 stall urinals
296	IS 771 : Part 4	Specification for glazed fire-clay sanitary appliances part 4 specific requirements of post-mortem slabs
297	IS 771 : Part 5	Specification for glazed fire-clay sanitary appliances part 5 specific requirements of shower trays
298	IS 771 : Part 6	Specification for glazed fire-clay sanitary appliances part 6 specific requirements of bed pan sinks
299	IS 771 : Part 7	Specification for glazed fire-clay sanitary appliances part 7 specific requirements of slope sinks

No	IS code	Indian Standard
300	IS 772	Specification for general requirements for enamelled cast iron sanitary appliances
301	IS 774	Specification for flushing cistern for water closets and urinals (other than plastic cisterns)
302	IS 14846	Specification for Sluice Valve for Water Works Purposes (50 to 1200 mm Size)
303	IS 1726	Specification for cast iron manhole covers and frames
304	IS: 5455	Specification for cast iron steps for manholes
305	IS 2064	Code of practice for selection, installation and maintenance of sanitary appliances
306	IS 2326	Specification for automatic flushing cisterns for urinals
307	IS 2548 : Part 1	Specification for plastic seats and covers for water closets : part 1 Thermo set seats and covers
308	IS 2548 : Part 2	Specification for plastic seats and covers for water closets : part 2 Thermo set plastic seats and covers
309	IS 2556 : Part 1	Specification for vitreous sanitary appliances (vitreous china) : Part 1 General requirements
310	IS 2556 : Part 2	Specification for vitreous sanitary appliances (Vitreous china) : part 2 specific requirements of wash down water-closets
311	IS 2556 : Part 3	Specification for vitreous sanitary appliances (Vitreous china) : part 3 specific requirements of squatting pans
312	IS 2556 : Part 4	Specification for vitreous sanitary appliances (Citreous china): part 4 specific requirements of wash basins
313	IS 2556 : Part 5	Specification for vitreous sanitary appliances (vitreous china) : part 5 specific requirements of laboratory sinks
314	IS 2556 : Part 6	Specific requirement of urinals and partition plates
315	IS 2556 : Part 7	Specification for vitreous sanitary appliances (vitreous china) Part 7 Specific requirements of half round channels Specific requirements of accessories for sanitary appliances
316	IS 2556 : Part 8	Specification for vitreous sanitary appliances (vitreous china) Part 8 Specific requirements of pedestal closed coupled wash-down and syphonic water closets

No	IS code	Indian Standard
317	IS 2556 : Part 9	Specification for vitreous sanitary appliances (vitreous china) : Part 9 Specific requirements of pedestal type bidets
318	IS 2556 : Part 14	Specification tor vitreous sanitary appliances (vitreous china): Part 14 Specific requirements of integrated squatting pans.
319	IS 2556 : Part 15	Specification for vitreous sanitary appliances (vitreous china) Part 15 specific requirements of universal water closets.
320	IS 2685	Code of practice for selection, installation and maintenance of sluice valves
321	IS 2963	Specification for copper alloy waste fittings for wash basins and sinks
322	IS 3042	Specification for single faced sluice gates (200 to 1200 mm size)
323	IS 3311	Specification for waste plug and its accessories for sinks and wash-basins
324	IS 3950	Specification for surface boxes for sluice valves
325	IS 4038	Specification for foot valves for water works purposes
326	IS 4346	Specification for washers for use with fittings for water services
327	IS 5219	Specification for cast copper alloys traps, part 1 ‘P’ and S’ traps
328	IS 5312 : Part 1	Swing Check Type Reflux (Non-Return] Valves for Water Works Purposes - Part 1 : Single-Door Pattern
329	IS 5312 : Part 2	Swing Check Type Reflux (non-return) Valves for Water Works Purpose - Part 2 : Multi-Door Pattern
330	IS 5961	Cast iron gratings for drainage purposes
331	IS 6411	Gel-coated glass fibre reinforced polyester resin bath tubs
332	IS 7231	Plastic flushing cisterns for water closets and urinals
333	IS 9739	Specification for pressure reducing valves for domestic water supply systems.
334	IS 9758	Specification for flush valves and fittings for water closets and urinals
335	IS 9762	Specification for polyethylene floats (spherical) for float valves

No	IS code	Indian Standard
336	IS 11246	Specification for glass fibre reinforced polyester resins (GRP) squatting pans
337	IS 12234	Specification for plastic equilibrium float valves for cold water services
338	IS 12701	Specification for rotational moulded polyethylene water storage tanks.
		Fluid Flow Measurements
339	IS 1192	Velocity area methods for measurement of flow of water in open channels.
340	IS 2912	Liquid Flow Measurement in Open Channels - Slope Area Method
341	IS 15122	Measurement of Liquid Flow in Open Channels Under Tidal Conditions
342	IS 15119 : Part 1	Measurement of Liquid Flow in Open Channels - Part 1 : Establishment and Operation of a Gauging Station
343	IS 15119 : Part 2	Measurement of Liquid Flow in Open Channels - Part 2 : Determination of the Stage-Discharge Relation
344	IS 14615 : Part 1	Measurement of Fluid Flow by Means of Pressure Differential Devices - Part 1 : Orifice Plates, Nozzles and Venturi Tubes Inserted in Circular cross-section conduits running full
345	IS 4477 : Part 2	Methods of measurement of fluid flow by means of venturi meters Part 2 compressible fluids
346	IS 14974	Liquid flow Measurement in Open Channels by Weirs and Flumes - Rectangular Broad-crested Weirs
347	IS 6062	Method of measurement of flow of water in open channels using standing wave flume - fall.
348	IS 6063	Method of measurement of flow of water in open channels using standing wave flumes
349	IS 6330	Liquid Flow Measurement in Open Channels by Weirs and Flumes - End Depth Method for Estimation of Flow in Rectangular Channels with a Free Overfall (Approximate Method)
350	IS 9108	Liquid flow measurement in open channels using thin plate weirs
351	IS 9115	Method for estimation of incompressible fluid flow in closed conduits by bend meters
352	IS 14574	Measurement of Liquid Flow in Open Channels by Weirs and Flumes - End Depth Method for Estimation of Flow in Non-rectangular Channels with a Free Overfall (Approximate Method)

No	IS code	Indian Standard
353	IS 9119	Method for flow estimation by jet characteristics (approximate method).
354	IS 9163 : Part 1	Dilution methods of measurement of steady flow part 1 constant rate injection method.
355	IS 9922	Measurement of Liquid Flow in Open Channels - General Guidelines for Selection of Method
356	IS 12752	Guidelines for the selection of flow gauging structures
357	IS 16098 : Part 1	Structured Wall Plastics Piping Systems for Non-pressure Drainage and Sewerage, Pipes and Fittings with smooth external surface, Type A
358	IS 16098 : Part 2	Structured Wall Plastics Piping Systems for Non-pressure Drainage and Sewerage, Pipes and Fittings with non-smooth external surface, Type B.

Note: For the elaborate list refer to the Bureau of Indian Standards.

APPENDIX A.1.1 THE PROHIBITION OF EMPLOYMENT AS MANUAL SCAVENGERS AND THEIR REHABILITATION ACT, 2013

रजिस्ट्री सं॰ डी॰ एल॰—(एन)04/0007/2003—13 REGISTERED NO. DL—(N)04/0007/2003—13

भारत का राजपत्र
The Gazette of India

असाधारण
EXTRAORDINARY
भाग II — खण्ड 1
PART II — Section 1
प्राधिकार से प्रकाशित
PUBLISHED BY AUTHORITY

सं॰ 35] नई दिल्ली, बृहस्पतिवार, सितम्बर 19, 2013/ भाद्र 28, 1935 (शक)
No. 35] NEW DELHI, THURSDAY, SEPTEMBER 19, 2013/ BHADRA 28, 1935 (SAKA)

इस भाग में भिन्न पृष्ठ संख्या दी जाती है जिससे कि यह अलग संकलन के रूप में रखा जा सके।
Separate paging is given to this Part in order that it may be filed as a separate compilation.

MINISTRY OF LAW AND JUSTICE

(Legislative Department)

New Delhi, the 19*th September*, 2013/*Bhadra* 28, 1935 (*Saka*)

The following Act of Parliament received the assent of the President on the 18th September, 2013, and is hereby published for general information:—

THE PROHIBITION OF EMPLOYMENT AS MANUAL SCAVENGERS AND THEIR REHABILITATION ACT, 2013

NO. 25 OF 2013

[18*th September*, 2013.]

An Act to provide for the prohibition of employment as manual scavengers, rehabilitation of manual scavengers and their families, and for matters connected therewith or incidental thereto.

WHEREAS promoting among the citizens fraternity assuring the dignity of the individual is enshrined as one of the goals in the Preamble to the Constitution;

AND WHEREAS the right to live with dignity is also implicit in the Fundamental Rights guaranteed in Part III of the Constitution;

AND WHEREAS article 46 of the Constitution, *inter alia,* provides that the State shall protect the weaker sections, and, particularly, the Scheduled Castes and the Scheduled Tribes from social injustice and all forms of exploitation;

AND WHEREAS the dehumanising practice of manual scavenging, arising from the continuing existence of insanitary latrines and a highly iniquitous caste system, still persists in various parts of the country, and the existing laws have not proved adequate in eliminating the twin evils of insanitary latrines and manual scavenging;

AND WHEREAS it is necessary to correct the historical injustice and indignity suffered by the manual scavengers, and to rehabilitate them to a life of dignity.

BE it enacted by Parliament in the Sixty-fourth Year of the Republic of India as follows:—

CHAPTER I

PRELIMINARY

Short title, extent and commencement.

1. (*1*) This Act may be called the Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013.

(*2*) It extends to the whole of India except the State of Jammu and Kashmir.

(*3*) It shall come into force on such date as the Central Government may, by notification in the Official Gazette, appoint:

Provided that the date so notified shall not be earlier than sixty days after the date of publication of the notification in the Official Gazette.

Definitions.

2. (*1*) In this Act, unless the context otherwise requires,—

(*a*) "agency" means any agency, other than a local authority, which may undertake sanitation facilities in an area and includes a contractor or a firm or a company which engages in development and maintenance of real estate;

(*b*) "appropriate government", in relation to Cantonment Boards, railway lands, and lands and buildings owned by the Central Government, a Central Public Sector Undertaking or an autonomous body wholly or substantially funded by the Central Government, means the Central Government and in all other cases, the State Government;

(*c*) "Chief Executive Officer", in relation to a Municipality or Panchayat, means, its senior-most executive officer, by whatever name called;

(*d*) "hazardous cleaning" by an employee, in relation to a sewer or septic tank, means its manual cleaning by such employee without the employer fulfilling his obligations to provide protective gear and other cleaning devices and ensuring observance of safety precautions, as may be prescribed or provided in any other law, for the time being in force or rules made thereunder;

(*e*) "insanitary latrine" means a latrine which requires human excreta to be cleaned or otherwise handled manually, either *in situ*, or in an open drain or pit into which the excreta is discharged or flushed out, before the excreta fully decomposes in such manner as may be prescribed:

Provided that a water flush latrine in a railway passenger coach, when cleaned by an employee with the help of such devices and using such protective gear, as the Central Government may notify in this behalf, shall not be deemed to be an insanitary latrine.

(*f*) "local authority" means,—

(*i*) a Municipality or a Panchayat, as defined in clause (*e*) and clause (*f*) of article 243P of the Constitution, which is responsible for sanitation in its area of jurisdiction;

(*ii*) a Cantonment Board constituted under section 10 of the Cantonments Act, 2006; and 41 of 2006.

(*iii*) a railway authority;

(*g*) "manual scavenger" means a person engaged or employed, at the commencement of this Act or at any time thereafter, by an individual or a local authority or an agency or a contractor, for manually cleaning, carrying, disposing of, or otherwise handling in any manner, human excreta in an insanitary latrine or in an open drain or pit into which the human excreta from the insanitary latrines is disposed of, or on a railway track or in such other spaces or premises, as the Central Government or a State Government may notify, before the excreta fully decomposes in such manner as may be prescribed, and the expression "manual scavenging" shall be construed accordingly.

Explanation.—For the purpose of this clause,—

(*a*) "engaged or employed" means being engaged or employed on a regular or contract basis;

(*b*) a person engaged or employed to clean excreta with the help of such devices and using such protective gear, as the Central Government may notify in this behalf, shall not be deemed to be a 'manual scavenger';

(*h*) "National Commission for Safai Karmacharis" means the National Commission for Safai Karamcharis constituted under section 3 of the National Commission for Safai Karmacharis Act, 1993 and continued by Resolution of the Government of India in the Ministry of Social Justice and Empowerment *vide* No.17015/18/2003-SCD-VI, dated 24th February, 2004 and as amended from time to time;

64 of 1993.

(*i*) "notification" means a notification published in the Official Gazette and the expression "notify" shall be construed accordingly;

(*j*) "occupier", in relation to the premises where an insanitary latrine exists, or someone is employed as a manual scavenger, means the person who, for the time being, is in occupation of such premises;

(*k*) "owner", in relation to the premises where an insanitary latrine exists or someone is employed as a manual scavenger, means, the person who, for the time being has legal title to such premises;

(*l*) "prescribed" means prescribed by the rules made under this Act;

(*m*) "railway authority" means an authority administering railway land, as may be notified by the Central Government in this behalf;

(*n*) "railway land" shall have the meaning assigned to it in clause (*32A*) of section 2 of the Railways Act, 1989;

24 of 1989.

(*o*) "sanitary latrine" means a latrine which is not an 'insanitary latrine';

(*p*) "septic tank" means a water-tight settling tank or chamber, normally located underground, which is used to receive and hold human excreta, allowing it to decompose through bacterial activity;

(*q*) "sewer" means an underground conduit or pipe for carrying off human excreta, besides other waste matter and drainage wastes;

(*r*) "State Government", in relation to a Union territory, means the Administrator thereof appointed under article 239 of the Constitution;

(*s*) "survey" means a survey of manual scavengers undertaken in pursuance of section 11 or section 14.

(*2*) Words and expressions used and not defined in this Act, but defined in the Cantonments Act, 2006, shall have the same meanings respectively assigned to them in that Act.

41 of 2006.

(*3*) The reference to a Municipality under Chapters IV to VIII of this Act shall include a reference to, as the case may be, the Cantonment Board or the railway authority, in respect of areas included within the jurisdiction of the Cantonment Board and the railway land, respectively.

Act to have overriding effect.

3. The provisions of this Act shall have effect notwithstanding anything inconsistent therewith contained in the Employment of Manual Scavengers and Construction of Dry Latrines (Prohibition) Act, 1993 or in any other law, or in any instrument having effect by virtue of any other law. 46 of 1993.

CHAPTER II

IDENTIFICATION OF INSANITARY LATRINES

Local authorities to survey insanitary latrines and provide sanitary community latrines.

4. (*1*) Every local authority shall,—

(*a*) carry out a survey of insanitary latrines existing within its jurisdiction, and publish a list of such insanitary latrines, in such manner as may be prescribed, within a period of two months from the date of commencement of this Act;

(*b*) give a notice to the occupier, within fifteen days from the date of publication of the list under clause (*a*), to either demolish the insanitary latrine or convert it into a sanitary latrine, within a period of six months from the date of commencement of this Act:

Provided that the local authority may for sufficient reasons to be recorded in writing extend the said period not exceeding three months;

(*c*) construct, within a period not exceeding nine months from the date of commencement of this Act, such number of sanitary community latrines as it considers necessary, in the areas where insanitary latrines have been found.

(*2*) Without prejudice to the provisions contained in sub-section (*1*), Municipalities, Cantonment Boards and railway authorities shall also construct adequate number of sanitary community latrines, within such period not exceeding three years from the date of commencement of this Act, as the appropriate Government may, by notification, specify, so as to eliminate the practice of open defecation in their jurisdiction.

(*3*) It shall be the responsibility of local authorities to construct community sanitary latrines as specified in sub-sections (*1*) and (*2*), and also to make arrangements for their hygienic upkeep at all times.

Explanation.—For the purposes of this section, "community" in relation to railway authorities means passengers, staff and other authorised users of railways.

CHAPTER III

PROHIBITION OF INSANITARY LATRINES AND EMPLOYMENT AND ENGAGEMENT AS MANUAL SCAVENGER

Prohibition of insanitary latrines and employment and engagement of manual scavenger.

5. (*1*) Notwithstanding anything inconsistent therewith contained in the Employment of Manual Scavengers and Construction of Dry Latrines (Prohibition) Act, 1993, no person, local authority or any agency shall, after the date of commencement of this Act,— 46 of 1993.

(*a*) construct an insanitary latrine; or

(*b*) engage or employ, either directly or indirectly, a manual scavenger, and every person so engaged or employed shall stand discharged immediately from any obligation, express or implied, to do manual scavenging.

(*2*) Every insanitary latrine existing on the date of commencement of this Act, shall either be demolished or be converted into a sanitary latrine, by the occupier at his own cost, before the expiry of the period so specified in clause (*b*) of sub-section (*1*) of section 4:

Provided that where there are several occupiers in relation to an insanitary latrine, the liability to demolish or convert it shall lie with,—

(*a*) the owner of the premises, in case one of the occupiers happens to be the owner; and (*b*) all the occupiers, jointly and severally, in all other cases:

Provided that the State Government may give assistance for conversion of insanitary latrines into sanitary latrines to occupiers from such categories of persons and on such scale, as it may, by notification, specify:

Provided further that non-receipt of State assistance shall not be a valid ground to maintain or use an insanitary latrine, beyond the said period of nine months.

(*3*) If any occupier fails to demolish an insanitary latrine or convert it into a sanitary latrine within the period specified in sub-section (*2*), the local authority having jurisdiction over the area in which such insanitary latrine is situated, shall, after giving notice of not less than twenty one days to the occupier, either convert such latrine into a sanitary latrine, or demolish such insanitary latrine, and shall be entitled to recover the cost of such conversion or, as the case may be, of demolition, from such occupier in such manner as may be prescribed.

Contract, agreement, etc., to be void.

6. (*1*) Any contract, agreement or other instrument entered into or executed before the date of commencement of this Act, engaging or employing a person for the purpose of manual scavenging shall, on the date of commencement of this Act, be terminated and such contract, agreement or other instrument shall be void and inoperative and no compensation shall be payable therefor.

(*2*) Notwithstanding anything contained in sub-section (*1*), no person employed or engaged as a manual scavenger on a full-time basis shall be retrenched by his employer, but shall be retained, subject to his willingness, in employment on at least the same emoluments, and shall be assigned work other than manual scavenging.

Prohibition of persons from engagement or employment for hazardous cleaning of sewers and septic tanks.

7. No person, local authority or any agency shall, from such date as the State Government may notify, which shall not be later than one year from the date of commencement of this Act, engage or employ, either directly or indirectly, any person for hazardous cleaning of a sewer or a septic tank.

Penalty for contravention of section 5 or section 6.

8. Whoever contravenes the provisions of section 5 or section 6 shall for the first contravention be punishable with imprisonment for a term which may extend to one year or with fine which may extend to fifty thousand rupees or with both, and for any subsequent contravention with imprisonment which may extend to two years or with fine which may extend to one lakh rupees, or with both.

Penalty for contravention of section 7.

9. Whoever contravenes the provisions of section 7 shall for the first contravention be punishable with imprisonment for a term which may extend to two years or with fine which may extend to two lakh rupees or with both, and for any subsequent contravention with imprisonment which may extend to five years or with fine which may extend to five lakh rupees, or with both.

Limitation of prosecution.

10. No court shall take cognizance of any offence punishable under this Act except upon a complaint thereof is made by a person in this behalf within three months from the date of the occurrence of the alleged commission of the offence.

CHAPTER IV

IDENTIFICATION OF MANUAL SCAVENGERS IN URBAN AND RURAL AREAS AND THEIR REHABILITATION

Survey of manual scavengers in urban areas by Municipalities.

11. (*1*) If any Municipality has reason to believe that some persons are engaged or employed in manual scavenging within its jurisdiction, the Chief Executive Officer of such Municipality shall cause a survey to be undertaken to identify such persons.

(*2*) The content and methodology of the survey referred to in sub-section (*1*) shall be such as may be prescribed, and it shall be completed within a period of two months from its commencement in the case of Municipal Corporations, and within a period of one month in the case of other Municipalities.

(*3*) The Chief Executive Officer of the Municipality, in whose jurisdiction the survey is undertaken, shall be responsible for accurate and timely completion of the survey.

(*4*) After completion of the survey, the Chief Executive Officer shall cause to be drawn up a provisional list of persons found to be working as manual scavengers within the jurisdiction of his Municipality and fulfilling the eligibility conditions as may be prescribed, shall cause such provisional list to be published for general information in such manner, as may be prescribed, and shall invite objections to the list from the general public.

(*5*) Any person having any objection, either to the inclusion or exclusion of any name in the provisional list published in pursuance of sub-section (*4*), shall, within a period of fifteen days from such publication, file an objection, in such form as the Municipality may notify, to the Chief Executive Officer.

(*6*) All objections received in pursuance of sub-section (*5*), shall be enquired into, and thereafter a final list of persons found to be working as manual scavengers within the local limits of the municipality, shall be published by it in such manner, as may be prescribed.

(*7*) As soon as the final list of manual scavengers, referred to in sub-section (*6*) is published, the persons included in the said list shall, subject to the provisions of sub-section (*2*) of section 6, stand discharged from any obligation to work as manual scavengers.

Application by an urban manual scavenger for identification.

12. (*1*) Any person working as a manual scavenger in an urban area, may, either during the survey undertaken by the Municipality in pursuance of section 11, within whose jurisdiction he works, or at any time thereafter, apply, in such manner, as may be prescribed, to the Chief Executive Officer of the Municipality, or to any other officer authorised by him in this behalf, for being identified as a manual scavenger.

(*2*) On receipt of an application under sub-section (*1*), the Chief Executive Officer shall cause it to be enquired into, either as part of the survey undertaken under section 11, or, when no such survey is in progress, within fifteen days of receipt of such application, to ascertain whether the applicant is a manual scavenger.

(*3*) If an application is received under sub-section (*1*) when a survey under section 11 is not in progress, and is found to be true after enquiry in accordance with sub-section (*2*), action shall be taken to add the name of such a person to the final list published under sub-section (*6*) of section 11, and the consequences mentioned in sub-section (*7*) thereof shall follow.

Rehabilitation of persons identified as manual scavengers by a Municipality.

13. (*1*) Any person included in the final list of manual scavengers published in pursuance of sub-section (*6*) of section 11 or added thereto in pursuance of sub-section (*3*) of section 12, shall be rehabilitated in the following manner, namely:—

(*a*) he shall be given, within one month,—

(*i*) a photo identity card, containing, *inter alia,* details of all members of his family dependent on him, and

(*ii*) such initial, one time, cash assistance, as may be prescribed;

(*b*) his children shall be entitled to scholarship as per the relevant scheme of the Central Government or the State Government or the local authorities, as the case may be;

(*c*) he shall be allotted a residential plot and financial assistance for house construction, or a ready-built house, with financial assistance, subject to eligibility and willingness of the manual scavenger, and the provisions of the relevant scheme of the Central Government or the State Government or the concerned local authority;

(*d*) he, or at least one adult member of his family, shall be given, subject to eligibility and willingness, training in a livelihood skill, and shall be paid a monthly stipend of not less than three thousand rupees, during the period of such training;

(*e*) he, or at least one adult member of his family, shall be given, subject to eligibility and willingness, subsidy and concessional loan for taking up an alternative occupation on a sustainable basis, in such manner as may be stipulated in the relevant scheme of the Central Government or the State Government or the concerned local authority;

(*f*) he shall be provided such other legal and programmatic assistance, as the Central Government or State Government may notify in this behalf.

(*2*) The District Magistrate of the district concerned shall be responsible for rehabilitation of each manual scavenger in accordance with the provisions of sub-section (*1*) and the State Government or the District Magistrate concerned may, in addition, assign responsibilities in his behalf to officers subordinate to the District Magistrate and to officers of the concerned Municipality.

Survey of manual scavengers in rural areas by Panchayats.

14. If any Panchayat has reason to believe that some persons are engaged in manual scavenging within its jurisdiction, the Chief Executive Officer of such Panchayat shall cause a survey of such manual scavengers to be undertaken, *mutatis mutandis,* in accordance with the provisions of section 11 and section 12, to identify such person.

Application by a rural manual scavenger for identification.

15. (*1*) Any person working as a manual scavenger, in a rural area, may, either during the survey undertaken by the Panchayat within whose jurisdiction he works, in pursuance of section 14 or at any time thereafter, apply, in such manner, as may be prescribed, to the Chief Executive Officer of the concerned Panchayat, or to any other officer authorised by him in this behalf, for being identified as a manual scavenger.

(*2*) On receipt of an application under sub-section (*1*), the Chief Executive Officer shall cause it to be enquired into, either as part of the survey undertaken under section 14 or when no such survey is in progress, within fifteen days of receipt of such application, so as to ascertain whether the applicant is a manual scavenger.

Rehabilitation of persons identified as manual scavengers by a Panchayat.

16. Any person included in the final list of manual scavengers, published in pursuance of section 14 or added thereto in pursuance of sub-section (*2*) of section 15 shall be rehabilitated, *mutatis mutandis*, in the manner laid down for urban manual scavengers in section 13.

CHAPTER V

IMPLEMENTING AUTHORITIES

Responsibility of local authorities to ensure elimination of insanitary latrines.

17. Notwithstanding anything contained in any other law for the time being in force, it shall be the responsibility of every local authority to ensure, through awareness campaign or in such other manner that after the expiry of a period of nine months, from the date of commencement of this Act,—

(*i*) no insanitary latrine is constructed, maintained or used within its jurisdiction; and

(*ii*) in case of contravention of clause (*i*), action is taken against the occupier under sub-section (*3*) of section 5.

Authorities who may be specified for implementing provisions of this Act.

18. The appropriate Government may confer such powers and impose such duties on local authority and District Magistrate as may be necessary to ensure that the provisions of this Act are properly carried out, and a local authority and the District Magistrate may, specify the subordinate officers, who shall exercise all or any of the powers, and perform all or any of the duties, so conferred or imposed, and the local limits within which such powers or duties shall be carried out by the officer or officers so specified.

Duty of District Magistrate and authorised officers.

19. The District Magistrate and the authority authorised under section 18 or any other subordinate officers specified by them under that section shall ensure that, after the expiry of such period as specified for the purpose of this Act,—

(*a*) no person is engaged or employed as manual scavenger within their jurisdiction;

(*b*) no one constructs, maintains, uses or makes available for use, an insanitary latrine;

(*c*) manual scavengers identified under this Act are rehabilitated in accordance with section 13, or as the case may be, section 16;

(*d*) persons contravening the provisions of section 5 or section 6 or section 7 are investigated and prosecuted under the provisions of this Act; and

(*e*) all provisions of this Act applicable within his jurisdiction are duly complied with.

Appointment of inspectors and their powers.

20. (*1*) The appropriate Government may, by notification, appoint such persons as it thinks fit to be inspectors for the purposes of this Act, and define the local limits within which they shall exercise their powers under this Act.

(*2*) Subject to any rules made in this behalf, an inspector may, within the local limits of his jurisdiction, enter, at all reasonable times, with such assistance as he considers necessary, any premises or place for the purpose of,—

(*a*) examining and testing any latrine, open drain or pit or for conducting an inspection of any premises or place, where he has reason to believe that an offence under this Act has been or is being or is about to be committed, and to prevent employment of any person as manual scavenger;

(*b*) examine any person whom he finds in such premises or place and who, he has reasonable cause to believe, is employed as a manual scavenger therein, or is otherwise in a position to furnish information about compliance or non-compliance with the provisions of this Act and the rules made thereunder;

(*c*) require any person whom he finds on such premises, to give information which is in his power to give, with respect to the names and addresses of persons employed on such premises as manual scavenger and of the persons or agency or contractor employing or engaging them;

(*d*) seize or take copies of such registers, record of wages or notices or portions thereof as he may consider relevant in respect of an offence under this Act which he has reason to believe has been committed by the principal employer or agency; and

(*e*) exercise such other powers as may be prescribed.

(*3*) Any person required to produce any document or thing or to give any information required by an inspector under sub-section (*2*) shall be deemed to be legally bound to do so within the meaning of section 175 and section 176 of the Indian Penal Code. 45 of 1860.

(*4*) The provisions of the Code of Criminal Procedure, 1973, shall, so far as may be, apply to any such search or seizure under sub-section (*2*) as they apply to such search or seizure made under the authority of a warrant issued under section 94 of the said Code. 2 of 1974.

CHAPTER VI

PROCEDURE FOR TRIAL

Offences to be tried by Executive Magistrate.

21. (*1*) The State Government may confer, on an Executive Magistrate, the powers of a Judicial Magistrate of the first class for the trial of offences under this Act; and, on such conferment of powers, the Executive Magistrate, on whom the powers are so conferred, shall be deemed, for the purposes of the Code of Criminal Procedure, 1973, to be a Judicial Magistrate of the first class. 2 of 1974.

(*2*) An offence under this Act may be tried summarily.

Offence to be cognizable and non-bailable.

22. Notwithstanding anything contained in the Code of Criminal Procedure, 1973, every offence under this Act shall be cognizable and non-bailable. 2 of 1974.

Offences by companies.

23. (*1*) Where an offence under this Act has been committed by a company, every person who, at the time the offence was committed, was in charge of, and was responsible to, the company for the conduct of the business of the company, as well as the company, shall be deemed to be guilty of the offence and shall be liable to be proceeded against and punished accordingly.

(*2*) Notwithstanding anything contained in sub-section (*1*), where any offence under this Act has been committed by a company and it is proved that offence has been committed with the consent or connivance of, or is attributable to, any neglect on the part of, any director, manager, secretary or other officer of the company, such director, manager, secretary or other officer shall be deemed to be guilty of that offence and shall be liable to be proceeded against and punished accordingly.

Explanation.—For the purposes of this section,—

(*a*) "company" means any body corporate and includes a firm or other association of individuals; and

(*b*) "director" in relation to a firm, means a partner in the firm.

CHAPTER VII

VIGILANCE COMMITTEES

Vigilance Committees.

24. (*1*) Every State Government shall, by notification, constitute a Vigilance Committee for each district and each Sub-Division.

(*2*) Each Vigilance Committee constituted for a district shall consist of the following members, namely:—

(*a*) the District Magistrate—Chairperson, *ex officio*;

(*b*) all members of the State Legislature belonging to the Scheduled Castes elected from the district—members:

Provided that if a district has no member of the State Legislature belonging to the Scheduled Castes, the State Government may nominate such number of other members of the State Legislature from the district, not exceeding two, as it may deem appropriate.

(*c*) the district Superintendent of Police— member, *ex officio*;

(*d*) the Chief Executive Officer of,—

(*i*) the Panchayat at the district level—member, *ex officio*;

(*ii*) the Municipality of the district headquarters—member, *ex officio*;

(*iii*) any other Municipal Corporation constituted in the district—member, *ex officio*;

(*iv*) Cantonment Board, if any, situated in the district—member, *ex officio*;

(*e*) one representative be nominated by the railway authority located in the district;

(*f*) not more than four social workers belonging to organisation working for the prohibition of manual scavenging and rehabilitation of manual scavengers, or, representing the scavenger community, resident in the district, to be nominated by the District Magistrate, two of whom shall be women;

(*g*) one person to represent the financial and credit institutions in the district, to be nominated by the District Magistrate;

(*h*) the district-level officer in-charge of the Scheduled Castes Welfare—Member-Secretary, *ex officio*;

(*i*) district-level officers of Departments and agencies who, in the opinion of the District Magistrate, subject to general orders, if any, of the State Government, have a significant role to play in the implementation of this Act.

(*3*) Each Vigilance Committee, constituted for a Sub-Division, shall consist of the following members, namely:—

(*a*) the Sub-Divisional Magistrate—Chairperson, *ex officio*;

(*b*) the Chairpersons and the Chief Executive Officers of Panchayats at intermediate level of the Sub-Division, and where Panchayats at intermediate level, do not exist, Chairpersons from two Panchayats at Village level to be nominated by the Sub-Divisional Magistrate—member, *ex officio*;

(*c*) the Sub-Divisional Officer of Police—member, *ex officio*;

(*d*) Chief Executive Officer of—

(*i*) the Municipality of the Sub-Divisional headquarters—member, *ex officio*; and

(*ii*) Cantonment Board, if any, situated in the Sub-Division—member, *ex officio*;

(*e*) one representative to be nominated by the railway authority located in the Sub-Division—member, *ex officio*;

(*f*) two social workers belonging to the organisation working for the prohibition of manual scavenging and rehabilitation of the manual scavengers, or representing the scavenger community resident in the Sub-Division, to be nominated by the District Magistrate, one of whom shall be a woman;

(*g*) one person to represent the financial and credit institutions in the Sub-Division, to be nominated by the Sub-Divisional Magistrate;

(*h*) the Sub-Divisional level officer in-charge of Scheduled Castes welfare—Member-Secretary, *ex officio;*

(*i*) Sub-Divisional level officers of Department and agencies who in the opinion of the Sub-Divisional Magistrate, subject to any general orders of the State Government or the District Magistrate, have a significant role to play in the implementation of this Act—member, *ex officio.*

(*4*) Each Vigilance Committee constituted at district and Sub-Divisional level shall meet at least once in every three months.

(*5*) No proceeding of a Vigilance Committees shall be invalid merely by reason of any defect in its constitution.

Functions of Vigilance Committee.

25. The functions of Vigilance Committee shall be—

(*a*) to advise the District Magistrate or, as the case may be, the Sub-Divisional Magistrate, on the action which needs to be taken, to ensure that the provisions of this Act or of any rule made thereunder are properly implemented;

(*b*) to oversee the economic and social rehabilitation of manual scavengers;

(*c*) to co-ordinate the functions of all concerned agencies with a view to channelise adequate credit for the rehabilitation of manual scavengers;

(*d*) to monitor the registration of offences under this Act and their investigation and prosecution.

State Monitoring Committee.

26. (*1*) Every State Government shall, by notification, constitute a State Monitoring Committee, consisting of the following members, namely:—

(*a*) the Chief Minister of State or a Minister nominated by him—Chairperson, *ex officio*;

(*b*) the Minister-in-charge of the Scheduled Castes Welfare, and such other Department, as the State Government may notify;

(*c*) Chairperson of the State Commissions for Safai Karamcharis, and Scheduled Castes, if any— member, *ex officio;*

(*d*) representatives of the National Commission for Scheduled Castes, and Safai Karamcharis—member, *ex officio;*

(*e*) not less than two members of the State Legislature belonging to the Scheduled Castes, nominated by the State Government:

Provided that if any State Legislature has no member belonging to the Scheduled Castes, the State Government may nominate the members belonging to the Scheduled Tribes;

(*f*) the Director-General of Police— member, *ex officio;*

(*g*) Secretaries to the State Government in the Departments of Home, Panchayati Raj, Urban Local Bodies, and such other Departments, as the State Government may notify;

(*h*) Chief Executive Officer of at least one Municipal Corporation, Panchayat at the district-level, Cantonment Board and railway authority as the State Government may notify;

(*i*) not more than four social workers belonging to organisation working for the prohibition of manual scavenging and rehabilitation of manual scavengers, or, representing the scavenger community, resident in the State, to be nominated by the State Government, two of whom shall be women;

(*j*) State-level head of the convener Bank of the State Level Bankers' Committee—member, *ex officio*;

(*k*) Secretary of the Department of the State Government dealing with development of the Scheduled Castes—Member-Secretary, *ex officio*;

(*l*) such other representative of Departments of the State Government and such other agencies which, in the opinion of the State Government, are concerned with the implementation of this Act.

(*2*) The State Monitoring Committee shall meet at least once in every six months and shall observe such rules of procedure in regard to the transaction of business at its meetings as may be prescribed.

Functions of the State Monitoring Committee.

27. The functions of the State Monitoring Committee shall be—

(*a*) to monitor and advise the State Government and local authorities for effective implementation of this Act;

(*b*) to co-ordinate the functions of all concerned agencies;

(*c*) to look into any other matter incidental thereto or connected therewith for implementation of this Act.

Duty of States or Union territories to send periodic reports to the Central Government.

28. Every State or Union territory Government and Union territory administration shall send such periodic reports to the Central Government about progress of implementation of this Act, as the Central Government may require.

Central Monitoring Committee.

29. (*1*) The Central Government shall, by notification, constitute a Central Monitoring Committee in accordance with the provisions of this section.

(*2*) The Central Monitoring Committee shall consist of the following members, namely:—

(*a*) The Union Minister for Social Justice and Empowerment—Chairperson, *ex officio*;

(*b*) Chairperson of the National Commission for Scheduled Castes—member, *ex officio*;

(*c*) Minister of State in the Ministry of Social Justice and Empowerment— member, *ex officio*;

(*d*) Chairperson, National Commission for Safai Karamcharis— member, *ex officio*;

(*e*) the Member of the Planning Commission dealing with development of the Scheduled Castes—member, *ex officio*;

(*f*) three elected members of Parliament belonging to Scheduled Castes, two from the Lok Sabha and one from the Rajya Sabha;

(*g*) Secretaries of the Ministries of,—

(*i*) Social Justice and Empowerment, Department of Social Justice and Empowerment;

(*ii*) Urban Development;

(*iii*) Housing and Urban Poverty Alleviation;

(*iv*) Drinking Water and Sanitation;

(*v*) Panchayati Raj;

(*vi*) Finance, Department of Financial Services; and

(*vii*) Defence,

members, *ex officio*;

(*h*) Chairman, Railway Board—member, *ex officio*;

(*i*) Director-General, Defence Estates— member, *ex officio*;

(*j*) representatives of not less than six State Governments and one Union territory, as the Central Government may, notify;

(*k*) not more than six social workers belonging to organisation working for the prohibition of manual scavenging and rehabilitation of manual scavengers, or, representing the scavenger community, resident in the country, to be nominated by the Chairperson, two of whom shall be women;

(*l*) Joint Secretary, Department of Social Justice and Empowerment in the Ministry of Social Justice and Empowerment, looking after development of Scheduled Castes—Member-Secretary, *ex officio*;

(*m*) such other representatives of Central Ministries or Departments and agencies which, in the opinion of the Chairperson, are concerned with the implementation of this Act.

(*3*) The Central Monitoring Committee shall meet at least once in every six months.

Functions of the Central Monitoring Committee.

30. The functions of the Central Monitoring Committee shall be,—

(*a*) to monitor and advise the Central Government and State Government for effective implementation of this Act and related laws and programmes;

(*b*) to co-ordinate the functions of all concerned agencies;

(*c*) to look into any other matter incidental to or connected with implementation of this Act.

Functions of National Commission for Safai Karamcharis.

31. (*1*) The National Commission for Safai Karamcharis shall perform the following functions, namely:—

(*a*) to monitor the implementation of this Act;

(*b*) to enquire into complaints regarding contravention of the provisions of this Act, and to convey its findings to the concerned authorities with recommendations requiring further action; and

(*c*) to advise the Central and the State Governments for effective implementation of the provisions of this Act.

(*d*) to take *suo motu* notice of matter relating to non-implementation of this Act.

(*2*) In the discharge of its functions under sub-section (*1*), the National Commission shall have the power to call for information with respect to any matter specified in that sub-section from any Government or local or other authority.

Power of State Government to designate an appropriate authority to monitor the implementation of this Act.

32. (*1*) The State Government may, by notification, designate a State Commission for Safai Karamcharis or a State Commission for the Scheduled Castes or such other statutory or other authority, as it deems fit, to perform, within the State, *mutatis mutandis*, the functions specified in sub-section (*1*) of section 31.

(*2*) An authority designated under sub-section (*1*) shall, within the State, have, *mutatis mutandis*, the powers of the National Commission for Safai Karamcharis as specified in sub-section (*2*) of section 31.

CHAPTER VIII

MISCELLANEOUS

Duty of local authorities and other agencies to use modern technology for cleaning of sewers, etc.

33. (*1*) It shall be the duty of every local authority and other agency to use appropriate technological appliances for cleaning of sewers, septic tanks and other spaces within their control with a view to eliminating the need for the manual handling of excreta in the process of their cleaning.

(*2*) It shall be the duty of the appropriate Government to promote, through financial assistance, incentives and otherwise, the use of modern technology, as mentioned in sub-section (*1*).

Protection of action taken in good faith.

34. No suit, prosecution or other legal proceeding shall lie against an appropriate Government or any officer of the appropriate Government or any member of the Committee for anything which is in good faith done or intended to be done under this Act.

Jurisdiction of civil courts barred.

35. No civil court shall have jurisdiction in respect of any matter to which any provision of this Act applies and no injunction shall be granted by any civil court in respect of anything, which is done or intended to be done, by or under this Act.

Power of appropriate Government to make rules.

36. (*1*) The appropriate Government shall, by notification, make rules for carrying out the provisions of this Act, within a period not exceeding three months from the date of commencement of this Act.

(*2*) In particular, and without prejudice to the generality of the foregoing power, such rules may provide for all or any of the following matters, namely:—

(*a*) the obligation of an employer, under clause (*d*) of sub-section (*1*) of section 2;

(*b*) the manner in which the excreta fully decomposes under clauses (*e*) and (*g*) of sub-section (*1*) of section 2;

(*c*) the manner of carrying out survey of insanitary latrine and publishing list thereof under clause (*a*) of sub-section (*1*) of section 4;

(*d*) procedure of giving notice and recovering cost of demolition of an insanitary latrine under sub-section (*3*) of section 5;

(*e*) content and methodology of the survey under sub-section (*2*) of section 11;

(*f*) the eligibility conditions for identification of manual scavengers and publication of provisional list of persons found to be working as manual scavengers under sub-section (*4*) of section 11;

(*g*) publication of final list of persons found to be working as manual scavengers under sub-section (*6*) of section 11;

(*h*) manner of application to be made to the Chief Executive Officer of the municipality, or to an officer authorised by him in this behalf, under sub-section (*1*) of section 12 or, as the case may be, sub-section (*1*) of section 15;

(*i*) provision of initial, one time, cash assistance under sub-clause (*ii*) of clause (*a*) of sub-section (*1*) of section 13;

(*j*) such other powers of Inspectors under clause (*e*) of sub-section (*2*) of section 20; and

(*k*) any other matter which is required to be, or may be, prescribed.

(*3*) Every rule made under this Act by the Central Government shall be laid, as soon as may be after it is made, before each House of Parliament, while it is in session, for a total period of thirty days which may be comprised in one session or in two or more successive sessions, and if, before the expiry of the session immediately following the session or the successive sessions aforesaid, both Houses agree in making any modification in the rule or both Houses agree that the rule should not be made, the rule shall thereafter have effect only in such modified form or be of no effect, as the case may be; so, however, that any such modification or annulment shall be without prejudice to the validity of anything previously done under that rule.

(*4*) Every rule made under this Act by the State Government shall, as soon as may be after it is made, be laid before each House of State Legislature, where there are two Houses and where there is one House of State Legislature, before that House.

Power of Central Government to make model rules.

37. (*1*) Notwithstanding anything contained in section 36 of this Act:—

(*a*) the Central Government shall, by notification, publish model rules for the guidance and use of State Governments; and

(*b*) in case the State Government fails to notify the rules under section 36 of this Act within the period of three months specified therein, then the model rules as notified by the Central Government shall be deemed to have come into effect, *mutatis mutandis*, in such State, till such time as the State Government notifies its rules.

(*2*) The model rules made by the Central Government under this Act shall be laid, as soon as may be after they are made, before each House of Parliament while it is in session, for a total period of thirty days which may be comprised in one session or in two or more successive sessions, and if, before the expiry of the session immediately following the session or the successive sessions aforesaid, both Houses make any modification in the rule, the rule shall thereafter have effect only in such modified form; so, however, that any such modification shall be without prejudice to the validity of anything previously done under that rule.

Power to remove difficulties.

38. (*1*) If any difficulty arises in giving effect to the provisions of this Act, the Central Government may, by order published in the Official Gazette, make such provisions, not inconsistent with the provisions of this Act, as may appear to it to be necessary or expedient for the removal of the difficulty:

Provided that no such order shall be made in relation to a State after the expiration of three years from the commencement of this Act in that State.

(*2*) Every order made under this section shall, as soon as may be after it is made, be laid before each House of Parliament.

Power to exempt.

39. (*1*) The appropriate Government may, by a general or special order published in the Official Gazette, for reasons to be recorded, and subject to such conditions as it may impose, exempt any area, category of buildings or class of persons from any provisions of this Act or from any specified requirement contained in this Act or any rule, order, notification, bye-laws or scheme made thereunder or dispense with the observance of any such requirement in a class or classes of cases, for a period not exceeding six months at a time.

(*2*) Every general or special order made under this section shall be laid, as soon as may be after it is made, before each House of Parliament or each House of State Legislature, where there are two Houses and where there is one House of State Legislature, before that House.

P.K. MALHOTRA,
Secy. to the Govt. of India.

PRINTED BY DIRECTORATE OF PRINTING AT GOVERNMENT OF INDIA PRESS, MINTO ROAD, NEW DELHI AND PUBLISHED BY THE CONTROLLER OF PUBLICATIONS, DELHI, 2013.

GMGIPMRND—2806GI(S3)—19-09-2013.

APPENDIX A 1.2
TIME FRAME FOR FULFILMENT OF RESPONSIBILITIES AND CERTAIN ACTIVITIES AND IMPLEMENTING AGENCIES

Table A1.2.1 Time frame for fulfilment of responsibilities and certain activities

No	Section under the Act	Subject Matter	Time period from the commencement of the Act	Responsibility
1	4(1)(a)	Carry out a survey of the insanitary latrines existing within its jurisdiction, and publish a list of such insanitary latrines	2 months	Local Authority
2	4(1)(b)	Give a notice to the occupier within 15 days from the date of publication of the list of insanitary latrines, to demolish and convert into a sanitary latrine	15 days from the publication of the list	Local Authority
3	4(1)(b)	(the occupier) to either demolish the insanitary latrine or convert it into a sanitary latrine	Within a period of 6 months (for sufficient reasons in recording, the local authority may extend the period by not exceeding another 3 months)	Occupier (Resident)
4	4(1)(c)	Construction of appropriate number of sanitary community latrines in the areas where insanitary latrines have been found	Within a period of note exceeding 9 months	Local Authority
5	4(2)	Construct adequate number of sanitary community latrines in the areas to eliminate open defecation	3 years from the date of commencement of the Act	Municipalities Cantonment Boards Railway Authorities
6	7	Not to engage or employ, either directly or indirectly, any person for hazardous cleaning of a sewer or septic tank	Within one year, as may be notified by the State Govt.	Person Local authority Agency
7	11(1)	Identification of manual scavengers	From the date of commencement of the Act	1 month for municipalities 2 months for municipal corporations

Every concerted effort should be taken so that there should be no further tolerance for pushing back the time frames for eradication of manual scavenging and failure to eradicate without reasonable cause beyond this would be contravention of the provisions of The Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013 and treated as an offence by public officials, with severe penalties.

Implementing Agencies

The implementing agencies under the Act should be the District Collector and Municipal Commissioner. As per the Section 18 of the Act, State Government shall confer such powers and impose such duties on local authority (Panchayat or municipal body) and District Magistrate as may be necessary to ensure that the provisions of this Act are properly carried out. It is incumbent upon the district magistrate or chief executive officer of the local authority to specify and confer such powers to the subordinate officers to perform all the duties as per the provisions of the Act. It is to be ensured by the authorities as notified by the appropriate government to ensure the following:

a. No person is engaged or employed as manual scavenger within their jurisdiction
b. No one constructs, maintains, uses or makes available for use, an insanitary latrine;
c. Identification and rehabilitation of the manual scavengers
d. Investigation and prosecution of persons contravening the provisions of the Act;

As per Section 33, sub-section 1 of the Act, “it shall be the duty of every local authority and other agency to use appropriate technological appliances for cleaning of sewers, septic tanks and other spaces within their control with a view to eliminating the need for manual handling of excreta in the process of their cleaning”. Sub-section 2 further specifies that, “it shall be the duty of the appropriate government to promote, through financial assistance, incentives and otherwise, the use of modern technology, as mentioned in sub-section 1”.

APPENDIX A 2.1
PERFORMANCE OF KNOWN SEWAGE TREATMENT PROCESSES UNDER INDIAN CONDITIONS

A study of pollution potential of water courses by sewage even after treatment was instituted by the Central Pollution Control Board and carried out by M/S Anna University on identified STPs in south India and M/S IIT Roorkee on identified STPs in north India. The results of performance of the STPs evaluated are reproduced here.

Table A 2.1.1 Summary of Results of Anna University
(Figures in Parameters are arithmetic average)

Treatment Plant	Total Coliform MPN/100 mL Influent X 10^6	Total Collform MPN/100 mL Effluent X 10^4	Prercent Reduct ion	Fecal Collform MPN /100 mL Influent X 10^6	Fecal Coliform MPN / 100 mL Effluent X 10^4	Percent Reduction
AABF	5 - 500	5 - 380	99.0 - 99.2	2.90 - 500	3.7 - 190	98.7 - 99.6
ASP	6.8 - 5,000	50 - 6,800	92.6 - 98.6	5 - 3,700	37 - 3,800	92.6 - 98.9
Tertiary Treated	0.68 - 98	<2 (all but one day)	97.1 - 99.9	1.1 - 68	<2 (all but one day)	98.2 - 99.9
OP	03.8 - 680	0.05 - 900	99.9- 98.7	0.7 -98	0.038 - 500	99.9- 94.4
TF	6.8 - 500	2 - 3,000	99.7- 94	3.0 - 370	2-1.100	99.5- 97.0

Table A 2.1.2 Annual performance of the five sewage treatment plants for Physico - Chemical characteristic

Characteristics		DEWATs		Nesapakkam		CPCL		Pondicherry		V. Valley	
		Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
TSS (mg/L)	Min	288	17	450	33	67	2	93	19	168	31
	Max	1037	358	1482	534	328	164	730	286	764	299
	Avg	594	189	1059	234	206	23	397	154	383	106
	SD	233	123	318	169	85	42	229	86	223	96
COD-T (mg/L)	Min	272	53	519	56	104	3	235	98	277	69
	Max	1120	207	1656	288	421	160	800	240	560	181
	Avg	637	118	1232	128	230	57	497	171	429	115
	SD	256	57	275	59	88	46	177	54	92	44
COD-S (mg/L)	Min	128	24	149	37	66	0	64	32	75	37
	Max	352	133	635	203	261	107	480	208	240	117
	Avg	233	65	397	102	139	34	210	99	159	65
	SD	75	37	132	49	67	31	127	52	62	29
BOD-T (mg/L)	Min	206	19	236	15	36	0.8	77	36	74	31
	Max	749	138	671	90	174	65	356	123	320	75
	Avg	343	59	520	53	93	14	212	55	181	43
	SD	174	36	108	26	47	17	116	33	61	15
BOD-S (mg/L)	Min	80	14	98	5	18	0.4	37	15	35	15
	Max	344	70	379	73	88	37	217	45	185	57
	Avg	201	30	238	33	46	8	102	29	95	29
	SD	78	18	75	21	22	10	59	9	50	13

Table A 2.1.3 Annual performance of the five sewage treatment plants for microbiological characteristics

Characteristics		DEWATs		Nesapakkam		CPCL		Pondicherry		V. Valley	
		Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
Total Coliforms	Min	500	5	680	50	68	0.0002	380	0.78	680	38
	Max	5000	380	500000	6800	9800	0.37	68000	3000	190000	5000
	Avg	5926	43	32152	1325	893	0.15	12492	565	21235	712
	SD	11125	65	77099	1691	1559	0.58	150501	587	38918	1183
Faecal Coliforms	Min	380	3.7	500	37	50	0.0002	380	0.78	500	19
	Max	5000	190	370000	5000	6800	0.98	38000	1100	68000	3800
	Avg	4555	28	22672	823	633	0.078	8506	371	9611	427
	SD	9887	38	57296	1034	1054	0.23	9787	321	14636	775
E.Coli	Min	190	0.68	98	18	38	0.0002	190	0.5	380	19
	Max	3800	98	180000	3800	3700	0.68	37000	980	38000	1900
	Avg	2569	15	12730	459	366	0.056	5387	243	4958	225
	SD	6301	21	29621	644	631	0.17	6540	237	7802	395
Faecal Streptococci	Min	13	0.29	68	5	1.3	0.0002	13	0.5	78	1.1
	Max	1300	3.8	5000	180	680	0.19	980	68	980	50
	Avg	2691	1.2	1373	51	95	0.016	393	10	317	10
	SD	393	1.2	1593	47	185	0.048	326	18	305	17

Table A 2.1.4 Summary Of Results of IIT, Roorkee (Figures in parameters are arithmetic average)

Treatment Plant	Total Coliform MPN/100 mL Influent X 10^6	Total Collform MPN/100 mL Effluent X 10^4	Percent Reduct ion	Fecal Collform MPN /100 mL Influent X 10^6	Fecal Coliform MPN / 100 mL Effluent X 10^4	Percent Reduction
UASB	2.3 - 23	1.9 - 23	99.2 - 99	0.23 - 15	0.023 - 23	99.9 - 98.5
UASB	1.6 - 43	1.1 - 23	99.3 - 99.5	0.39 - 23	0.11 - 4-3	99.7 - 99.8
OP	4.3 - 930	1.5 - 430	99.7 - 99.5	0.023 - 230	0.15 - 210	99.3 - 99.1
ASP	1.5 - 4.3	9.3 - 930	93.8	0.21 - 1.5	0.15 - 930	99.3
Anaerobic Filter	28	450	83.9	6.8	130	80.9

Table A 2.1.5 Sewage Treatment Plants in Delhi

Sl.No	Name of the STP's & Capacity (mgd)	Design capacity (MLD)	Actual flow (MLD)	Type of STP	Present Status
1	Coronation Pillar STP's 1) (10) 2) (10 + 20)	 45.46 45.46 90.92	 40.87 63.46 56.55	Activated sludge process (ASP), trickling filter & ASP	Under utilised Over the Des. Cap. Under Utilized
2.	Delhi Gate (2.2)	10.00	10.00	High rate bio-filters Densadeg technology	Running on designed capacity
3.	Ghitorni (5)	22.73	Nil	Activated sludge process	Not in operation
4.	Keshopur STPs 1) (12) 1) (20) 2) (40)	 54.55 90.92 181.84	 46.55 95.10 106.46	All the three plants designed on activated sludge process	i)12 mgd not running, sewage passes through PST. ii) Over the Des. Cap. iii) Under- utilized
5.	Kondli STP's 1) (10-Phase-I) 2) (25 -Phase-II) 3) (10-Phase-III)	 45.46 113.65 45.46	 56.55 57.96 28.36	All three activated sludge process	Over the capacity Under- utilized Under- utilized
6.	Mehrauli STP (5)	22.73	4.95	Extended aeration	Under-utilized
7.	Najafgarh STP (5)	22.73	2.27	Activated sludge proc.	Under- utilized
8.	Nilothi STP (40)	181.84	15.0	Activated sludge process	Under- utilized
9.	Narela STP (10)	45.46	2.50	Activated sludge process	Under- utilized
10.	Okhla STP's 1) (12) 2) (16) 3) (30) (37) (45)	 54.55 72.73 136.38 168.20 204.57	 39.09 40.91 136.98 159.11 181.84	All the plants designed on activated sludge process	Under- utilized Under- utilized Running in cap. Under-utilized Under-utilized
11.	Papankalan STP (20)	90.92	37.73	Activated sludge process	Under-utilized
12	Rithala STP's 1) (40) Old 2) (40) New	 181.84 181.84	 46.28 185.07	Activated sludge process & High rate aerobic ASP & biofor/biofilter	Under-utilized Over the des. cap.
13.	Rohini STP (15)	68.19	Nil	Activated sludge process	Not in operation
14.	Sen N.H. STP (2.2)	10.0	10.0	High rate Bio filter	Running on designed capacity.
15.	Timarpur O.P. (6)	27.27	4.79	Oxidation ponds	Under-utilized
16.	Yamuna Vihar STP's 1) Ph-I(10) 2) Ph-II(10)	 45.46 45.46	 27.27 14.77	Activated sludge process	Under-utilized Under-utilized
17.	Vasant Kunj STP's 1) (2.2) 2) (3.0)	 10.00 13.63	 3.18 4.36	ASP & Extended aeration	Under-utilized Under-utilized
Total	**30**	**2330**	**1478**		

Table A 2.1.6 Performance Evaluation of Sewage Treatment Plants in Delhi

Sl. No.	Name of STP & Capacity (mgd)	Design Capacity, MLD	Actual flow, MLD	Performance Evaluation of STP' (24 Hour composite Monitoring for every three hourly samples)										% reduction		
				Influent Quality					Effluent Quality							
				pH	TSS	COD	BOD	Cond.	pH	TSS	COD	BOD	Cond.	TSS	COD	BOD
1	Cor. Pillar(10)	45.46	40.87	7.2	179	317	112	908	7.4	35	61	18	1090	80.45	80.76	83.93
	(20+10)	136.38	120.01	6.44	342	172	48	1700	6.9	93	48	15	1730	72.81	72.09	68.75
2	Keshopur(12*)	54.55	46.55	-	-	-	-	-	-	-	-	-	-	-	-	-
	(20)	90.92	95.1	7.3	404	560	282	1390	7.6	78	149	45	1390	80.69	73.39	84.04
	(40)	181.84	106.46	7.3	404	560	282	1390	7.8	21	55	10	1520	94.80	90.18	96.45
3	Okhla(12)	54.55	39.09	7.3	498	517	204	1440	7.8	21	54	10	1460	95.78	89.56	95.10
	(16)	72.73	40.91	7.4	291	486	207	1510	7.7	83	108	48	1400	71.48	77.78	76.81
	(30)	136.38	136.98	7.4	647	551	222	1480	7.6	76	153	45	1470	88.25	72.23	79.73
	(37)	168.2	159.11	7.3	480	515	249	1590	7.8	32	62	12	1540	93.33	87.96	95.18
	(45)	204.57	181.84	7.3	480	515	249	1590	7.7	27	51	19	1530	94.38	90.10	92.37
4	Narela (10)	45.46	2.5	7.4	426	447	100	1720	8	38	72	8	1720	91.08	83.89	92.00
5	Y. Vihar (Ph.-I 10,	45.46	27.27	7.1	391	505	174	1110	7.7	44	84	17	1050	88.75	83.37	90.23
	Ph.-II 10)	45.46	14.77	7.2	405	538	199	1020	7.5	39	44	20	1070	90.37	91.82	89.95
6	Timarpur O.P -(6)	27.27	4.79	6.7	412	272	106	1650	7.3	11	26	4	1650	97.33	90.44	96.23
7	Najafgarh (5)	22.73	2.27	7.4	165	205	54	810	7.7	29	38	1	687	82.42	81.46	98.15
8	Nilothi (40)	181.84	15	7.7	432	328	90	2340	7.8	21	26	4	1960	95.14	92.07	95.56
9	Dr. SenN.H.(2.2)	10	10	7.5	370	585	236	1680	7.4	36	46	16	1660	90.27	92.14	93.22
10	Delhi Gate (2.2)	10	10	7.5	263	605	147	1020	7.3	26	62	20	1030	90.11	89.75	86.39
11	Papankalan (20)	90.92	37.73	7.6	142	275	103	2190	7.9	39	46	10	1580	72.54	83.27	90.29
12	Kondli Ph.-I (10)	45.46	56.55	7.3	363	507	241	1390	7.8	68	140	27	1390	81.27	72.39	88.80
	Ph.-II (25)	113.65	57.96	7.3	604	588	261	1550	7.6	45	50	34	1350	92.55	91.50	86.97
	Ph.-III (10)	45.46	28.36	7.3	519	615	237	1530	7.8	16	50	14	1220	96.92	91.87	94.09
13	Mehrauli(5)	22.73	4.95	7.8	251	326	126	1090	8.1	12	35	7	1180	95.22	89.26	94.44
14	Rithala {(40 Old)	181.84	46.28	7.2	330	399	205	1260	7.5	75	54	14	1240	77.27	86.47	93.17
	(40 New)}	181.84	185.07	7.2	330	399	205	1260	7.3	47	151	55	1230	85.76	62.16	73.17
15	Vasant Kunj (2.2)	10	3.18	7.5	379	460	323	1710	7.8	23	43	7	1450	93.93	90.65	97.83
	(3)	13.63	4.36	7.4	479	565	306	1400	7.9	49	80	20	1470	89.77	85.84	93.46
16	Rohini (15)	68.19	Nil	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Ghitorni (5)	22.73	Nil	-	-	-	-	-	-	-	-	-	-	-	-	-
Total		2330	1478													

- Keshopur 12 mgd STP is not running fully, it is observed that the sewage passes though Primary Settling Tank. All values are in mg/1 except pH and conductivity (µ mhos / cm)

Table A 2.1.7 Performance of Bacteriological Reduction in Sewage Treatment Plants in Delhi

Sl. No.	Name of the STP & capacity (mgd)	Performance evaluation of Sewage Treatment Plants in Delhi				% Reduction	
		Influent Bacteriological Quality		Effluent Bacteriological Quality			
		Total Coliform (Nos/100ml)	Faecal Coliform (Nos/100ml)	Total Coliform (Nos/100ml)	Faecal Coliform (Nos/100ml)	Total Coliform	Faecal Coliform
1.	Najafgarh (5)	10900000	5100000	320000	120000	**97.06**	**97.65**
2.	Papankala (20)	13100000	10300000	120000	70000	**99.08**	**99.32**
3.	Delhi gate (2.2)	26000000	19000000	1700000	1100000	**93.46**	**94.21**
4.	Dr. Sen N. H. (2.2)	133000000	102000000	240000	21700	**99.82**	**99.98**
5.	Nilothi (40)	61000000	50000000	120000	70000	**99.80**	**99.86**
6.	Cor. Pillar (10)	39000000	32000000	200000	110000	**99.49**	**99.66**
7.	Cor. Pillar (30)	78000000	44000000	700000	200000	**99.10**	**99.55**
8.	Narela (5)	17000000	10000000	110000	40000	**99.35**	**99.60**
9.	Vasant Kunj (3)	6900000	3900000	178000	101000	**97.42**	**97.41**
10.	Vasant Kunj (2.2)	71000000	46000000	17000	8000	**99.98**	**99.98**
11.	Okhla (12)	370000000	65000000	2900000	230000	**99.22**	**99.65**
12.	Okhla (16)	51000000	27000000	990000	530000	**98.06**	**98.04**
13.	Okhla (30)	204000000	107000000	115000000	25000000	**43.63**	**76.64**
14.	Okhla (37)	197000000	111000000	1280000	710000	**99.35**	**99.36**
15.	Okhla (45)	197000000	111000000	4100000	600000	**97.92**	**99.46**
16.	Y. Vihar (Ph.-I 10)	1210000000	410000000	19400000	4600000	**98.40**	**98.88**
17.	Y. Vihar (Ph.-II 10)	1570000000	370000000	8500000	5200000	**99.46**	**98.59**
18.	Keshopur (20)	430000000	135000000	91000000	7200000	**78.84**	**94.67**
19.	Keshopur (40)	430000000	135000000	11500000	5100000	**97.33**	**96.22**
20.	Kondli (Ph.-I 10)	670000000	320000000	24000000	13900000	**96.42**	**95.66**
21.	Kondli (Ph.-II 25)	910000000	480000000	5500000	1800000	**99.40**	**99.63**
22.	Kondli (Ph.-III 10)	570000000	370000000	2700000	140000	**99.53**	**99.96**
23.	Rithala (40 Old)	1080000000	710000000	32000000	4600000	**97.04**	**99.35**
24.	Rithala (40 New)	1080000000	710000000	49000000	5900000	**95.46**	**99.17**
25.	Mehrauli (5)	290000000	210000000	490000	20000	**99.83**	**99.99**
26.	Dr. Sen N.H (2.2) (After Bio-filter)	133000000	102000000	179000	13500	**99.87**	**99.99**
27.	Dr. Sen N.H (2.2) (After U.V. reatment)	133000000	102000000	27000	11200	**99.80**	**99.99**

The values reported for the CPCL plant in Table A 2.1.3 relate to the quality of recovered water after the secondary treated sewage is further treated by chemical coagulation, sedimentation, filtration and R O.

The performance of oxidation ponds one in the south coastal temperate climate at Puducherry and the other at north in the cold hilly region of Rishikesh have also been evaluated in this study. In the Puducherry ponds, removals were 93% for total BOD and from 37,000/100 ml to 500/100 ml for faecal coliforms. In the Rishikesh pond system, the removals were 82% for total BOD and from 6000000/100 ml to 28000/100 ml for faecal coliforms.

The faecal coliform reduction from 3000/100 ml and 70,000/100 ml to almost nil have been documented in the study when secondary treated sewage was chemically coagulated with alum or Iron salts and chlorinated with of 3 to 4 mg/l as in Figure A 2.1.1

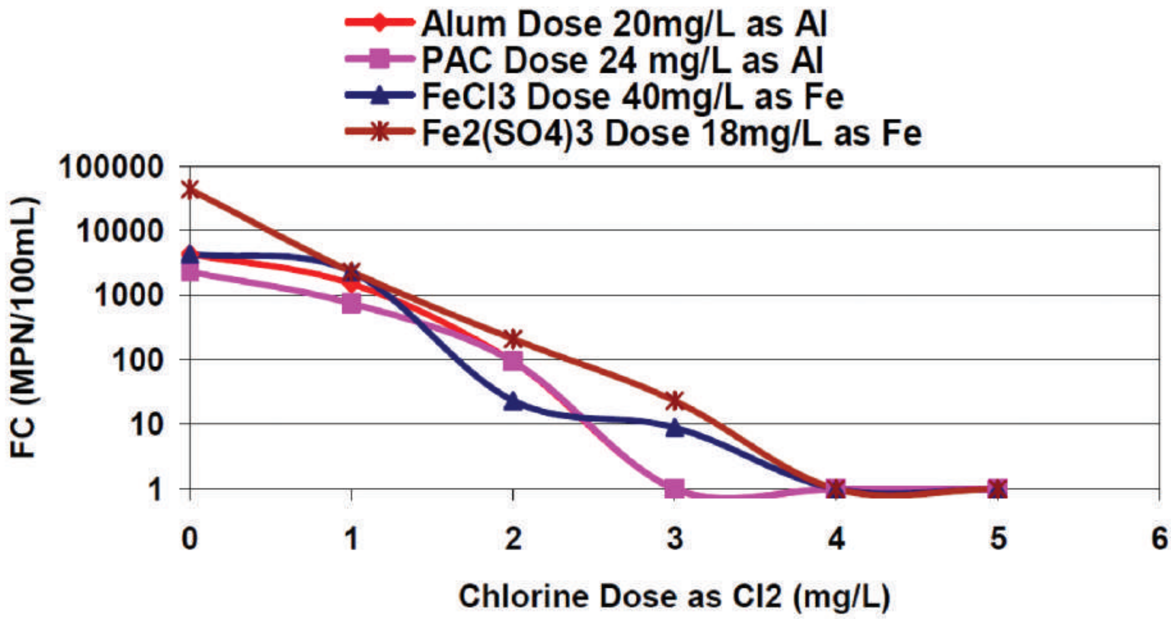


Figure A 2.1.1 Removal of FC with chlorination after coagulation with different coagulants at optimum doses.

The performance results do not cover the later day STP processes such as SBR, MBBR and MBR etc as these STPs were not in popular use at that time. All the same, the studies establish the position that the same STP process exhibits varying degrees of removals under varying conditions of climate, capacity utilization, nature of inlet sewage etc and almost all processes can be expected to attain a required degree of removal of BOD and faecal coliforms provided the design takes into account the insights as brought out above.

APPENDIX A 2.2
ESTIMATION OF FUTURE POPULATION
(Retained as in 2nd edition)

1.PROBLEM

Assuming that the scheme of water supply will commence to function from 1986, it is required to estimate the population 30 years hence, i.e. in 2016 and also the intermediate population 15 years after 1986, i.e. in 2001.

Table A2.2-1

Year	Population	Increment
1921	40,185	---
1931	44,522	15,873
1941	60,395	15,873
1951	75,614	15,219
1961	98,886	23,272
1971	124,230	25,344
1981	158,800	34,570
Total		118,615
Average		19,769

2. SOLUTION

2.1 ARITHMETIC PROGRESSION METHOD

Increase in population from 1921 to 1981
i.e. in 6 decades = 1,58,800
(-) 40,185
= 1,18,615
= 1,58,800 - 40,185 = 1,18, 615
or increase per decade = 1/6 × 1,18,615 = 19,769
Population in 2001 = Population in 1981 + Increase for 2 decades
= 1,58,800 + 2 × 19,769
= 1,58,800 + 39,538 = 1,98,338
Population in 2016 = Population in 1981 + Increase for 3.5 decades
= 1,58,800 + 3.5 × 19,769 = 2,27,992

2.2 GEOMETRIC PROGRESSION METHOD

Rate of growth (r) per decade between

1931 and 1921	=	4,337/40,185	=	0.108
1941 and 1931	=	15,873/44,522	=	0.356
1951 and 1941	=	15,219/60,395	=	0.252
1961 and 1951	=	23,272/75,614	=	0.308
1971 and 1961	=	25,344/98,886	=	0.256
1981 and 1971	=	34,570/1,24,230	=	0.278

Geometric Mean,

$$r_g = \sqrt[6]{0.108 \times 0.356 \times 0.252 \times 0.308 \times 0.256 \times 0.278} = 0.2442$$

Assuming that the future growth follows the geometric mean for
the period 1921 to 1981 rg = 0.2442

Population in 2001 = Population in 1981 × $(1 + rg)^2$

= 1,58,800 × $(1.2442)^2$ = 2,45,800

Population in 2016 = Population in 1981 × $(1 + rg)^{3.5}$

= 1,58,800 × $(1.2442)^{3.5}$ = 3,41,166

2.3 METHOD OF VARYING INCREMENT OR INCREMENTAL INCREASE METHOD

In this method, a progressively decreasing or increasing rather than a constant rate is adopted. This is a modification over the Arithmetical Progression method.

Table A2.2-2

Year	Population	Increase (X)	Incremental Increase (Y)
1921	40,185		
1931	44,522	4,337	
1941	60,395	15,873	11,536
1951	75,614	15,219	- 654
1961	98,886	23,272	8,053
1971	124,230	25,344	2,072
1981	158,800	34,570	9,226
Total		1,18,615	30,233
Average		1/6 × 118,615 = 19,769	1/5 × 30,233 = 6,047

Population can be projected using the formula:

$$P_n = P_1 + nY + \frac{n(n+1)Y}{2}$$

Therefore, population in 2001 can be given as

$$P_{2001} = P_{1981} + 2\times19769 + \frac{2\times3\times6047}{2}$$

= 1,58,800 + 39,538 + 18,141

= 2,16,479

$$P_{2016} = P_{1981} + 3.5\times19769 + \frac{3.5\times4.5\times6047}{2}$$

Similarly, population in 2016 can be given as

= 1,58,800 + 69,192 + 24,188

= 2,75,612

2.4 GRAPHICAL PROJECTION METHOD

From the Figure presented on the following page, the figures for 2001 and 2016 years obtained are as follows:

2001 - 253,000

2016 - 362,000

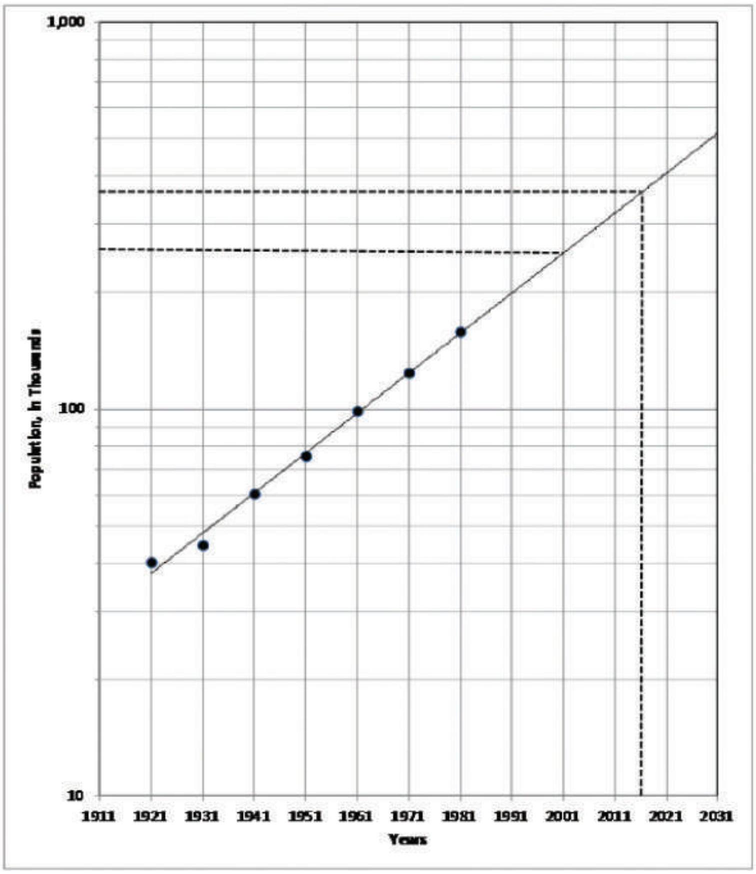


Figure A2.2-1 Semi log graph for estimation of future population

APPENDIX A 3.1
COMPUTATION OF STORM RUNOFF AND DESIGN OF STORM SEWER
(Retained as in 2nd edition)

PROBLEM

Design a system of storm sewers for the area shown in Figure A3.1-1 based on the Rational Formula for the estimation of peak runoff.

Basic Data and Assumptions imperviousness

Built up and paved area	-	0.7
Open space, lawns, etc.	-	0.2
Inlet time		
Built up and paved area (t_b)	-	8 minutes.
Open space, lawns (t_1)	-	15 minutes.
Minimum velocity in sewer	-	0.8 mps
Minimum depth of cover above crown	-	0.5 metres.

Rainfall intensity = consider one year storm as the area is central and high priced. (Use Table 3.7 for the record of rainfall intensity and frequency of rainfall). Use Manning's chart for sewer design.

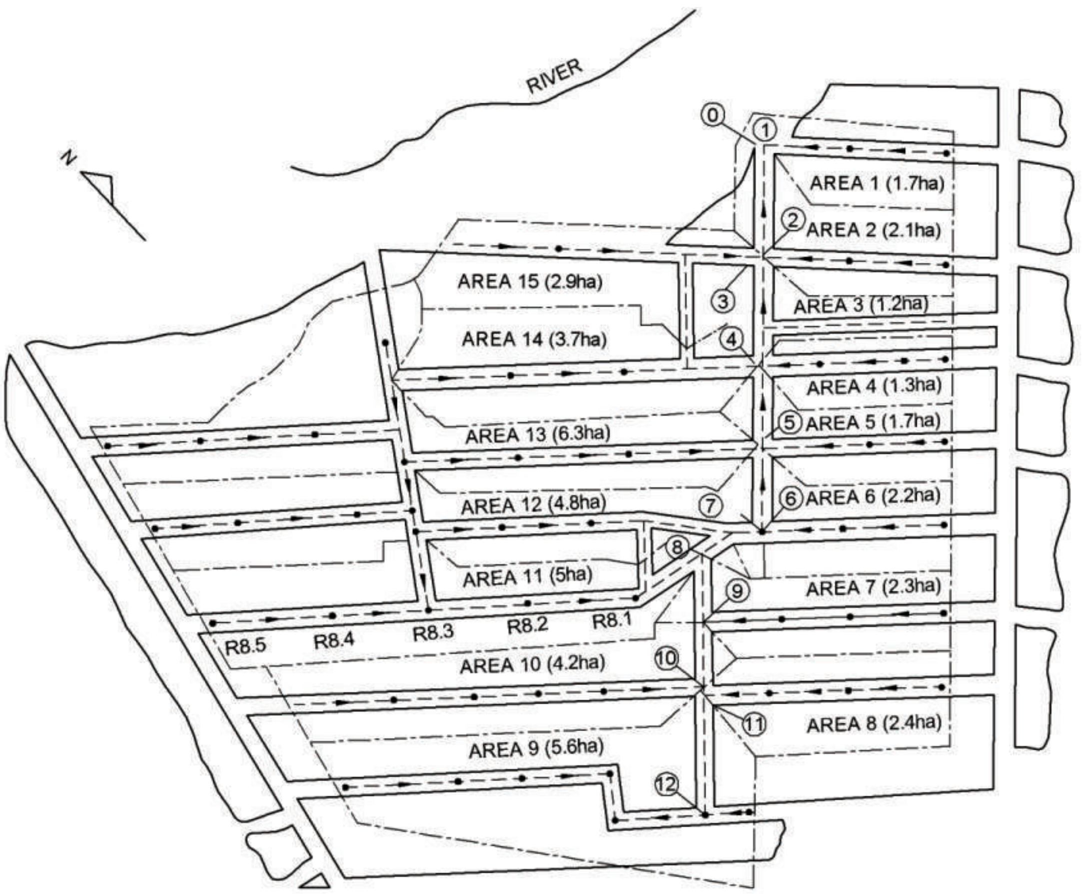


Figure A3.1-1

1 SOLUTION

Quantity of storm water runoff is calculated using the Rational Formula given in Section 3.9.2.1. i.e.]
Q = 10 C i A
Where,
Q : Runoff in m^3/hr
C : Coefficient of runoff
i : Intensity of rainfall in mm/hr and
A : Area of drainage district in hectares

Storm water runoff is determined in the following manner.

I) From the rainfall records for the last 26 years (Table 3.7), the storm occurring once in a year, i.e. 26 times in 26 years, the time-intensity values for this frequency are obtained by interpolation and are as follows;

Intensity, i mm/hr	30	35	40	45	50	60
Duration, t minute	44	36	28.5	22.5	13.5	9.75

II) The generalised formula adopted for intensity and duration is

$$i = \frac{a}{t^n}$$

Where,

i : Intensity of rainfall in mm/hr
t : Duration in minutes and a and *n* are constants

A graph Figure A3.1-3 is plotted for one year storm using the values i and t from the above table on a log-log paper. From the line of best fit the values of a and n are found out. From the plotted line values of a and n are 160 and 0.4 respectively.

iii) Now using equation i = (160 / $t^{0.4}$), i.e. after substituting the values of a and n for different values of i for various values of t are calculated and tabulated as below and a curve (Figure A3.1-4) is plotted on an ordinary graph paper.

The table for intensity-duration curve for one year storm is given in Table A 3.1-1

Table A3.1-1

t_{min}	5	10	15	20	25	30	35	40	45	60	80	100	120
i = a/t^n	84.2	64.0	54.0	48.5	44.2	41.2	38.6	36.8	34.8	31.0	27.8	25.4	23.6

iv) Another graph (Figure A3.1-5) of runoff-coefficient C vs. duration time t is plotted as per values given in Table 3.8 (Hornet's Table).

v) From the above two graphs (Figure A3.1-4 and Figure A3.1-5) the values of C and i for the same duration time t are determined and the curves for 10 C i vs t for the various values of imperviousness are plotted (Figure A3.1-6). The value of 10 C i gives the rate of runoff in m^3/hr per hectare of the tributary area. These curves are ultimately used in calculating the runoff from the tributary areas for a given time of concentration and imperviousness factor.

2 DESIGN OF STORM SEWER SYSTEM

Table A3.1-2 gives the various components of the storm sewer system design.

Column 1-4 identify the location of drain, street and manholes.

Columns 5-6 record the increment in tributary area with the given imperviousness factors.

Column 7 gives the tributary area increment with equivalent 100 percent imperviousness factor.

Column 8 records the total area served by each drain.

Column 9 records the time of concentration at each upper end of line (drain).

The time of concentration is found by taking the weighted average of the two areas. i.e.,

$$t_c = \frac{A_1 t_b + A_2 t_1}{A_1 + A_2}$$

Where,

A_1: Built up area
A_2 : Area of lawns

Column 10 records the time of flow in each drain. For example the time of flow in line 1 is calculated to be 70 / (60 ×1.0) = 1.17 min.

Column 11 is the total time of concentration for each drain.

Column 12 is the value of runoff as 10 C i read from the Figure A3.1-6 for the corresponding time of concentration.

Column 13 gives the total runoff from each tributary area.

Column 14 gives the runoff in lps from each tributary area.

Columns 15-18 record the chosen size, required grade resulting capacity, velocity of flow for each drain or line. These designs of storm sewers are computed from the Manning's chart for each required flow and maintaining a minimum velocity.

Columns 19-23 identify the profile of the drain.

Column 19 is taken form the plan

Column 20 = Col.19 ×Col.16

Column 21 the required drop in manholes is obtained directly from the recommended values in section 3.17.1.

Column 22 gives invert elevation at the upper end with minimum cover of 0.6m at starting manhole.

Table A3.1-2

Line Number	Location of drain			Tributary area (hectares) increment				t_c Time of Concentration			Runoff m^3/hr		Flow Q	Design						Profile		
	Street	Manhole from	Manhole to	0.7 Imp factor	0.2 Imp factor	Eq 100% Imp factor	Total Area	Time of (t_i) inlet to upper end	Time of flow in drain t_f	TOTAL $t_c = t_i + t_f$	Per hectare (10Ci)	Total	lps	Dia mm	Slope m/1000	Capacity lps	Velocity mps	Length m	fall m	Drop in Manhole	Invert Elevation Upper end	Invert Elevation Lower end
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	South st	5	4	0.286	0.366	0.274	0.274	12.0	-	12.0	345	94.5	26.6	200	10.0	32	1.0	70	0.7	0.000	37.400	36.700
2		4	3	0.167	0.488	0.214	0.488	13.3	1.17	14.47	335	164.0	46.0	250	6.65	50	1.0	125	0.83	0.025	36.675	35.845
3	North south St.2	R 32	R 3.1	0.415	0.312	0.352	0.352	11.0	-	11.0	348	123.0	35.0	250	6.65	50	1.0	70	0.47	0.000	36.700	36.230
4		R 31	3	0.358	0.36	0.324	0.676	11.5	1.17	12.67	340	264.0	74.0	350	4.55	98	1.0	70	0.32	0.050	36.180	35.860
5	South St.	3	2	0.256	0.466	0.274	1.438	12.5	3.27	15.77	335	480.0	135.0	450	3.14	160	1.0	125	0.40	0.066	35.779	35.379
6	North south St.3	R2.2	R 2.1	0.230	0.492	0.260	0.260	12.8	-	12.8	340	87.5	25.0	200	10.0	32	1.0	70	0.70	0.000	38.000	37.300
7		R 21	2	0.410	0.310	0.348	0.608	11.0	1.17	12.17	342	208.0	59.0	300	5.55	70.	1.0	70	0.39	0.050	37.250	36.860
8	South St.	R 2	1	0.256	0.466	0.274	2.320	12.5	5.37	17.87	330	765.0	214.0	600	2.22	280	1.0	160	0.36	0.200	35.179	34.819
9	North south St.4	R 12	R1.1	0.660	0.282	0.517	0.517	10.2	-	10.2	350	182.0	51.0	250	10.0	60	1.25	70	0.70	0.000	36.800	36.100
10		R 11	1	0.580	0.362	0.479	0.996	10.8	0.94	11.74	344	330.0	92.0	350	5.0	100	1.1	70	0.35	0.050	36.050	35.700
11	South St.	1	Pump house	0.670	0.330	0.494	3.810	10.4	8.05	18.45	325	1240.0	345.0	700	1.67	400	1.0	25	0.42	0.234	34.585	34.165

Thus for lines 1, 3, 6 and 9, the invert elevations are respectively 37.400, 36.700, 38.000 and 36.000. In case a manhole having more than one inlet, the drop in the manhole is considered with respect to the lowest invert level of the inlets to fix the invert level of the outlet.

Column 23 = Col.22 - Col.20 = invert elevation at the lower end of the line.

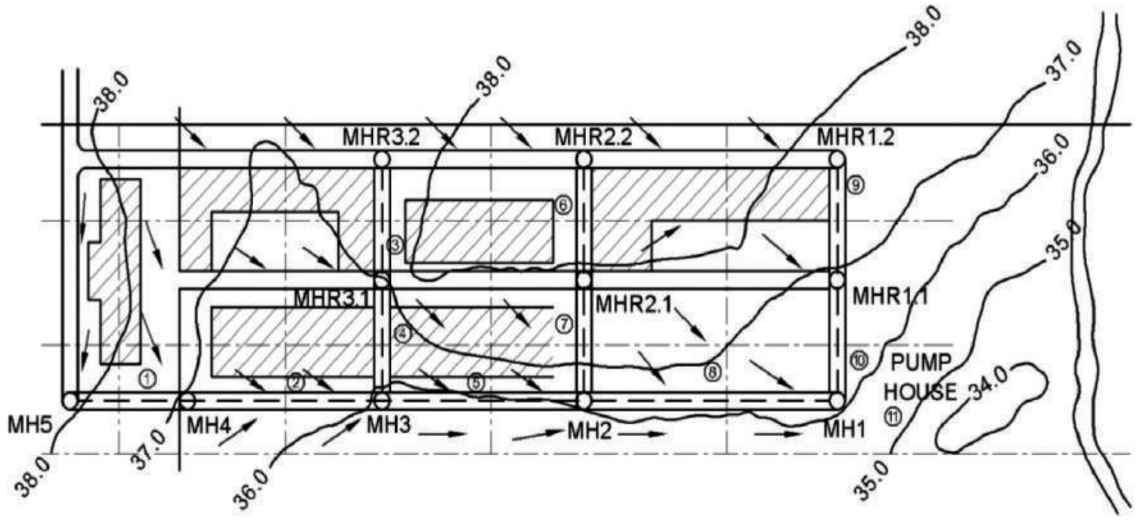


Figure A3.1-2

INTENSITY " i " (mm / hr)	30	35	40	45	50	60
DURATION " t " (minutes)	44	36	28.5	22.5	13.5	9.75

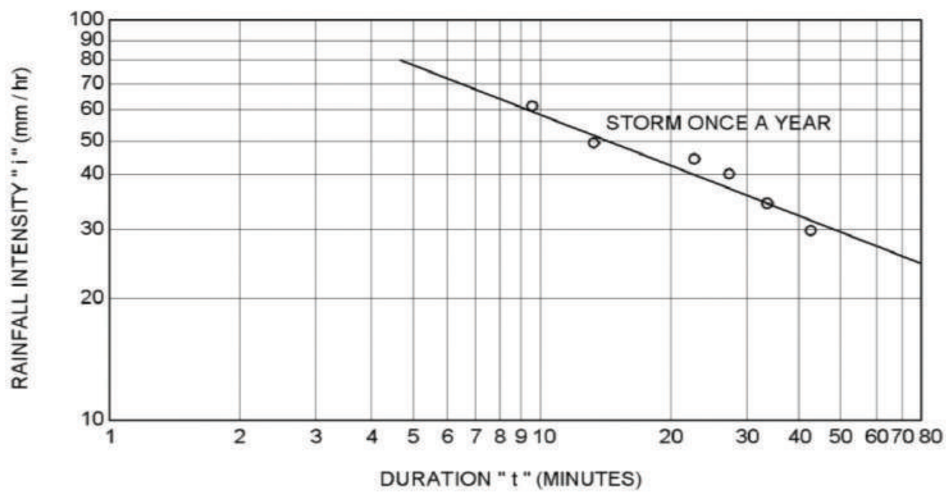


Figure A3.1-3

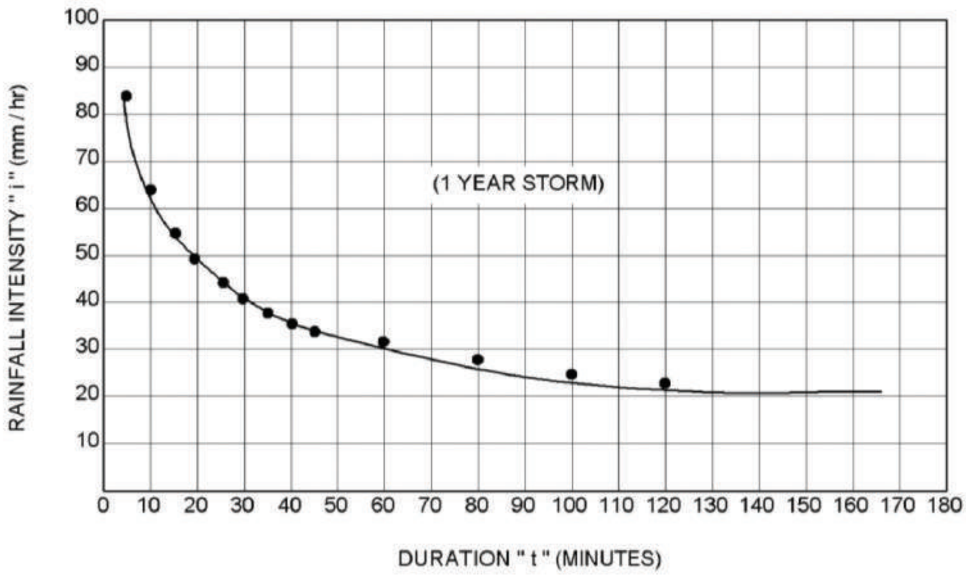


Figure A3.1-4

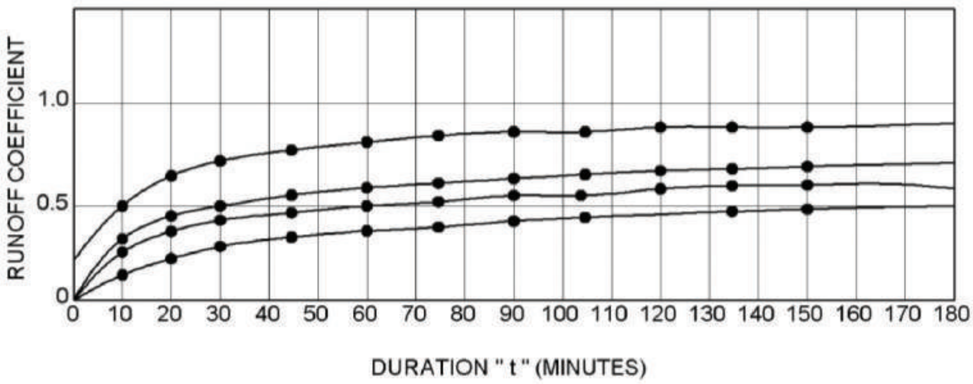


Figure A3.1-5 After horner area rectangle

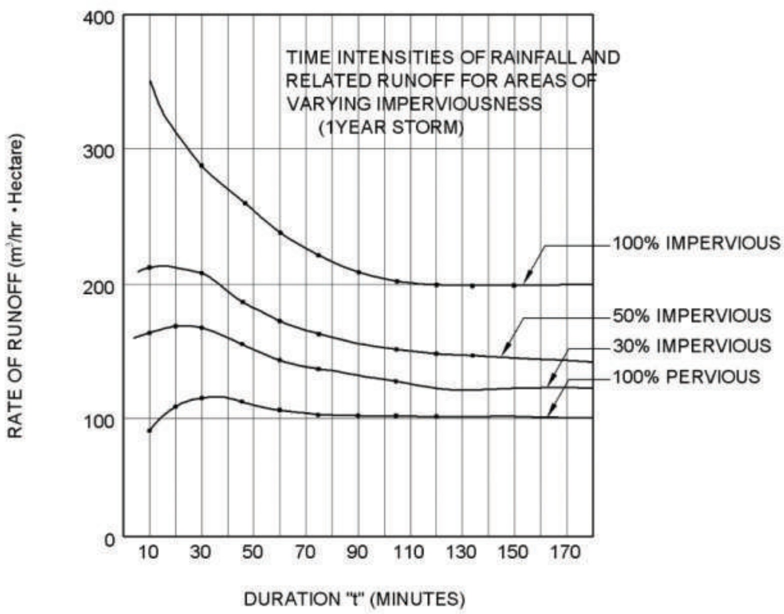


Figure A3.1-6

APPENDIX A 3.2 A
NOMOGRAM FOR MANNING'S FORMULA FOR GRAVITY SEWERS FLOWING FULL AND MANNING'S N VALUE OF 0.013.
(For discharges from 100 lpm to 100000 lpm)

For other values of Manning's n, the velocity and discharge will be inversely proportional.
Example-Find the discharge and velocity of a sewer flowing full of diameter 200 mm, slope of 1 in 200 and a Manning's n value of 0.0125.

Answer-From the nomogram, V = 0.75 m/s and discharge = 1,300 lpm. For n value of 0.0125,
V = 0.75 × 0.013/0.0125 = 0.78 m/s & discharge = 1,300 × 0.013/0.0125 = 1,352 lpm

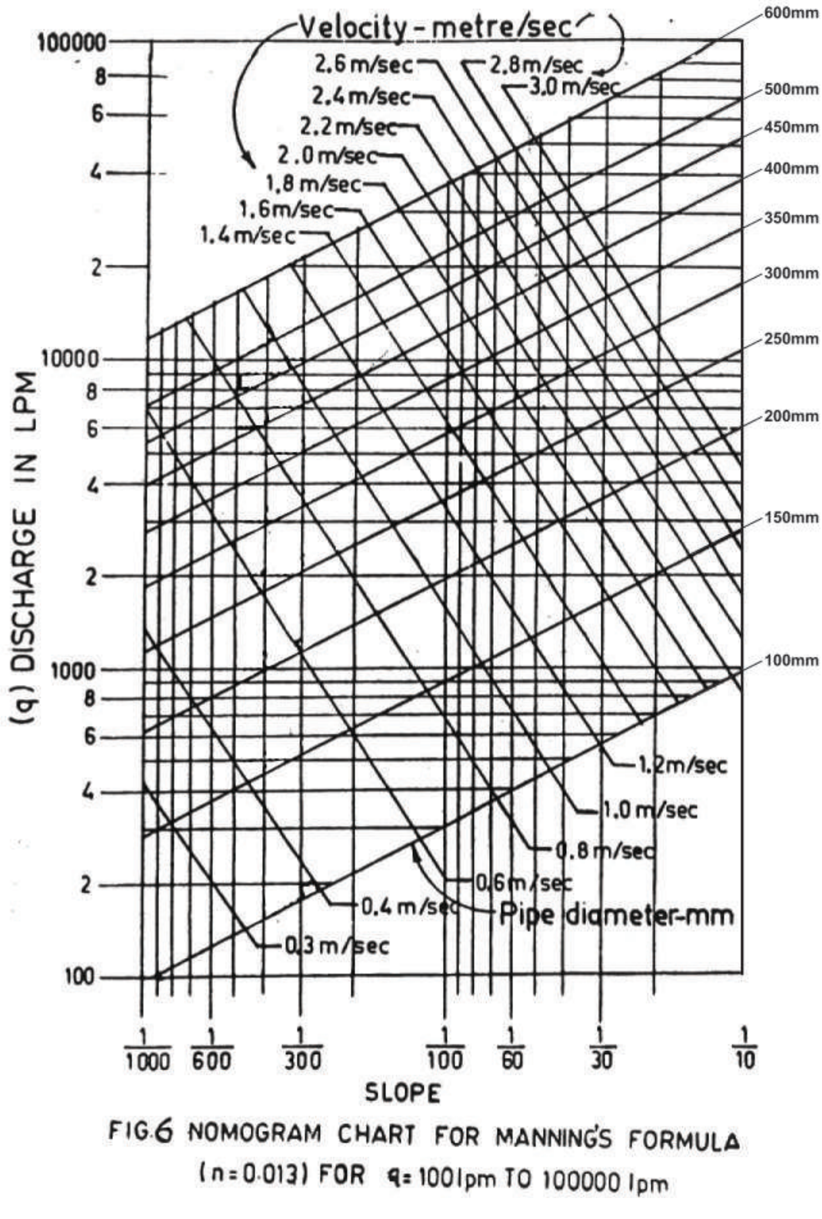


Figure A3.2A-1

Source-"Data Matrix for Public Health Engineers", TWAD Board, 1991

APPENDIX A 3.2 B

NOMOGRAM FOR MANNING'S FORMULA FOR GRAVITY SEWERS FLOWING FULL AND MANNING'S N VALUE OF 0.013

(For discharges from 1000 lpm to 1000000 lpm)

For other values of Manning's n the velocity and discharge will be inversely proportional.

Example-Find the discharge and velocity of a sewer flowing full of diameter 900 mm, slope of 1 in 1,000 and a Manning's n value of 0.012.

Answer-From the nomogram, V = 0.90 m/s and discharge = 35,000 lpm. For n value of 0.0125,
V = 0.90 × 0.013/0.0125 = 0.94 m/s & discharge = 35,000 × 0.013/0.0125 = 36,400 lpm

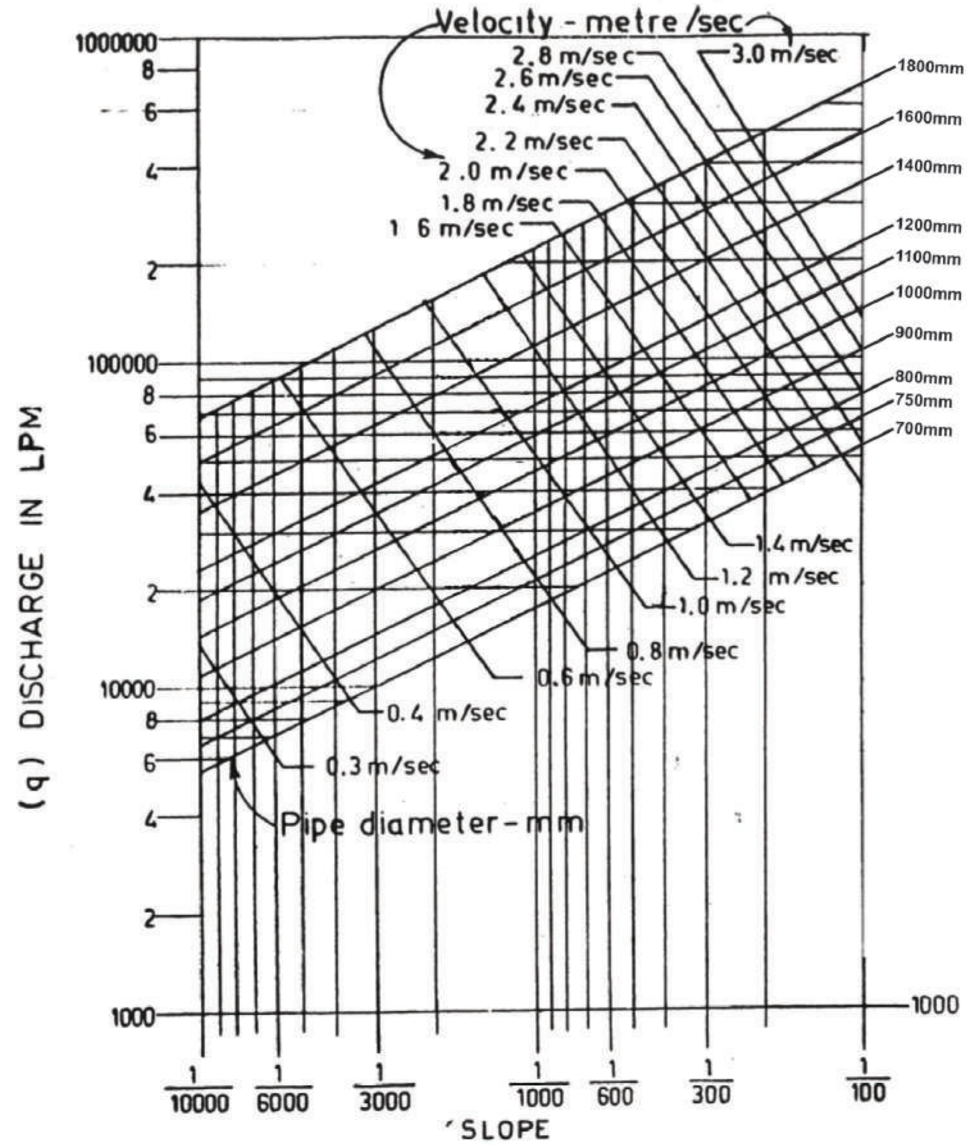


FIG 7 NOMOGRAM CHART FOR MANNING'S FORMULA

Figure A3.2B-1

Source-"Data Matrix for Public Health Engineers", TWAD Board, 1991

APPENDIX A 3.3
MS EXCEL FOR MANNING FORMULA FOR CIRCULAR GRAVITY PIPES FLOWING FULL

No	A	B	C
1	Appendix 3.3		
2	MS Excel For Manning Formula for Circular Gravity Pipes Flowing Full		
3	Given diameter and slope of sewer, find discharge and velocity		
4	This is left blank for the designer to enter his design notes		
5	This is left blank for the designer to enter his design notes		
6	This is left blank for the designer to enter his design notes		
7	diameter, mm	200	Enter by Designer
8	slope 1 in	250	Enter by Designer
9	value of Manning's n	0.013	Enter from Table 3.11
10	diameter power 0.67	34.81	POWER(B7,0.67)
11	slope power 0.5	0.06	POWER((1/B8),0.5)
12	Velocity, m/sec	0.67	(1/B9)*(3.968/1000)*B10*B11
13	diameter power 2.67	1392355	POWER(B7,2.67)
14	Flow rate l/s	21.1	(1/B9)*(3.118/1000000)*B13*B11
15	Flow in MLD	1.82	B14*3600*24/1000000

APPENDIX A 3.4 A
COMPUTATIONS OF DIAMETER, SLOPES, DISCHARGES IN GRAVITY SEWERS BY USING APPENDIX A 3.3

1 Given a sewer diameter, slope & depth of flow, find velocity and discharge

Diameter of sewer (D) = 200 mm
Depth of flow (d) = 160 mm
Sewer Material: Cement concrete pipe in “Good” condition (with collar joints)
Slope of the sewer line = 1 in 250
Manning’s co-efficient is uniform across sewer section
Use Manning value as 0.013 from Table 3.11
From Appendix A 3.2 A and A 3.2 B,
Velocity is 0.67 m/s and Discharge is 1260 lpm
Ratio of d/D is 160 / 200 = 0.8
Ratio of v/V from Table 3.12 is 1.14
Hence velocity is = 0.67 × 1.14 = 0.76 m/s
Ratio of q/Q from Table 3.12 is 0.968
Hence discharge is = 1260 × 0.968 = 1220 lpm

2 Given a sewer diameter, slope & discharge needed, find depth of flow

Diameter of sewer (D) = 200 mm
Discharge required = 1260 lpm
Sewer Material: Cement concrete pipe in “Good” condition (with collar joints)
Slope of the sewer line = 1 in 250
Manning’s co-efficient is uniform across sewer section
Use Manning value as 0.013 from Table 3.11
From Appendix A 3.2 A and A 3.2 B,
Velocity is 0.67 m/s and Discharge is 21.1 lps
Ratio of discharge is = 21.1 / 21.4 = 0.968
Corresponding ratio from Table 3.12 is d/D is 0.8
Hence, depth of flow is = 200 × 0.8 = 160 mm

3 Given discharge needed and available slope, find the diameter

Discharge needed = 612 lpm
Sewer Material: Cement concrete pipe in “Good” condition (with collar joints)
Available slope of the sewer line = 1 in 180
d/D ratio should not exceed 0.8
From Table 3.12, for d/D of 0.8, q/Q is 0.968
Discharge at full depth is = 612 / 0.968 = 632 lpm
From Appendix A 3.4 A, by entering the discharge and slope
Required diameter is 143 mm & velocity is 0.63 m/s as below
Use nearest higher diameter

APPENDIX A 3.4 B
MS EXCEL FOR MANNING FORMULA FOR CIRCULAR GRAVITY PIPES FLOWING FULL

No	A	B	C
1	Appendix 3.3		
2	MS Excel For Manning Formula for Circular Gravity Pipes Flowing Full		
3	Given discharge and slope of sewer, find diameter and velocity		
4	This is left blank for the designer to enter his design notes		
5	This is left blank for the designer to enter his design notes		
6	This is left blank for the designer to enter his design notes		
7	Discharge, l/s	10.20	Enter by Designer
8	slope 1 in	180	Enter by Designer
9	slope power 0.5	0.07	POWER((1/B8), 0.5)
10	value of Manning's n	0.013	Enter from Table 3.11
11	diameter power 2.67	570563	B7*B10/(3.118/1000000)/B9
12	diameter, mm	143	POWER(B11,(1/2.67)
13	diameter power 0.67	27.83	POWER(B12,0.67)
14	velocity m/s	0.63	POWER(B12,0.67)

APPENDIX A 3.5 A
NOMOGRAM FOR HAZEN WILLIAMS FORMULA FOR MAINS FLOWING FULL AND C VALUE OF 100
(For discharges from 100 to 100000 lpm)

For other values of C, the velocity and discharge will be directly proportional.
Example-Find the discharge and velocity of a sewer of diameter 300 mm flowing full slope of 1 in 100 and a Hazen Williams C value of 130

Answer-From the nomogram, V = 0.75 m/s and discharge = 5,700 lpm. For C value of 130,
V = 0.75 × 130 / 100 = 0.98 m/s & discharge = 5,700 × 130 / 100 = 7,400 lpm

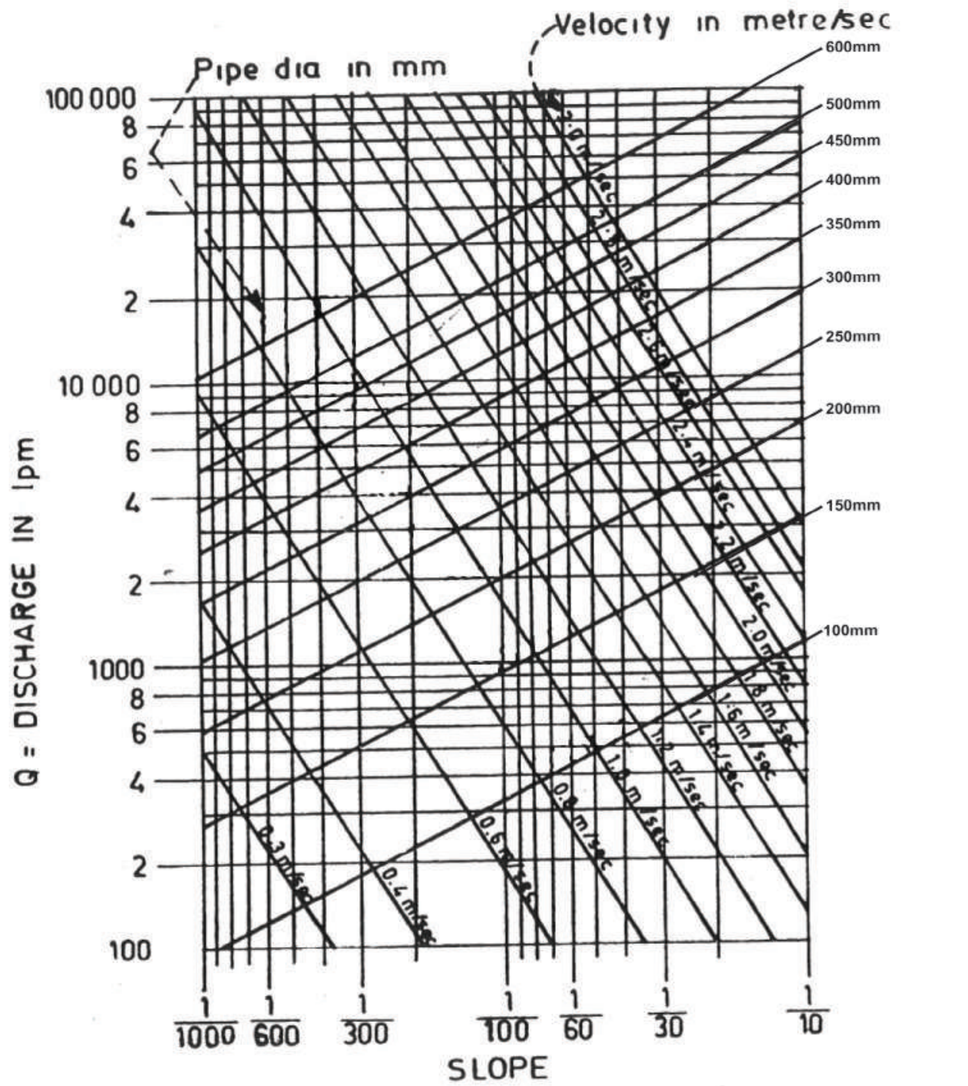


FIG 3 NOMOGRAM CHART FOR HAZEN-WILLIAMS FORMULA
(C = 100) FOR Q = 100 lpm TO 100000 lpm

Figure A3.5A-1

Source-"Data Matrix for Public Health Engineers", TWAD Board, 1991

APPENDIX A 3.5 B
NOMOGRAM FOR HAZEN WILLIAMS FORMULA FOR MAINS FLOWING FULL AND C VALUE OF 100
(For discharges from 1000 to 1000000 lpm)

For other values of C the velocity and discharge will increase pro rata.

Example-Find the discharge and velocity of a sewer flowing full of diameter 1,200 mm, slope of 1 in 1,000 and a Hazen Williams C value of 130

Answer-From the nomogram, V = 0.95 m/s and discharge = 63,000 lpm. For C value of 130,
V = 0.95 × 130 / 100 = 1.24 m/s & discharge = 63,000 × 130 / 100 = 81,900 lpm

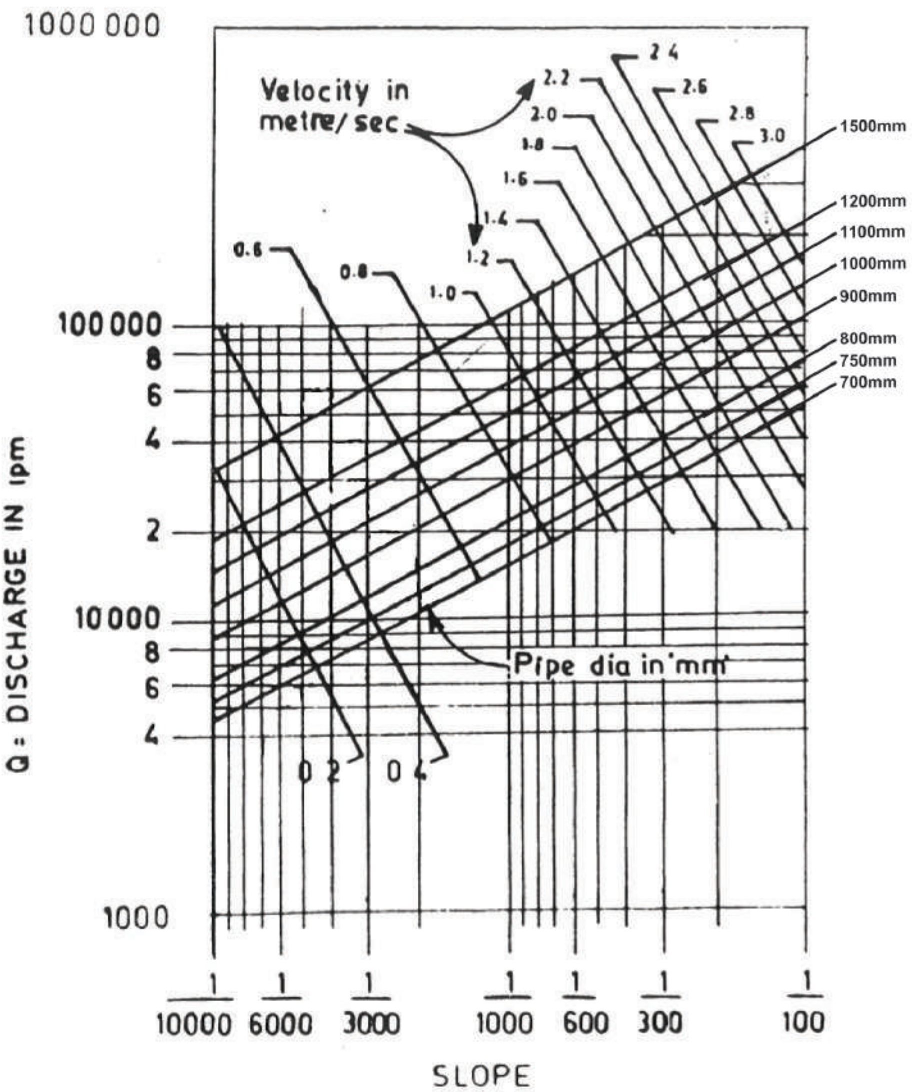


FIG 4 NOMOGRAM CHART FOR HAZEN-WILLIAMS FORMULA

(C = 100) FOR Q = 1000 lpm TO 1000000 lpm

Figure A3.5B-1

Source-“Data Matrix for Public Health Engineers”, TWAD Board, 1991

APPENDIX A 3.6
HAZEN WILLIAMS FORMULA FOR CIRCULAR SEWERS FLOWING UNDER PRESSURE

No	A	B	C
1	Appendix 3.6		
2	Hazen Williams Formula for Circular Sewers Flowing Under Pressure		
3	Given diameter and slope, find velocity and flow rate		
4	This is left blank for the designer to enter his design notes		
5	This is left blank for the designer to enter his design notes		
6	This is left blank for the designer to enter his design notes		
7	diameter, mm	300	Enter by Designer
8	slope 1 in	210	Enter by Designer
9	Hazen Williams C	140	Enter from Table 3.11
10	diameter power 0.63	36.36	POWER(B7,0.63)
11	diameter power 2.63	3272118	POWER(B7,2.63)
12	Slope power 0.54	0.056	POWER((1/B8),0.54)
13	Velocity m/s	1.295	(4.567/1000)*B9*B10*B12
14	Discharge cum / day	7913	(3.1/10000)*B11*B12*B9
15	Discharge in MLD	7.91	B14/1000
16			
17	Given flow rate and slope of sewer, find diameter and velocity		
18	Discharge cum / day	7913	Enter by Designer
19	Slope 1 in	210	Enter by Designer
20	Slope power 0.54	0.056	POWER(1/B19,0.54)
21	Hazen Williams C	140	Enter by Designer
22	diameter power 2.63	3272275	B18/(3.1/10000)/B20/B21
23	diameter, mm	300	POWER(B22,(1/2.63))
24	diameter power 0.63	36	Power(B23,0.63)
25	velocity, m/s	1.295	(4.567/1000)*B20*B21*B24

APPENDIX A 3.7
DESIGN OF SANITARY SEWER SYSTEM
(Retained as in 2nd edition)

1 PROBLEM

Design a system of sanitary sewers for the given area shown in the Figure A3.7-1 with the following details:

1. Population Density - 300 persons/hect.
2. Water Supply - 250 lpd/head (ultimate).
3. Maximum rate of infiltration - 20,000 lpd/hect.
4. Minimum depth of cover to be provided over the crown of the sewer - 1 m
5. Minimum velocity in sewer at peak flow - 0.6mps
6. Maximum velocity in sewer - 2.0 mps
7. Minimum size of the sewer - 150 mm
8. Waste water reaching sewers - 90% of W/S
9. Peak flow - 3.5 × Ave. flow

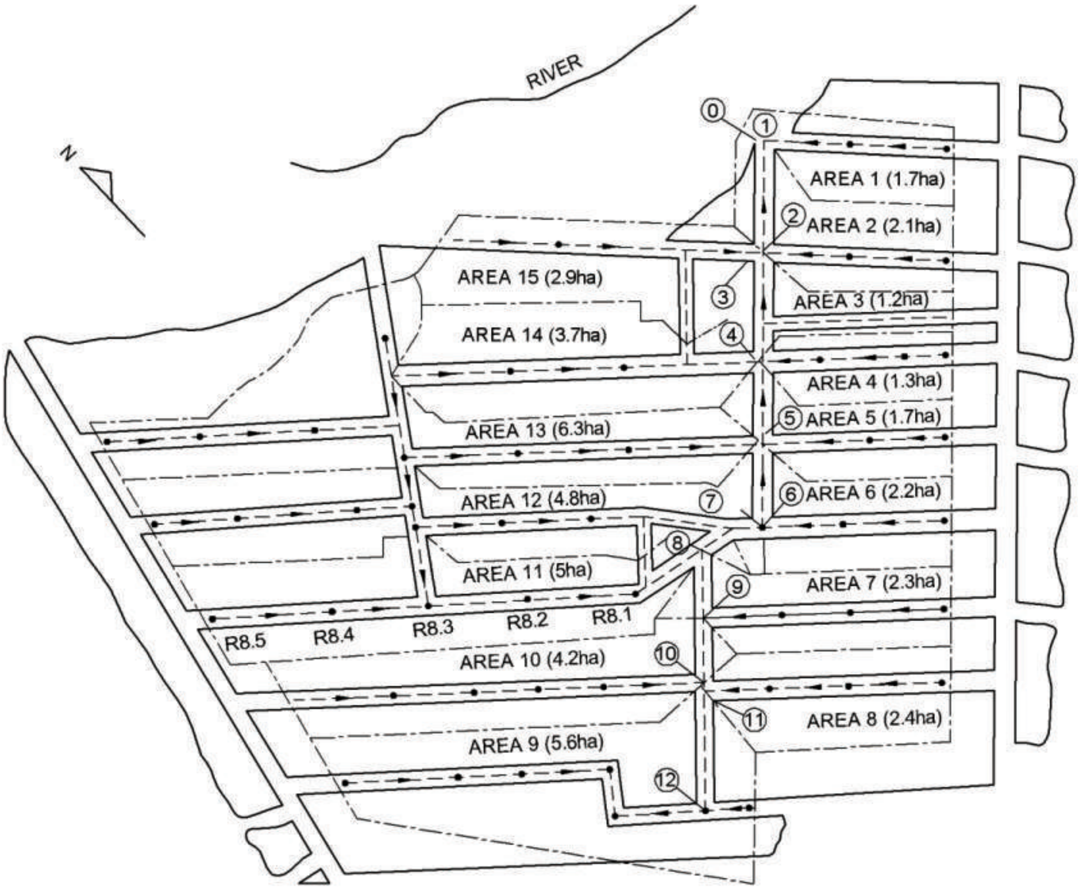


Figure A3.7-1

2 SOLUTION

1. Draw a line to represent the proposed sewer in each street or valley to be served. Near the line indicate by an arrow the direction in which sewage is to flow.
2. Locate the manhole, giving each an identification number.
3. Sketch the limits of the service areas for each lateral.
4. Measure the areas (ha) of the several service areas.
5. Prepare a table as shown in Table A3.7-1 with the columns for the different steps in computation and a line for each section of sewer between manholes.

Columns 1-6 for the line manhole, location of the manhole, manhole numbers, ground level at starting manhole and length of line between the manholes.

Columns 7-8 the corresponding area for the next street of sewer and in Col.8 the sum of the areas are entered.

Column 9 the population served by each corresponding line is entered.

Column 10 shows the sewage flow (mld) through each line. The sewage flow is assumed as 90% of the per capita water supply.

Column 11 shows the ground water infiltration for each area = 20,000 × 10^{-6} × Col.8.

Column 12 gives the peak flow i.e. Col.10 × 3 + Col.11.

Column 13 gives the peak flow in lps.

Column 14-15 indicate the diameter and slope of the pipes determined from the Manning's chart.

Columns 16-17 indicate the discharge through pipe flowing full and the actual discharge through the pipes i.e. as Col. 13.

Column 18 also determined from the Manning's chart when pipe following full.

Column 19 calculated from the hydraulic elements curve for the circular pipes.

Column 20 gives Col.6 × Col.15.

Columns 21-22 invert levels of the lines are calculated.

Table A3.7-1 Design of a sewer system

Line	Location	Manhole		Ground level at start manhole	Length	Area Served (ha)		Population	Sewage flow	Ground water infiltration	Peak flow		Diameter	Slope	Discharge lps		Velocity mps		Total fall	Invert Elevation m	
		From	To		m	Increment	Total		mld	mld	mld	lps	mm		Q Full	Q Actual	V Full	V Actual	m	Upper end	Lower end
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Street	R.8.5	R.8.4	38.275	120	0.80	0.80	240	0.054	0.016	0.205	2.37	150	0.008	14	2.37	0.75	0.57*	0.96	37.125	36.165
2	Street	R.8.4	R.8.3	37.960	116	1.20	2.00	600	0.135	0.040	0.512	5.92	150	0.008	14	5.92	0.75	0.72	0.93	36.135**	35.205
3	Street	R.8.3	R.8.2	36.873	114	1.40	3.40	1020	0.230	0.068	0.873	10.10	150	0.008	14	10.10	0.75	0.82	0.91	35.175	34.265
4	Street	R.8.2	R.8.1	36.895	116	0.90	4.30	1290	0.290	0.066	1.10	12.73	150	0.008	14	12.73	0.75	0.86	0.93	34.235	33.305
5	Street	R.8.1	8	36.420	75	0.70	5.0	1500	0.34	0.10	1.29	14.92	200	0.005	24	14.92	0.70	0.74	0.38	34.275	33.895
6	Street	8	7	36.117	41	14.5	19.5	5850	1.32	0.39	5.01	57.96	300	0.005	70	57.96	1.0	1.13	0.21	33.845	33.635
7	Street	7	6	35.830	26	4.8	24.3	7300	1.64	0.48	6.22	71.96	350	0.005	100	71.96	1.2	1.32	0.13	33.605	33.475
8	Main St.	6	5	35.105	88	2.2	26.5	7950	1.80	0.53	6.83	79.02	350	0.005	100	79.02	1.2	1.32	0.44	33.445	33.005
9	-do-	5	4	34.412	86	7.8	34.3	10300	2.31	0.68	8.76	101.35	400	0.0033	125	101.35	1.0	1.12	0.29	32.975	32.685
10	-do-	4	3	34.181	36	5.0	39.3	11800	2.65	0.70	10.05	116.28	400	0.0033	125	116.28	1.0	1.14	0.12	32.655	32.535
11	-do-	3	2	34.105	77	1.2	40.5	12150	2.73	0.80	10.35	119.75	400	0.0033	125	119.75	1.0	1.14	0.26	32.505	32.245
12	-do-	2	1	34.905	117	5.0	45.5	13650	3.07	3.91	11.65	134.79	450	0.0033	160	134.79	1.0	1.12	0.39	32.208	31.811
13	-do-	1	0	33.250	41	1.7	47.2	14200	3.2	0.94	12.14	140.46	450	0.0033	160	140.46	1.0	1.12	0.14	31.788	31.641

* Since velocity is less than 0.6mps, flushing once a day is necessary; ** A minimum level difference of 30 mm is provided between incoming and outgoing sewers to provide necessary slope in the manhole.

APPENDIX A 3.8
ILLUSTRATIVE EXAMPLES FOR STRUCTURAL DESIGN OF BURIED CONDUITS
(Retained as in 2nd edition)

General assumptions

The general assumptions relating to the characteristics of soil and other factors for the examples are given below:

i) Saturated density of fill(w)= 2,000 kg/m^3

ii) Kμ = Kμ' = 0.130, ordinary maximum tor clay (thoroughly wet)

iii) r_{sd} for rigid conduit on ordinary bedding= 0.7 for positive projection and -0.3 for negative projection

iv) Projection ratio = 1

v) Concentrated surcharge corresponding to wheel load for Class AA wheel loading=6.25T

vi) Impact factor = 1.5

vii) Factor of Safety for safe supporting strength = 1.1

viii) The design also provides for accidental surcharge of drains and accounts for a water load of 75% as per standard practice, based on the assumption that the sewage flow is 3/4 full.

Determination of fill loads over pipes

EXAMPLE I

1 PROBLEM

Determine the fill load on a 1,200 mm dia. NP2 Class concrete pipe installed in a trench of width of 2.3 m and depth of 4.00 m.

2 SOLUTION

Pipe thickness 't' = 65mm for D of 1,200mm

B_c = D + 2t = 12,00 + 130 = 1,330mm = 1.33m

B_d = 2.3m

H = 4.00 – 1.33 = 2.67 m

H/ B_d = (2.67 / 2.3) = 1.16

B_d is < 2B_c Hence trench formula is applicable.

C_d = 0.9965 or 1.00 (from Table3.19) for ordinary maximum for clay.

From Equation (3.29)

$W_c = C_d\, w\, B_d^2$ = 1.00 × 2,000 × 2.32 = 10,580 kg/m

EXAMPLE II

1 PROBLEM

Determine the fill load on 900mm dia NP2 Class concrete pipe installed in a trench of width 2.1 m and depth 6.0 m.

2 SOLUTION

Pipe thickness 't' 50mm for D of 900mrn

Bc = D + 2t = 900 + 100 = 1,000mm =1m

w = 2,000kg/m^2

H = 6.0 – 1.0 = 5.0m

B_d = 2.1m

(H / B_d) = (5.0 / 2.1) = 2.38

$2B_c < B_d < 3B_c$ Hence either the trench or embankment formula can be used,

From Table 3.19

Cd = 1.77188 or say 1.8

From Equation (3.29)

$W_c = C_d\ w\ B_d^2 = 1.8 \times 2{,}000 \times 2.1^2 = 15{,}876$ kg/m or say 16,000 kg/m.

EXAMPLE III

1 PROBLEM

Determine the fill load on a 1,200mm dia NP2 Class concrete pipe installed as a positive projecting conduit under a fill of 7 m height above the top of pipe. The pipe wall thickness is 65mm and the fill weight 2,000 kg/m^3.

2 SOLUTION

Assume r_{sd} = 0.7 and p = 1.0

H = 7 m

B_c = 1,200 + 130 = 1,330mm = 1.33m

H/B_c = 7/1.33 = 5.26

rsd × p = 0.7 × 1 = 0.7

C_c = 9 (from Figure 3.34)

Using Equation (3.25)

$W_c = C_c\ w\ B_c^2 = 9 \times 2{,}000 \times 1.332 = 31{,}850$ kg/m

EXAMPLE IV

1 PROBLEM

Determine the fill load on a 1,200mm dia NP2 Class pipe installed as a negative projection conduit in a trench the depth of which is such that the top of the pipe is 2 m below the surface of natural ground in which the trench is dug. The height of the fill over the top of the pipe is 10m.

2 SOLUTION

Assume the width of the trench as 2 m and fill weight, w = 2,000 kg/m^3

Assume r_{sd} = – 0.3 and p' = 1.0

H = 10m, B_d = 2.00m H/B_d = 10/2 = 5.00

For values of p' = 1.0 r_{sd} = – 0.3 and H/B_d = 5.00

C_n = 3.2 (from Figure 3.36)

Using Equation (3.26)

$W_c = C_n\ w\ B_d^2$ = 3.2 × 2,000 × 2.02 = 25,600 kg/m

EXAMPLE V

1 PROBLEM

Determine the load on 1,500mm dia conduit in tunnel condition 15 m deep in a soil of silty sand.

2 SOLUTION

The maximum width of excavation (Bt) may be assumed as 1,950mm; and the cohesion coefficient (C) of the soil as 500 kg/m^2

Kμ = 0.15 and w = 1,800 kg/m^3

H =15 m; Bt = 1.95 m

H/Bt = 15/1.95 = 7.7

Ct = 3.00 (from Figure 3.42)

Using Equation (3.31)

$W_t = C_t.\ B_t.(w\ B_t - 2C)$ = 3.00 ×1.95 (1,800 × 1.95 – 2 × 500)

= 3.00 × 1.95 × 2,510 = 14,680 kg/m

EXAMPLE VI

1 PROBLEM

Determine the load on a 600 mm dia NP2 Class pipe (t = 40 mm) under 1 m cover caused by 6.25 Tonnes Wheel load applied directly above the centre of pipe.

2 SOLUTION

L = 1 m (since standard length of conduit 1 m)

H = 1 m

B_c = 600+80 = 680 mm = 0.68 m

(L/2H) = (1.0/2× 1) = 0.50

(B_c /2H) = (0.68/2 × 1) = 0.34

From Table 3.21 for values of (L/2H) = 0.50

And (B_c /2H) = 0.34

C_s = 0.248

Using Equation (3.33)

W_{sc} = C_s (PF / L) = (0.248 × 6250 × 1.5/1.0) = 2,325 kg/m

EXAMPLE VII

1 PROBLEM

Determine the load on a 1,200 mm dia concrete pipe under 2 m of cover resulting from a broad gauge railway track loading;

2 SOLUTION

Assumed thickness of pipe = 100 mm

Axle load P = 22.5 tonnes

Impact factor F = 1.75

Length of sleeper 2A = D = 2.7 m

Assume 4 axles spaced 1.84 m on the locomotive (2B)

M = 4 × 2B = 4 × 1.84 = 7.36 m; H = 2 m

Weight of track structure =wt = 0.3 T/m

Using equation (3.37)

$$U = \frac{PF + 2W_t B}{4AB} = \frac{PF}{4AB} + \frac{W_t}{2A}$$
$$= \frac{22.5 \times 1.75}{2.7 \times 1.84} + \frac{0.3}{2.7} \quad T/m^2$$
$$= 7.925 + 0.111 = 8.036 \text{ tonnes/m}^2$$

Bc = 1,200 + 200 = 1,400mm = 1.4 m

$$\frac{D}{2H} = \frac{2.7}{2 \times 2} = 0.675$$
$$\frac{M}{2H} = \frac{4 \times 1.84}{2 \times 2} = 1.84$$

From Table 3.21

Influence Coefficient C_s = 0.652

Using Equation (3.36)

W = 4 C_s U B_c = 4 × 0.652 × 8.036 × 1.4 = 29.34 tonnes/m = 29,340 kg/m

(Since it has been given that it is a broad gauge track, the formula W = 32.14 C_s B_c, could be used directly without calculating the value of U).

Using the formula W = 32.14 C_s B_c

W = 32.14 × 0.652 × 1.4 = 29.337 t/m. or 29,337 kg/m

EXAMPLE VIII

1 PROBLEM

Design the structural requirement tor a 900mm dia. NP3 class sewer pipe which is to be laid in 6m deep trench of 2.0 m width assuming that the total vertical load will account tor concentrated surcharge of 6.25 T applied at the centre of the pipe. The water load should also be considered.

2 SOLUTION

The type of bedding for the purpose of this example may be assumed as Ab class with load factor of 2.8.

B_c = 900 + 2 × 50 = 1,000 mm = 1.0 m
H = 6 – 1 = 5 m
B_d = 2.0
H/B_d = 5/2.0 = 2.50
Cd = 1.764 (from table 3.13 for saturated top soil)
Using equation (3.29) ……. $W_c = C_d \, w \, B_d^2$
Wc = 1.764 × 2,000 × 22 = 14,110 kg/m.
L = 1m, H = 5m

$$\frac{L}{2H} = \frac{1}{10} = 0.1$$

and

$$\frac{B_c}{2H} = \frac{1}{10} = 0.1$$

From Table 3.21 $C_s = 0.019$
Using Equation (3.33)
$W_{sc} = C_s$ (PF/L) = (0.019 × 6,250 × 1.5) / 1 = 178 kg/m

$$Water\ Load\ W_w = \frac{22}{7} \times \frac{9}{10} \times \frac{9}{10} \times \frac{1}{4} \times 1{,}000 \times \frac{75}{100} = 471\,kg/m$$

$W_t = W_c + W_{sc} + W_w$ = 14,110 + 178 + 471 = 14,759 or say 14,800 kg/m

Safe supporting strength of 900 mm NP_2 pipe with class A_b bedding = [(3,750 × 2.8) / 1.5] = 7,000 kgs/m which is less than the total load on the pipe i.e. 14,800 kgs/m.

Safe supporting strength of 900 mm NP_3 pipe with class A_b bedding = [(10,140 × 2.8) / 1.5] = 18,928 kgs/m. which is more than the total load on the pipe i.e. 14,800 kgs/m.

Design of anti flotation blocks

EXAMPLE IX

1 PROBLEM

A RCC pipeline of internal dia 2,000mm and barrel thickness of 115mm is to be laid below Ground level. Each pipe is 2.5 metre long and weighs 2 Tonnes. The minimum overburden required to prevent the pipe from upliftment is to be determined. Where there is no over-burden the size of RCC of antiflotation block required to prevent it from flotation is to be determined.

2 SOLUTION

Depth of cover to prevent flotation of an empty pipeline.

$$H_{min}\ B_c\ (w_s - w_o) + W_c = \left(\frac{\pi}{4}\right) B_c^{\ 2}\ w_o$$

Where,

H_{min} : Minimum depth of fill required to prevent flotation of empty pipe
B_c : O.D. of pipe, meters
W_s : Density of (soil) fill material = 1,800 kg/m^3
W_o : Density of water = 1,000 kg/m^3

To show that the pipe gets lifted up if there is no over burden
Weight of empty pipe W_c = 2,000 kg/metre
B_c = 2.00 + 0.23 = 2.23 metre (O.D. of pipe)
When there is no over burden weight of water
displaced = $(\pi / 4)\ B_c^2\ w_o$
$(\pi / 4)$ (2.23)2 1,000 = 3,910 kg or 3.91 tonnes

Since the weight of Empty pipe (2 tonnes) is less than the upward weight of water (3.91 tonnes) the pipe will float.

Depth of minimum overburden required to prevent flotation with a factor of safety 1.2

$H_{min}\ B_c\ (ws - wo) + W_c = (\pi / 4) \times B_c^2\ w_o$
$H_{min} \times 2.23\ (1.8 - 1.00) + 2 = [(\pi/ 4)] \times 2.232 \times 1 \times$ (Factor of safety of 1.2)
H_{min} = 1.5 metres

Hence it is desirable to provide a cover of 1.5 metres to prevent flotation of pipeline.

Where it is not possible to provide the above minimum over burden anti flotation blocks can be provided for each pipe to prevent flotation of pipeline.

The Anchoring force required to be created is equal to the 1st term of the Equation (3.32).

$H_{min}\ B_c\ (w_s - w_o)$
H_{min} = 1.5m with a factor of safety of 1.2
B_c = 2.23m
w_s = 1,800 kg/m^3
w_o = 1,000 kg/m^3
1.5 × 2.23 × (1.8 – 1.00) = 2,680 kg/metre length of pipe
Anchoring force required for each pipe of 2.5 metre long
= 2.68 × 2.5 = 6.7 tonnes per pipe

Volume of concrete to be provided;

Submerged weight of concrete: (2,400 – 1,000) = 1,400 kg/m3 or 1.4 tonnes/m^3

Volume = (6.7 / 1.4) = 4.78 m^3

Provide anti flotation block of size 2.85 × 1.5 × 1.20 m for each pipe of 2.5 m long (Figure A3.8-1).

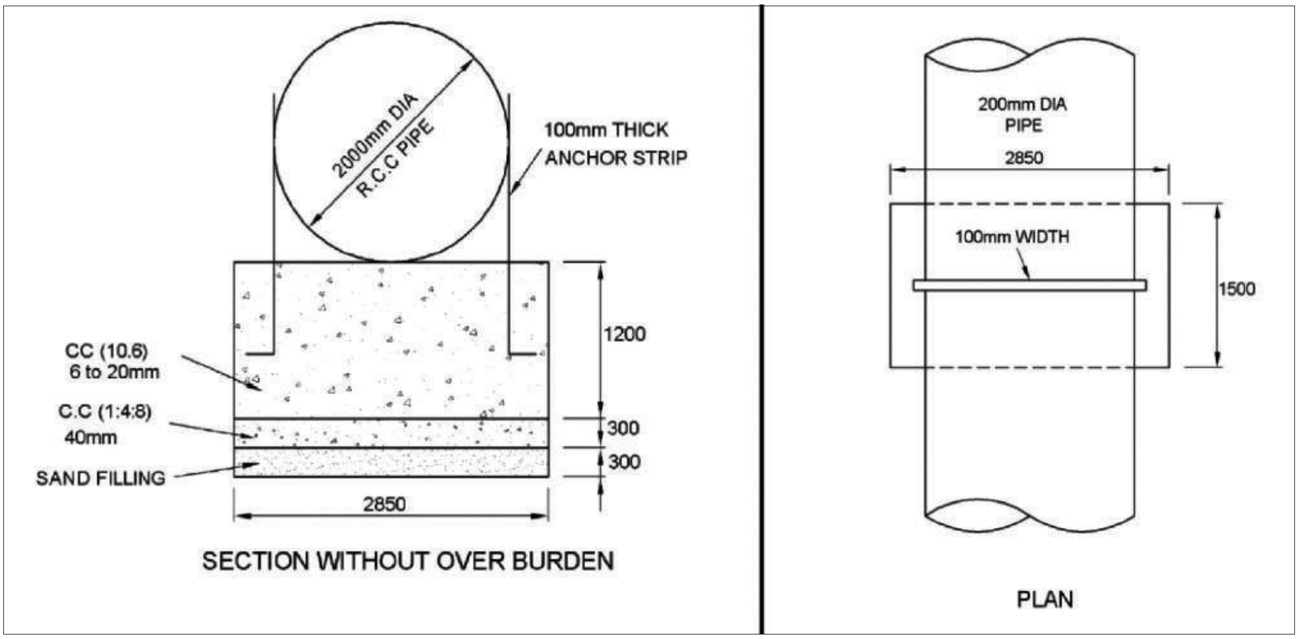


Figure A3.8.1 Anti Floatation Blocks

APPENDIX A 3.9
THREE EDGE BEARING TESTS FOR PIPE STRENGTH
(Retained as in 2nd edition)

The load which the pipe must withstand without failure is termed three-edge bearing strength. For non reinforced concrete pipes, the point of load at which the pipe cracks and fails is the termination of a three-edge bearing test.

For reinforced concrete pipes, these specifications provide two criteria for passing the three-edge bearing test; first, there is an intermediate load based on the appearance of a crack 0.25 mm wide and 0.3 m long. The final requirement for reinforced pipe is the ultimate three-edge bearing strength at the final failure of the pipe where no further load increase can be supported.

In conducting this test, the pipe is placed horizontally on two parallel wooden rails resting on 15cm × 15cm bearing block or other solid support that extends the length of the pipe. An upper bearing block is placed on the top of the pipe. Next, a rigid I-beam or other structural member is placed on the upper bearing block to apply the load to the block.

Table A3.9-1 Three edge bearing strengths of concrete pipes are given below

	Load to produce 0.25 crack (kg/liner meter)				Ultimate load (kg/liner meter)		
Dia of pipe mm	Concrete				Concrete		
	NP_2 P_1 P_2 & P_3	NP_3	NP_4	NP_1	NP_2 P_1 P_2 & P_3	NP_3	NP_4
1	2	3	4	5	6	7	8
80	1,040	-	-	-	1,560	-	-
100	1,040	-	-	1,560	1,560	-	-
125	-	-	-	-	-	-	-
150	1,040	-	-	1,560	1,560	-	-
200	-	-	-	-	-	-	-
250	1,140	-	-	1,670	1,710	-	-
300	1,200	-	-	1,790	1,800	-	-
350	1,260	3,040	-	1,880	1,890	4,363	-
400	1,360	3,460	3,460	2,020	2,040	5,190	5,190
450	1,480	3,730	-	2,220	2,220	5,640	-
500	1,660	4,160	4,160	-	2,490	6,240	6,240
600	1,900	4,720	4,720	-	2,850	7,980	7,980
700	2,100	5,320	5,120	-	3,150	7,980	7,980
800	2,300	6,060	6,060	-	3,430	9,090	9,090
900	2,500	6,760	6,760	-	3,750	10,140	10,140
1,000	2,680	7,400	7,400	-	4,020	11,100	11,100
1,100	2,780	8,200	8,200	-	4,170	12,300	12,300
1,200	2,880	9,000	9,000	-	4,320	13,500	13,500
1,400	2,900	-	10,610	-	4,470	-	17,950
1,600	2,980	-	12,800	-	4,470	-	18,300
1,800	2,980	-	13,800	-	4,470	-	20,700

APPENDIX A 3-10
RELATIVE LIMITATIONS ON USE OF PIPE MATERIALS (IN ALPHABETICAL ORDER) IN SPECIFIC LOCATIONS
(Pipe materials listed in alphabetical order)

Asbestos Cement (AC) Pipes	
AC-1	Not suitable for high sulphate levels in sewage / soil water, unless good lining such as HDPE/GRP/PVC/PE/CM with sulphate resistant cement lining is provided or pipe manufactured with sulphate resistant cement or Alumina cement. The quality of the lining shall be ensured by the competent authority.
AC-2	Not in aggressive soils/groundwater or tidal zone unless sulphate resistant cement or high alumina cement is used in manufacture.
AC-3	Not in locations where live load from vehicular traffic will occur on the laid pipeline
Cast Iron or Ductile Iron (CIDI) Pipes	
CIDI-1	Never to be used near buried electricity transmission high tension cables
CIDI-2	Wherever used above ground supports at each pipe length shall be ensured without any subsidence.
CIDI-3	Pipes with external synthetic coatings not to be used in marine coastal environments to prevent leaching of constituent chemicals into the environment
Glass Fiber Reinforced (GRP) Pipes	
GRP - 1	Not in area where future works may affect the pipe side support.
GRP - 2	Not in ground contaminated or possibly contaminated by certain chemicals in concentrations deleterious to the resin of the pipe.
GRP - 3	Do not use pipes/couplings with chips, cracks, crazing, layer delamination or exposed fibres or ends of pipes not sealed with resin
GRP - 4	Do not use pipe and couplings, stored unprotected from sunlight for more than 9 months.
GRP - 5	Do not use in ground conditions having low stiffness, e.g. tidal zone.
GRP - 6	Not in location subjected to vehicular load and has insufficient cover.
GRP - 7	Not in areas subject to excavations by other service providers within 2m radial distance of pipeline.
GRP - 8	Not in ground subject to differential settlement or extreme movement
GRP - 9	Not in ground offering low side support strength to the pipe.
GRP - 10	Do not use when control of construction practices is not adequate to ensure quality of embedment for flexible pipes.

GRP - 11	Not suitable for uncertainties in geotechnical analysis to determine if flexible pipe structurally suitable
GRP - 12	Uplift precaution in locations where high groundwater table and empty pipe may be encountered
Mild Steel (MS) Pipes	
MS - 1	Never to be used near electricity transmission cables
MS - 2	Never to be used below ground unless proper protection against corrosion from soil and soil water is ensured
MS - 3	Can be considered with appropriate lining and protection for gravity flow under exceptional circumstances. The quality of the lining shall be ensured by the competent authority.
MS - 4	Choice of spiral welded Vs or horizontal welded pipes shall be evaluated with respect to overburden
Reinforced Cement Concrete (RCC) Pipes	
RCC - 1	Not suitable for high sulphate levels in sewage / soil water, unless good lining such as HDPE/GRP/PVC/PE/CM with sulphate resistant cement lining is provided or pipe manufactured with sulphate resistant cement or Alumina cement. The quality of the lining shall be ensured by the competent authority.
RCC - 2	Not in aggressive soils/groundwater or tidal zone unless sulphate resistant cement or high alumina cement is used in manufacture.
Stoneware Pipes with hemp yarn and cement mortar (SWCM) packing joints	
SWCM - 1	Not in unstable ground, i.e. refilled ground, tidal zone.
SWCM - 2	Not suitable for above ground installation.
SWCM - 3	Not in the vicinity of trees with aggressive root systems.
SWCM - 4	Not to be used for crossing beneath water courses.
Stoneware Pipes with O ring (SQOR) joints	
SWOR - 1	Not in unstable ground, i.e. refilled ground, tidal zone.
SWOR - 2	Not suitable for above ground installation.
SWOR - 3	Not to be used for crossing beneath water courses.
Synthetic Pipes like Profile Wall, Double walled corrugated, PE, Solid Wall, HDPE, UPVC (SP) Pipes	
SP - 1	Not in location subjected to vehicular load and has insufficient cover.
SP - 2	Not in areas subjected to third party interference, e.g. excavations within 2m of pipeline by other parties.
SP - 3	Not in ground offering low side support strength to the pipe

SP - 4	Not in ground which allows migration of pipe embedment material into it.
SP - 5	Not in ground contaminated with deleterious chemicals
SP - 6	Not suitable for above ground installation
SP - 7	Not suitable as reticulations systems except for special applications

Note: Wherever special circumstances are encountered the above limitations can be overcome by appropriate precautions with the documented approval of the competent authority

APPENDIX A 4.1
COMPUTATION OF FRICTION FACTOR IN PUMPING MAINS

1	B	C	D
2	Appendix A 4-1		
3	Friction factor for Fittings in Pressure Mains		
4	Given the type and numbers of fittings, find the total friction factor		
5	This is left blank for the designer to enter his design notes		
6	Number of Sudden contractions	Enter by Designer	2
7	Friction Factor for each	From Table 4.2	0.5
8	Friction factor for all	D6*D7	1
9	Entrance shape well rounded	Enter by Designer	1
10	Friction Factor for each	From Table 4.2	0.5
11	Friction factor for all	D9*D10	0.5
12	Elbow 90 degrees	Enter by Designer	4
13	Friction Factor for each	From Table 4.2	1
14	Friction factor for all	D12*D13	4
15	Elbow 45 degrees	Enter by Designer	4
16	Friction Factor for each	From Table 4.2	0.75
17	Friction factor for all	D15*D16	3
18	Elbow 22 degrees	Enter by Designer	2
19	Friction Factor for each	From Table 4.2	0.5
20	Friction factor for all	D18*D19	1
21	Tee 90 degrees	Enter by Designer	4
22	Friction Factor for each	From Table 4.2	1.5
23	Friction factor for all	D21*D22	6
24	Tee in straight pipe	Enter by Designer	1
25	Friction Factor for each	From Table 4.2	0.3
26	Friction factor for all	D24*D25	0.3
27	Gate valve open	Enter by Designer	4

28	Friction Factor for each	From Table 4.2	0.4
29	Friction factor for all	D27*D28	1.6
30	Valve with reducer and increaser	Enter by Designer	3
31	Friction Factor for each	From Table 4.2	0.5
32	Friction factor for all	D30*D31	1.5
33	Globe valve	Enter by Designer	4
34	Friction Factor for each	From Table 4.2	10
35	Friction factor for all	D33*D34	40
36	Angle	Enter by Designer	2
37	Friction Factor for each	From Table 4.2	5
38	Friction factor for all	D36*D37	10
39	Swing check	Enter by Designer	1
40	Friction Factor for each	From Table 4.2	2.5
41	Friction factor for all	D39*D40	2.5
42	Venturi meter	Enter by Designer	1
43	Friction Factor for each	From Table 4.2	0.3
44	Friction factor for all	D42*D43	0.3
45	Orifice	Enter by Designer	1
46	Friction Factor for each	From Table 4.2	1
47	Friction factor for all	D45*D46	1
48	Total friction factor	D8+D11+D14+D17+D20+D23+D26+D29+D32+ D35+D38+D41+D44+D47	72.7

APPENDIX A 4.2
CALCULATION OF KW NEEDED FOR PUMPING

Given

Low sewage level	= 3.5 m
Delivery level	= 32.5 m
Velocity	= 0.883 m/s
Discharge	= 7,913 cum / day
Slope	= 210
Length of pumping main	= 4,200 m
Top of goose neck before delivery	= 34.0 m
Friction factor due to fittings as in Appendix 4-1	
Type of pump is submersible	
Efficiency assumed	= 0.65
Safety factor for estimation	=1 / 0.9

Answer

Goose neck is treated as well rounded entrance	= factor is 1
Hence friction loss due to fittings is	= 70 + 2 = 72
Discharge	= 7,913 × 1,000 / 24 / 3,600 = 91.6 lps
Velocity head	= 0.883 × 0.883 / 2 / 9.81 = 0.04
Loss of head in fittings	= 0.04 × 72 = 2.87 m
Top elevation of goose neck at delivery	= 34.0 m
Add factor of safety against cavitation	= 1 m
Static lift	= (34+1) – 3.5 = 31.5 m
Friction loss	= 4,200 / 210 = 20 m
Total system head	= 2.87 + 31.5 + 20 = 54.37 m
Pump efficiency	= 0.65
Actual kW needed	= 91.6 × 54.37 / 100.5/ 0.65 / 0.9 = 85 kW

APPENDIX A 4.3

EFFECTS OF SILTING AND EROSION SEWAGE PUMPING MAIN PERFORMANCE

The following is an extract from the "Master Plan for Water and Sewerage" by the WHO and UNDP for the Chennai Metropolitan Area prepared dated 1977 and which was the basis for the country's first birth of an exclusive Water Supply and Sewerage Board at Chennai.

Five numbers of differently aged sewage pumping mains of Chennai sewerage system were selected and the hydraulics were evaluated using Rhodamine B Fluorescent tracer dyes injected into the pump deliveries and the concentrations were measured with a fluorometer at the start and discharge of the pumping mains and related to the measured flows, diameter and length of the pipe lines which were all Cast Iron mains with spigot socket lead joints. The study was aimed to establish the velocity profiles, siltation in the pumping mains and the resulting friction co-efficient. All the pumping mains were low lift pumping stations and hence the Manning's n was selected as the criteria of friction factor evaluation.

1 The Physical Setting and Methodology

The sandy soils in the area coupled with the local practice of scouring cooking pots with sand contribute to the inordinate quantities of grit and silt found in Madras sewage. This phenomenon was recognized by Mr. J. W. Madeley, and his investigations conducted in the early 1900's led to the construction of degritting wells ahead of the major pump stations which however were mostly non-operational. As part of the present investigations, tests were conducted at five of the pump stations. Static head and friction losses were measured at several flows with dual pressure gauges immediately downstream from the pump station manifold. Flows were measured by using a Turner fluorometer and standardized solutions of Rhodamine "B" dye. The dye was fed at a constant rate into the pump bell mouth by a calibrated peristaltic pump and samples were collected at a point far enough downstream from the pump to ensure complete mixing. Flow rates were computed from the observed dilution of the standard fluorescent dye solution.

The results of these tests are presented in Table A4.3-1. The measurements of flow, total head and static head are given in columns (1) to (3). The dynamic head column (4) is the difference between the total and static heads. Column (5) shows the calculated flow velocities. The "K" value in column (6) is equal to Δhd/Q2. The Manning's roughness coefficient, n, was calculated from the Manning equation:

$$Q = (A/n)R^{2/3}(\Delta h_d/L)^{1/2}$$

Examination of Table A4.3-1 shows that the calculated K and n values change with flow and velocity. Higher apparent n values are associated with lower velocities. Hydraulic theory dictates that there are only two possible causes for this phenomenon, either the basic relation changes or the cross sectional area of the pipe and / or the roughness of its interior change. Dr. Walter L Moore discussed the first of these possibilities in his 1959 ASCE paper entitled "Relationships between pipe resistance formulas", where it was shown that the friction loss constant K, does increase slightly as the flow is reduced towards the point where the laminar flow regime begins. To account for this phenomenon, Dr Moore developed a procedure for varying the exponent "m" as a function of the Reynolds Number and, thereby, allowing K to remain constant.

Table A4.3-1 Force Main Friction Loss Analysis

Force main	Q flow	Δh_T	Δh_S	Δh_d	Velocity	Measured K $\Delta h_d/Q^2$	Computed Roughness Coefficient
	m^3/s	Total Head meters of water	Static Head metres of water	Dynamic Head metres of water	m/s	S^2 / m^5	"n"
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Greams road	0.095	4.92	2.81	2.11	0.83 / 0.57	234	0.0104
625 m of 380 mm	0.136	7.03	2.81	4.22	1.19 / 0.82	228	0.0102
1,595 m of 460 mm	0.195	11.96	2.81	9.15	1.71 / 1.19	241	0.0106
New Purasawalkam	0.387	2.39	1.4	1.0	0.43 / 0.32	6.68	0.0154
3,017 m of 1,065 mm	0.449	2.67	1.4	1.27	0.50 / 0.38	6.30	0.0150
1,723 m of 1,200 mm	0.544	3.16	1.4	1.76	0.61 / 0.46	5.95	0.0145
	0.66	7.38	1.4	5.98	0.74 / 0.57	13.7	0.0221
Langs Garden	0.0665	2.8	nil	2.8	0.91	633	0.0134
603 m of 305 mm	0.074	3.5	nil	3.5	1.01	639	0.0135
Chetput	0.0296	5.62	nil	5.62	0.58	6414	0.0205
990 m of 225 mm	0.043	5.975	nil	5.97	0.85	3229	0.0146
	0.0296	5.45	nil	5.45	0.58	6220	0.0202
Law College	0.071			1.8	0.32	357	0.0240
2,107 m of 535 mm	0.085			3.2	0.38	443	0.0267
	0.111			5.49	0.50	446	0.0268
	0.15			4.45	0.67	198	0.0179
	0.17			3.4	0.76	118	0.0138
	0.202			4.45	0.90	109	0.0133

Modified K values were computed using Dr Moore's method in an attempt to explain the severe variations noted in column (6), but this refinement did little to stabilise the K values, and therefore, the variations must be attributed to the silt buildup changing the cross sectional are of the lines.

Data developed from the Law College tests were subjected to further analysis with the results shown in Table A4.3-2. Assuming that the variations in K values were in fact due to the partial clogging of the pipe, equivalent pipe sizes and areas were computed as in columns (4) and (5) of Table A4.3-2. The % shown in column (6) represent the unclogged area of a 535 mm diameter pipe which would have a cross sectional area equal to the equivalent pipe noted in column (5). Column (7) shows the apparent velocity of the flow, noted in column (1), travelling through a clean, 535 mm diameter line.

Considering these measured and computed data the bottom 40 to 45 percent of the Law College force main is evidently clogged with silt and remains so until the flow reaches an apparent velocity of approximately 0.55 m/s. at velocities greater than 0.6 m/s scouring begins to take place, and the pipe is essentially cleaned out when the apparent velocity exceeds 0.7 m/s. This phenomenon is illustrated graphically in Figure A4.3-1 is the measured flow versus head loss for the 535 mm force main is plotted.

Table A4.3-2 Analysis of Law College Force Main Losses.

Q	h	k	Equivalent pipe size (for n = 0.0135)	Equivalent pipe area	Equivalent portion of unclogged pipe	Apparent Velocity
m^3/s	m		mm	sqm	%	m/s
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0.071	1.8	357	430	0.145	65	0.32
0.085	3.2	443	413	0.134	60	0.38
0.111	5.49	445	412	0.134	60	0.50
0.15	4.45	198	480	0.181	81	0.67
0.17	3.4	118	529	0.220	98	0.76
0.202	4.45	109	537	0.226	101	0.90

Four conclusions can be drawn from the results of the force main tests.

Firstly, the clogging of force mains with silt is a significant problem, and the current degritting methods are not effective. The Law College force main is not an exception because equally large concentrations of grit were observed in the flow of all force mains tested. Clogging takes place rapidly because the 40 percent reduction in the cross section of the Law College force main occurred within a period of twelve hours.

Secondly, no special tools or equipment are required to remove silt from a force main in as much as subjecting the line to velocities of greater than 0.8 m/s appears to remove essentially all the accumulations.

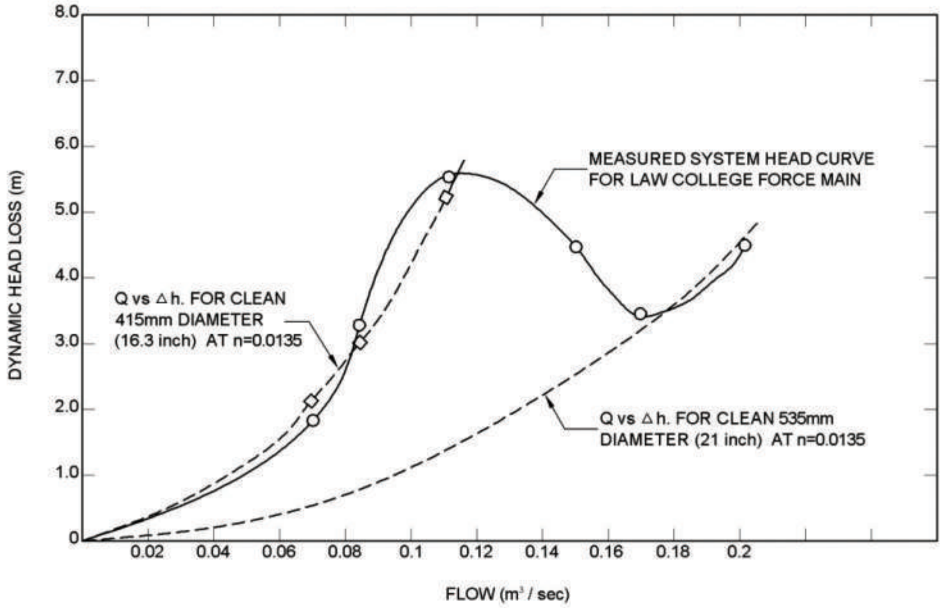


Figure A4.3-1 Measured Flow vs. head in the Law College Sewage Pumping Station

Thirdly, no economy in power cost is gained by designing the large force mains to operate at low velocities unless much more effective grit removal is practiced. Larger lines will fill; up with silt until a scour velocity is reached and then produce the friction losses commensurate with the smaller equivalent pipe.

Fourthly, force mains which have been operated at reasonably high velocities exhibit a friction loss coefficient “n” when clean similar to that of smooth wrought iron pipe. Evidently, the larger quantities of grit transported through these lines has polished their interiors. In fact Greams road force main was apparently so thoroughly polished that it responded hydraulically like a smooth brass or glass pipeline. It was therefore concluded that a friction loss co-efficient of 0.0125 is more representative of the Madras Force mains than the normally accepted values for new cast iron of 0.013.

This historical record establishes the need to ensure (a) adequate grit removal before pumping and adequate non silting velocities in the design stage itself as otherwise, like the mains reported herein, the siltation may be severely restraining the pumping main capacities in the years to come and especially in locations where the densification of population is very slow in newer habitations and eventually when the population does pick up to designed capacity, the pumping mains would have been severely choked calling for radical “cut and cure” techniques.

By a similar argument, the same can also happen to the gravity sewer collection pipes also and it will not be easy to “cut and cure” such gravity sewers.

The study also advances a case effectively on the need for incremental sewerage and non conventional options as in chapter-3 especially in the case of newer layouts.

APPENDIX A 4.4

EVALUATING OPTIONS FOR SIZING THE SEWAGE PUMPING MAIN AND PUMP SETS

1	Appendix A 4-4										
2	B	C	D	E	F	G	H	I	J	K	L
3	Condition of flow		Immediate flows			Intermediate flows			Ultimate flows		
4	Stage		low	ave	peak	low	ave	peak	low	ave	peak
5	Average flow, cum / day	Enter by Designer		1500			3800			7900	
6	Proportion	Enter by Designer	0.6	1	2.2	0.6	1	2.2	0.6	1	2.2
7	Design flow, cum / day	E5*D6, E5*E6, E5*F6	900	1500	3300	2280	3800	8360	4740	7900	17380
8	Hazen Williams C	Enter by Designer	100	100	100	100	100	100	100	100	100
9	Desired velocity, m/s	0.8, D9*E6/D6, D9*F6/D6	0.8	1.3	2.9	0.8	1.3	2.9	0.8	1.3	2.9
10	Area needed, sqm	D7/24/3600/D9	0.013	0.013	0.013	0.033	0.033	0.033	0.069	0.069	0.069
11	Dia needed, m	SQRT(D10*4/3.14)	0.129	0.129	0.129	0.205	0.205	0.205	0.296	0.296	0.296
12	Dia needed, mm	D11*1000	129	129	129	205	205	205	296	296	296
13	Radius, m	D11/2	0.064	0.064	0.064	0.102	0.102	0.102	0.148	0.148	0.148
14	Radius power 0.63	POWER(D13,0.63)	0.178	0.178	0.178	0.238	0.238	0.238	0.300	0.300	0.300
15	S power 0.54	D9/0.848/D8/D14	0.053	0.089	0.195	0.040	0.066	0.145	0.031	0.052	0.115
16	S	POWER(D15,(1/0.54))	0.004	0.011	0.048	0.003	0.007	0.028	0.002	0.004	0.018
17	Slope 1 in	1/D16	229.6	89.1	20.7	394.8	153.3	35.6	605.1	234.9	54.6
18	length, m	Enter by Designer	960	960	960	960	960	960	960	960	960
19	Friction in pipeline, m	D18/D17	4.2	10.8	46.4	2.4	6.3	27.0	1.6	4.1	17.6
20	Velocity head, m	D9*D9/2/9.81	0.033	0.091	0.439	0.033	0.091	0.439	0.033	0.091	0.439
21	Frction factor in fittings	'Appendix-4-1'!C47	72.7	72.7	72.7	72.7	72.7	72.7	72.7	72.7	72.7
22	Friction in fittings, m	D20*D21	2.4	6.6	31.9	2.4	6.6	31.9	2.4	6.6	31.9
23	Static lift, m	Enter by designer	26.5	26.5	26.5	26.5	26.5	26.5	26.5	26.5	26.5
24	Total head, m	D22+D23	28.9	33.1	58.4	28.9	33.1	58.4	28.9	33.1	58.4
25	Efficiency of pumpset	Enter by designer	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
26	Discharge, lps	D7*1000/24/3600	10.4	17.4	38.2	26.4	44.0	96.8	54.9	91.4	201.2
27	Kw required	D26*D24/D25/100.5	3.7	7.1	27.7	9.5	18.1	70.3	19.7	37.6	146.1
28	**Option 1**										
29	Provide 150 mm pipeline at zero year and another 150 mm at 11th year and another 250 mm in 21st year and change pumpsets at 11th and 21st years										
30	The augmnentation at 21st year can be decided based on realistic conditions at that time. May be suitable for smaller systems										
31	**Option 2**										
32	Provide 200 mm pipeline at zero year and provide pump sets also as for the 11th year flowrate and use the storage volume in the wet well and sewer system										
33	The augmnentation at 21st year can be decided based on realistic conditions at that time. May be suitable for very large systems										
34	**Basis for Decision**										
35	Unlike water pumping, sewage varies widely and grit adds to the problem										
36	Hence, paramount importance is to ensure minimum of 0.8 m/s all times.										
37	Each system to be weighed carefully based on calculations for that system										

APPENDIX A 5.1
ODOUR CONTROL

1 Introduction

Raw sewage must not be allowed to stagnate. If this occurs, anaerobic process sets in as shown in Figure 5.2. This in turn can generate Hydrogen Sulphide gas. It is this gas which causes foul odour problems because it smells like rotten egg. The need for control of this foul odour is the fact that this gas can be harmful to human beings. This chapter deals with the effects of this gas on human health, the locations where this gas can form and the technologies of its control.

2. Mechanism of its Entry and Effects on Human Beings

- The gas enters the body through eyes or mucous membrane of breathing organs.
- Blood seeps out from the capillaries in cavities of the lungs, causes pulmonary oedema, leading to breathing difficulties and death by suffocation.
- In sewer facilities, it is generated in rising mains with no oxygen supply and in inverted siphons, etc., where sludge is likely to accumulate easily.
- It is generated in grit chamber, pumping well, sedimentation basin, and sludge thickening tank in sewage treatment plants.
- Hydrogen sulphide generated in sewage and deposited sludge is sealed within and in the static condition, so it does not disperse to the atmosphere easily. However, when agitated, it disperses all at once to the atmosphere.

The relationship between its concentration and its toxic effect is shown in Table A5.1-1.

Table A5.1-1 Relationship between concentration of hydrogen sulphide and its toxic effects

onc. (ppm) of H2S	Effects and reaction on organ by H2S		
0.025 0.3 3 to 5	Sense of odour Sensitive persons can sense the odour (limit of sense of odour) Anybody can sense the odour Foul unpleasant odour of medium strength		
10		Permissible concentration (lower limit for irritation of the mucous membrane of the eye)	
20 to 30	Although bearable, after getting accustomed to the odour (olfactory fatigue), any higher concentration cannot be sensed.	Breathing organs Lowest limit for irritating the lungs	
50			Eyes
100 to 300	Olfactory nerve paralysis for 2 to 15 minutes; feels like unpleasant odour has reduced.	If exposed continuously for 8 to 48 hours, bronchitis, pneumonia, and death by suffocation due to pulmonary oedema	Conjunctivitis, itchiness, pain in the eyes, feeling

onc. (ppm) of H_2S	Effects and reaction on organ by H_2S		
170 to 300		Scorching pain in the mucous membrane of respiratory tract; if exposure is less than 1 hour (limit), serious symptoms may not occur	of sand in the eye, glare, bloodshot eyes and swelling, turbidity of cornea, corneal damage and separation, bending and haziness of field of vision, increase in pain due to light
350 to 400		Exposure for 1 hour or more may lead to loss of life	
600		Exposure for 30 minutes hour may lead to loss of life	
700	Cerebral nerves After excessive respiration for a short period, respiratory paralysis occurs immediately thereafter		
800 to 900	Loss of consciousness, respiratory arrest, death		
1,000	Swoon, respiratory arrest, death		
5,000	Instantaneous death		

Source: JSWA, 2003

3 Locations where the gas is formed

The factors causing foul odour are unnecessary sewage stagnation and anaerobic activity. The locations where these can occur are

a) Sewers that are choked and not flowing,

b) Sewage pumping station sumps where sewage is not pumped out then & there,

c) Primary clarifiers, sludge thickeners, digesters and sludge drying beds in STPs.

Immediately on forming, the gas is however in dissolved form. When the sewage gets agitated like flowing through sewers, this gas is released into the air. At this stage, its foul odour is troublesome. Even though ammonia is also present in sewage, it does not cause any odour problem because it is present as ammonium bicarbonate salt. It is split into ammonia only during biological treatment and gets nitrified if additional oxygen is supplied. Even if it is not nitrified, its concentration is too low to cause a foul odour problem. There can be stray gases like methyl sulphide, dimethyl sulphide and methyl mercaptan, but their concentrations are usually negligible for any human discomfort.

4 Control Technologies

Odour control processes are as follows.

4.1 Odour Prevention

The objective is to reduce the number of locations and volume of odour-generating substances.

i) Sealing of locations emitting odour

Some of the methods to seal odour can be through using air-tight manhole cover, air-tight door, trap seal, air curtain.

ii) Anti- septic

In this method, the odour is controlled by restraining the decomposition of organic matter through use of sterilizer and maintaining aerobic condition through use of air and ozone.

iii) Cleaning

Debris tends to be accumulated around screen and grit removal facility and consideration is required during design to make cleaning of the structure easy.

4.2 Ventilation

Generated odour is ventilated and discharged to air by dilution and dispersion.

4.3 Deodorisation

There are many kind of deodorisation system. Optimal deodorisation system should be selected in consideration of air flow, constituents and intensity of nuisance odour, target of deodorisation, ambient environment, manageability of O&M, and economic efficiency. Consideration should be made whether central deodorisation or individual deodorisation system should be adopted in each STP or pumping stations.

4.4 Odour Enclosure

Providing a cover over the units, which produce odour, helps in containing the odour to be removed. The head room in such cases shall be a minimum 4.5 m as per the industrial safety requirements. The material of the cover can be synthetic types mounted on a funicular polygon. All materials and fasteners shall be non-corrodible. Some installations are shown in Figure A5.1-1.

(A) Figure A5.1-1 Covers over sewage structure — Flat type and Dome type (Yokohama City)

4.5 Deodorisation Processes

4.5.1 Aeration Oxidation Process (Activated Sludge Basins)

Principle

Odour-generating gas is fed into aeration tank where it is oxidized and decomposed by the action of activated sludge.

Target substances

Sulphur compound

Salient Features

Both capital and O&M costs are low. Blower needs mist filter and dust filter for protection and corrosion resistance.

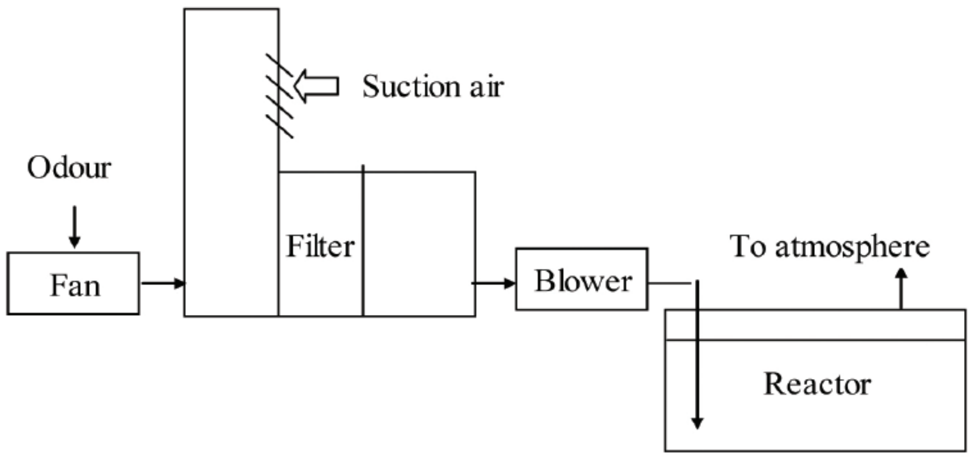


Figure A5.1-2 Schematic diagram of aeration oxidation process (activated sludge basins)

4.5.2 Soil Deodorisation System

i) Principle

Odour-generating substances are fed into soil where it is adsorbed, oxidized and decomposed by action of bacteria in soil.

Target substances

Organic substance, which is nutrient for bacteria

Salient Features

In this case, the capital cost is low but large footprint is required. Gradual consolidation of soil prevents permeability and discharging efficiency. Therefore, periodic maintenance of soil is required through ploughing and replacement.

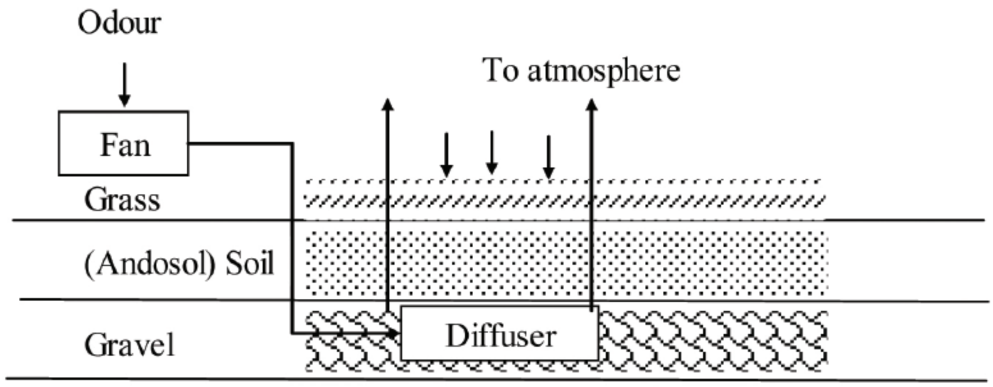


Figure A5.1-3 Schematic diagram of soil deodorisation system

4.5.3 Biofiltration

i) Principle

In this process, odour-generating substances fed to soil is adsorbed, oxidized and decomposed by action of bacteria.

ii) Target substances

Organic substance, which is nutrient for bacteria and hydrogen sulphide

iii) Salient Features

O&M cost is relatively low and footprint of equipment is small. The process is suitable for high strength of odour and acclimation period of bacteria is needed.

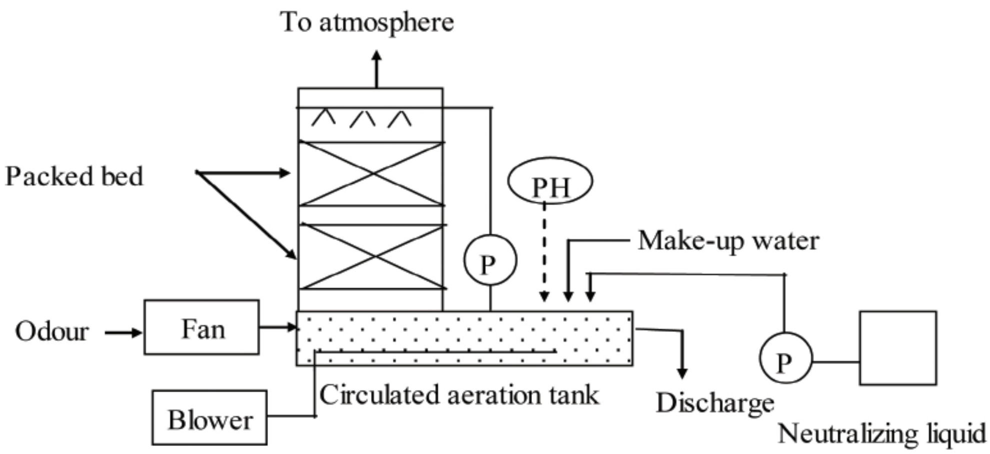


Figure A5.1-4 Schematic diagram of biofiltration

4.5.4 Water Scrubber Process

Principle

Odour is removed by contact of the odour-generating substances with water and dissolving odour.
Target substances

Ammonia, Amines and other water soluble substances

Salient Features

Both capital and O&M costs are low. This is generally used as the pre-treatment of following deodorisation process. When secondary treated wastewater is used as washing water, caution is needed because secondary treated water may emit odour.

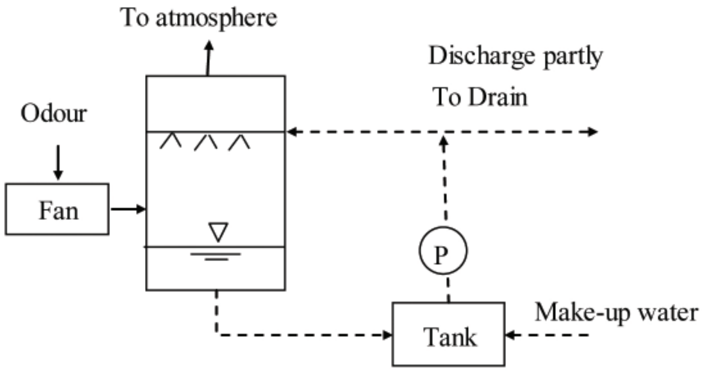


Figure A5.12-5 Schematic diagram of water scrubber process

4.5.5 Activated Carbon Process

i) Principle

Odour-generating substances are removed by adsorbing physically and chemically.

ii) Target substances

Hydrogen sulphide, Methyl sulphide, Ammonia, Trimethylamine

iii) Salient Features

Activated carbon is relatively expensive and characterised by high pressure loss. Periodically exchange or regeneration of activated carbon is necessary. Mist and dust in gas need to be removed. This system is suitable for low strength odour.

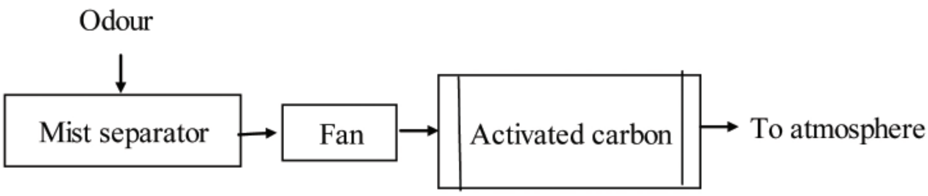


Figure A5.1-6 Schematic diagram of activated carbon process

4.5.6 Ion Exchange Resin

i) Principle

By passing odour-generating substance through ion exchange resin, odour-generating substances are removed by chemical adsorption of alkaline and acid substances and physical adsorption of neutral substances.

ii) Target substances

Almost all odour-generating substances

iii) Salient Features

Resin is relatively costly and pressure loss is large. Regeneration of resin is rather easy. Sometimes activated carbon process and ion exchange process are configured in series.

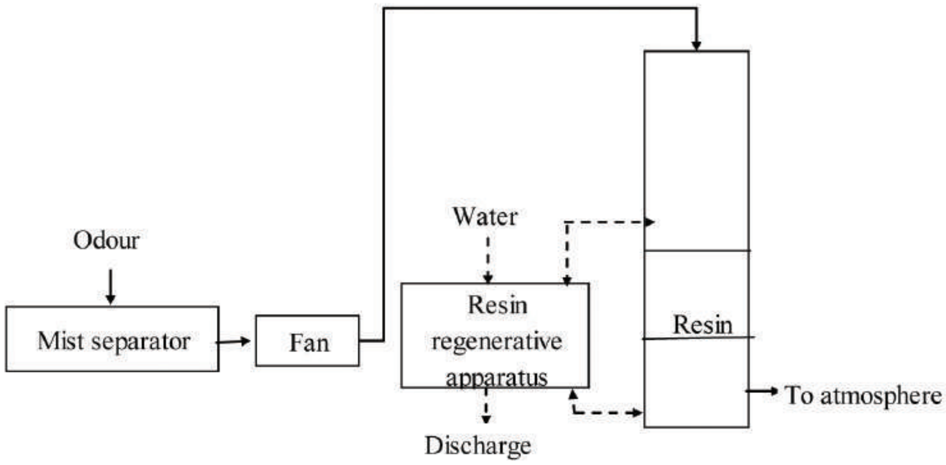


Figure A5.1-7 Schematic diagram of ion exchange resin

4.5.7 Chemical Oxidation Process

Principle

Odour-generating substances are removed by the oxidation action of oxidants such as sodium hypochlorite, and chlorine water.

Target substances

Oxidisable substances

Salient Features

In case if the exhausted gas contains chlorine, absorption equipment with alkaline solution is needed.

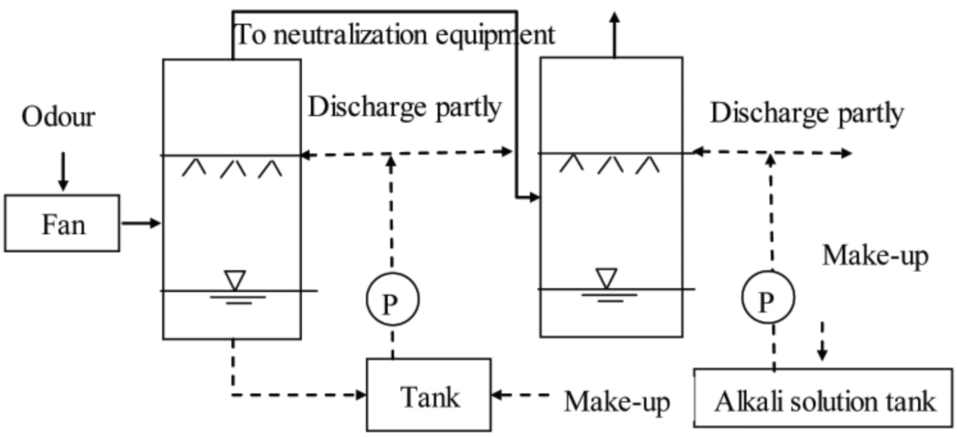


Figure A5.1-8 Schematic diagram of chemical oxidation process

4.5.8 Acid and Alkaline Scrubber Process

i) Principle

In acid scrubber process, odour-generating substances are kept in contact with hydrochloric acid or sulphuric acid, and are removed by neutralization reaction. In alkaline scrubber process, odour-generating substances are kept in contact with sodium hydroxide, and are removed by neutralization reaction.

ii) Target substances

Ammonia, Amines (acid scrubber process), Hydrogen sulphide, Methyl mercaptan (alkaline scrubber process)

iii) Salient Features

In this process, neutralization equipment is needed. Since there are many contact methods between chemical and odour-generating substances, close examination is needed in their selection. It is important to mention that pH of solvent influences the efficiency of deodorisation.

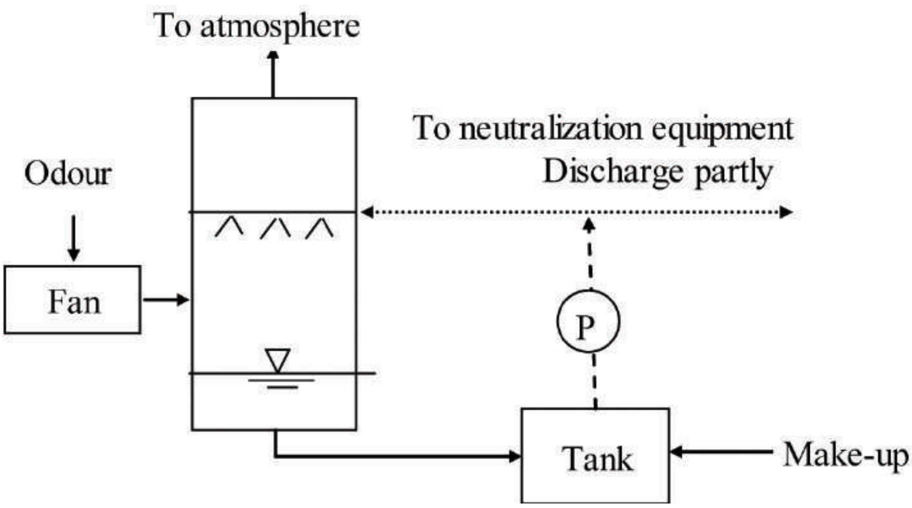


Figure A5.1-9 Schematic diagram of acid and alkaline scrubber process

4.5.9 Direct Combustion Process

i) Principle

Odour-generating substances are combusted and decomposed in incinerator at a very high temperature of approximately 800°C.

ii) Target substances

Almost all of odour-generating substances

iii) Salient Features

In case when ventilated odour-generating substances from various facilities are used as inflow to the incinerator, capital cost and operation cost would be economical. In case of individual combustion, capital cost and operation cost would be high. In this process, the temperature of air flow has to be raised high, whatever the concentration of the odour-generating substance may be. Therefore, small air flow with high concentration of odour-generating substance has advantage and higher removal efficiency. However, oxygen concentration in odour- generating gas should not be too low and SOx and NOx concentration in odour-generating gas should be examined.

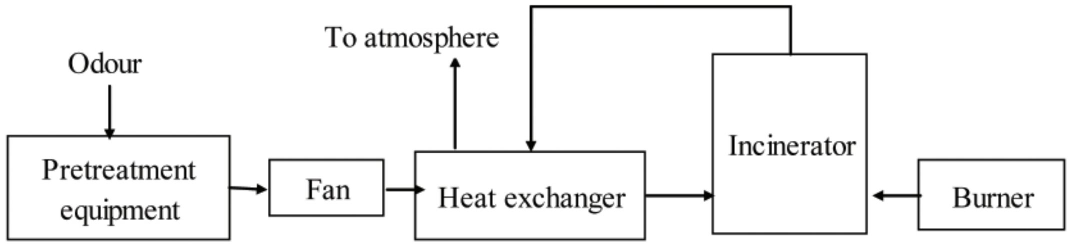


Figure A5.1-10 Schematic diagram of direct combustion process

4.5.10 Catalytic Combustion Process

i) Principle

In this process, odour-generating substances are heated up and destroyed at a temperature of approximately 350 °C by heat exchanger using incinerator in presence of catalyst such as platinum and vanadium.

ii) Target substances

Almost all the odour-generating substances

iii) Salient Features

Fuel consumption in this process is lower than that of the direct combustion process. This process is advantageous in case of high-concentration odour-generating substances below the explosion limit. If oily smoke is present, it sticks on the surface of catalyst, and reduces the activation, so it needs to be washed and removed once or twice a year.

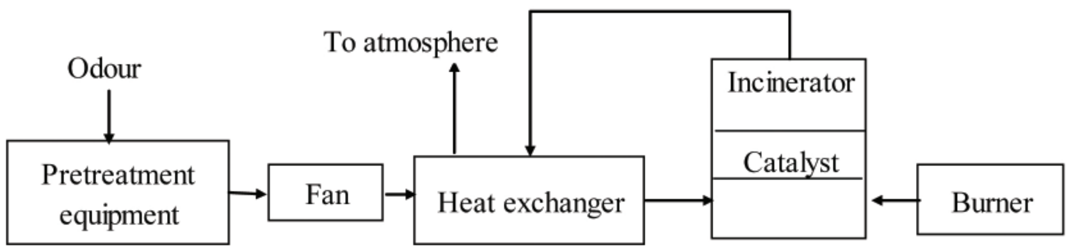


Figure A5.12-1 Schematic diagram of catalytic combustion process

4.5.11 Ozone Oxidation Process

i) Principle

Odour-generating substances are removed by the oxidation action of ozone.

ii) Target substances

Odour-generating substances with low concentration and a large volume (except ammonia)

iii) Salient Features

Ozone is harmful and with sharp smell. Monitoring of excessive ozone residue in treated gas is needed and if necessary, activated carbon system can be installed for removal of ozone. When the odour-generating substances are in wet situation, efficiency of removal will be higher.

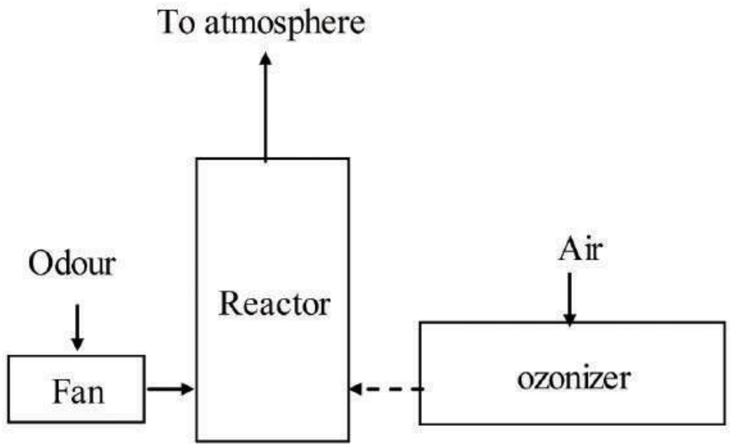


Figure A5.1-12 Schematic diagram of ozone oxidation process

4.6 Methods of Covers

1) Primary covers

Primary covers are installed near the water surface of tanks. These are well used for locations where odour is comparatively strong, such as primary sedimentation basin and sludge thickening tank, and in cases where upper parts are not used.

2) Secondary covers

Building is installed on tanks etc.

3) Double covers

This combines 1) and 2).

After collecting high-concentration odour with few quantity of air as much as possible, it is more economical to deodorize and effective. Therefore, non-working clearance of the water surface of tanks and covers, and working clearance of floors, ceilings, and walls should be necessary minimum in order to carry out operation and maintenance of the facilities.
Typical methods are shown in Figure A5.1-13.

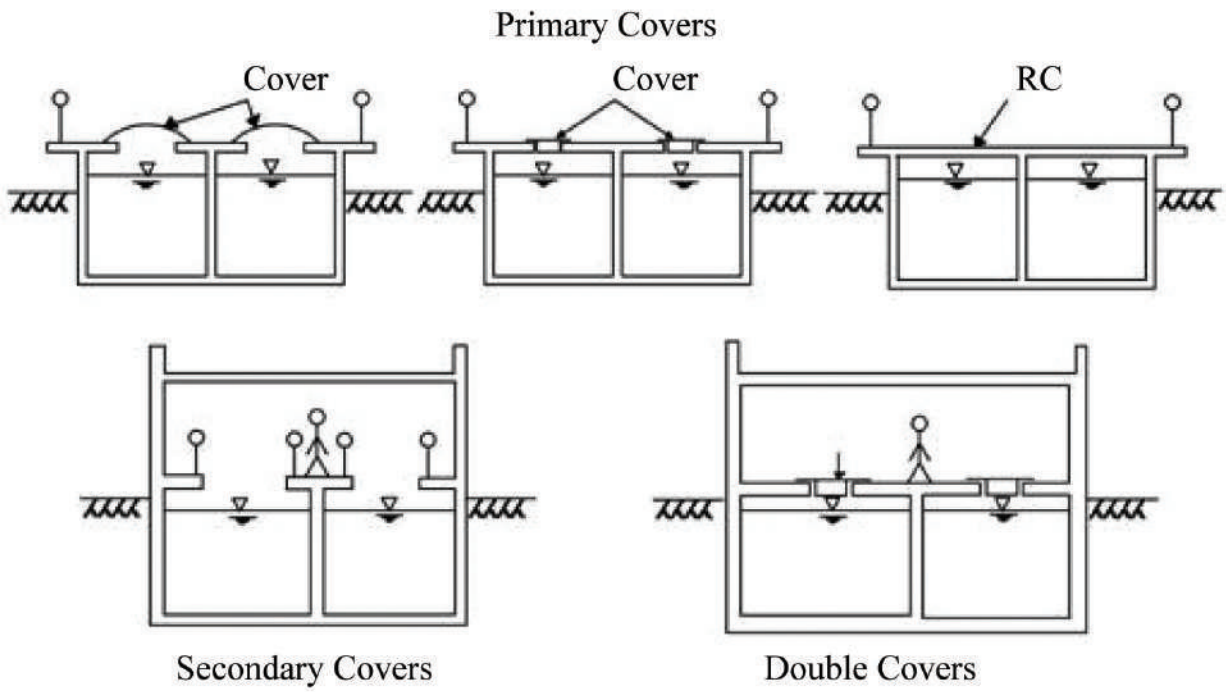
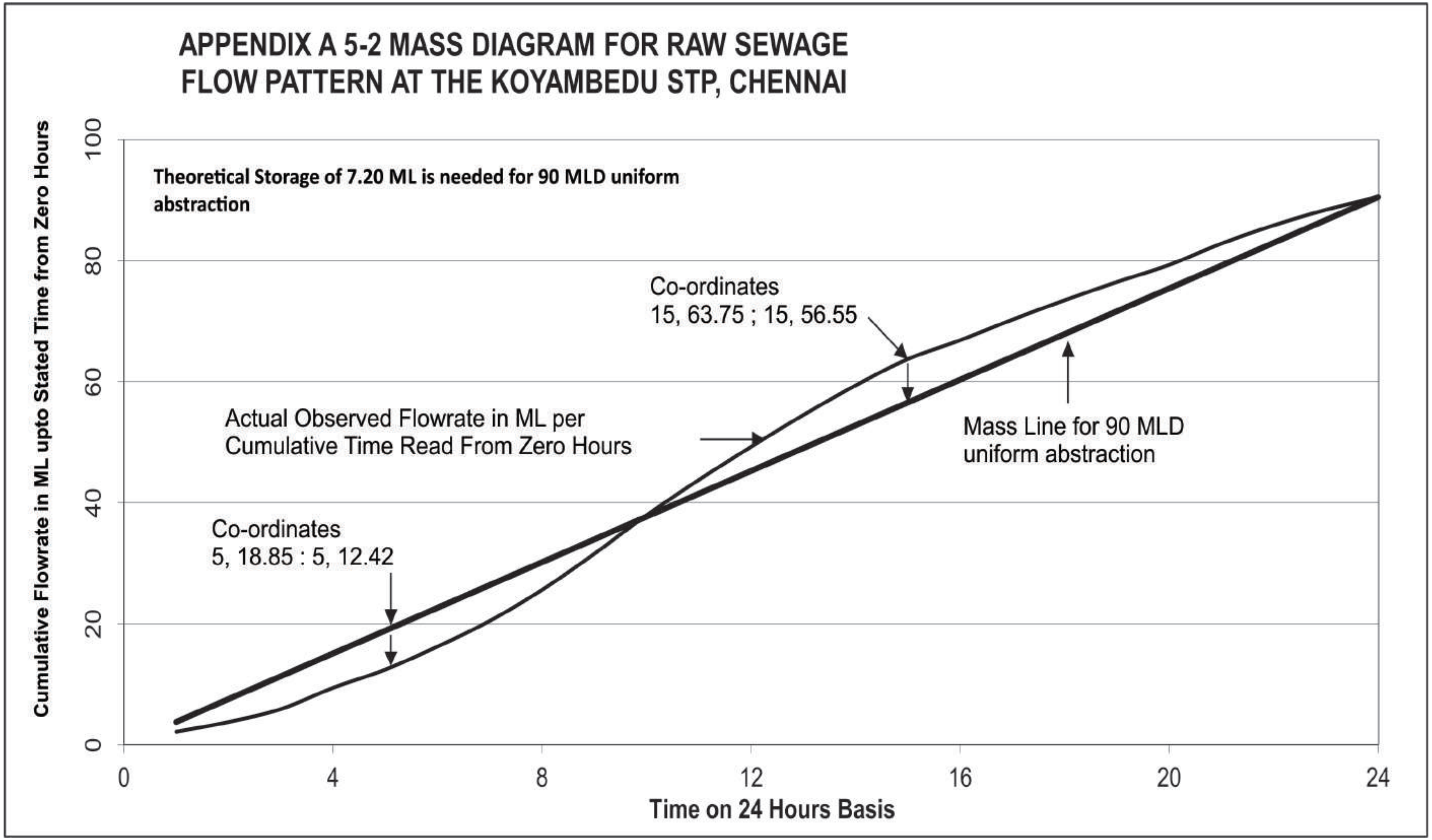


Figure A-5-1-13 Methods of providing domes over odour producing units in STPs

APPENDIX A 5.2
MASS DIAGRAM FOR RAW SEWAGE FLOW PATTERN AT THE KOYAMBEDU STP, CHENNAI



APPENDIX A 5.3
LABORATORY

5.3.1 General

A well designed and adequately equipped laboratory under a competent analyst is essential in all sewage treatment plants. Very small size plants such as stabilization ponds need not have their own laboratories if the facilities of a nearby laboratory are available. The results of the laboratory analysis will aid in the characterization of any waste water, pinpoint difficulties in the operation and indicate improvement measures, evaluate the composition of effluents and thus estimate the efficiency of operation and also measure the pollution effects of the discharge of such effluents upon the receiving water bodies.

The analytical data accumulated over a period to time is an important document in safeguarding the treatment plant from allegations of faulty operation. The laboratory should also engage in research and special studies for evolving improvements and innovations in the plant operation. The laboratory therefore, must form an integral part of the treatment plant.

5.3.2 Planning of Laboratory Facilities

5.3.2.1 Physical Facilities

The actual design of the laboratory depends on the size and type of treatment plants and type and volume of analytical work required to be carried out. Due consideration, therefore should be given to the space requirement for permanent installed equipments and smooth performances or analytical work by the personnel. Necessary provision for future expansions should also be incorporated in the laboratory design.

5.3.2.2 Size of the Laboratory

The size and equipments needed for the laboratory depends on the capacity of the STP. Even the smallest STP shall be provided with a laboratory, where at least a few simple analyses such as SS, pH, BOD and residual chlorine can be made. On the other hand large STP providing complete treatment may require a well planned laboratory building with facilities for physical, chemical, biological and bacteriological work.

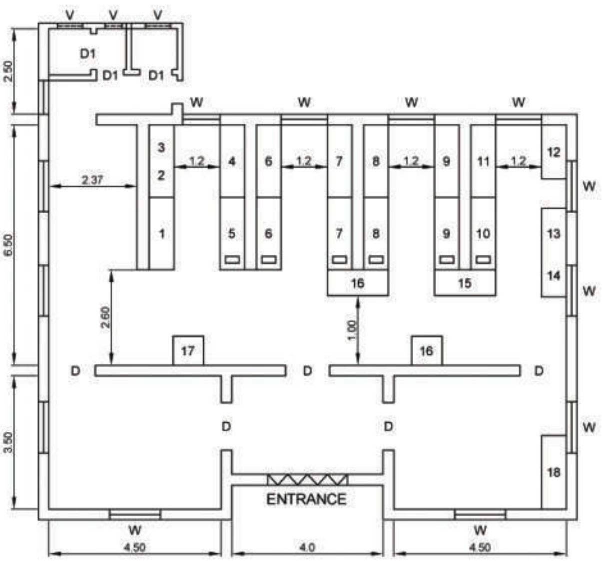
A recommended layout for a STP control laboratory of about 25 mld treatment capacity is presented as Figure A 5.3-1. The total area of the laboratory is about 130 sqm with a small toilet hall and wash room. It includes the main laboratory hall of 75 sqm with work benches and smaller rooms of about 13 sqm each. One of these rooms can be used as the office and the other can be used as a balance room or instrument room etc. The laboratory should have a separate emergency exit.

5.3.2.3 Location

The laboratory should be easily accessible from any unit of the plant and so located as to provide adequate natural lighting (preferably north light) and ventilation, it should be away from pumps and other heavy operating machinery.

5.3.2.4 Floor Space

Minimum floor space required accommodating the equipment necessary to be installed in the room and to avoid interference in the work should be provided. The width of walkways between rows of tables or equipments should be not less than 1m but preferably 1.2m. Total floor space requirement of any work room should be arrived at by accounting for space requirement for all equipments and their placement and the number of staff utilizing the room.



1 LAB STIRRER
2 CENTRIFUGE
3 GAS CHROMATO GRAPH
4 P H METER
5 TURBIDITY METER
6 TITRATIONS
7 DISTILLATIONS
8 WORK SPACE
9 COLORIMETER
10 AUTO CLAVE
11 HOT PLATE
12 ANALYTICAL BALANCE
13 DESICCATORS
14 HOT AIR OVEN
15 WATER BATH
16 SAMPLES
17 REFRIGERATOR
18 BOD INCUBATOR
19 DEMINERALISER

Figure A 5.3-1 Typical layout and list of equipments for sewage treatment plant control laboratory

5.3.2.5 Walls

Walls should be; finished smooth in light colours. The wall space and offsets should be convenient to locate cabinets, benches, hoods, incubators, alongside, without any loss of floor space.

5.3.2.6 Lighting

All work rooms in a laboratory including stairways and passages should be well lighted. The window areas in terms of floor area should not be less than 20 percent and all windows should be fitted with transparent glass panels. Long windows should be preferred to broad windows for greater depth of penetration of light into work rooms. North-South facing should be preferred for prevention of glare on work tables and benches. There must be adequate artificial lighting to supplement day-light, well distributed to provide uniform general lighting with minimum shadow effects. Spot lights should be provided to specific equipment and instruments such as weighing balances, hoods, etc. Adequate number of plug points should be provided for extra lighting and equipment when required,

5.3.2.7 Power Supply

Adequate electric power supply for at least 200 amps at L.T. voltage is required. Many laboratory equipments require higher voltage and provision for such exigencies should be made.

It is also desirable to provide suitable voltage stabilizers to protect sophisticated equipment from damage due to wide fluctuations in the line voltage. This may require consideration in terms of individual units or for the laboratory as a whole.

5.3.2.8 Floor

Floors should be of smooth finish but not slippery and should be easy to wash and keep clean. Concrete flooring with mosaic finish and dadooing up to window sill level is recommended.

5.3.2.9 Work Tables and Benches

A provision of 10 m space of work tables and benches per worker should be sufficient. These tables should be preferably located along the walls. Tables located in any other position should have a clear gangway of width not less than 1 m. between adjacent rows. Wall side tables are generally kept 60 to 75 cm wide and centre tables are designed 140 cm wide to allow work space on both sides. Height of tables should be 90 to 95 cm for working in a standing posture and 75 to 80 cm for working in a sitting posture. Table tops should be finished smooth with acid resistant tiles/sheets. A separate rigid table of size 120 cm x 60 cm with revolving adjustable stool should generally be provided for analytical balance. Adequate number of stools should be provided along with work tables and benches. Drains connected to table sinks should also be resistant to attack from corrosive substances.

5.3.2.10 Reagent Cabinets and Cupboards

These should be provided in adequate number and size for storing chemicals and reagents and stock solutions, etc. in a systematic order. Sliding glass panelled shutters should be preferred to hinge shutters in these cabinets. The laboratory tables could be provided with cupboards and open glass shelves on the top to provide additional space for storage of chemicals and stock solutions.

5.3.2.11 Sinks

Both table sinks and separate sinks with adequate water supply shall be provided. Table sinks are fitted with gooseneck taps extending high enough above the table to permit washing of litre cylinders. Separate sinks of sufficient size and depth located at suitable points shall also be provided for washing the glassware. Plumbing to sinks and wash basins shall be of proper design and of corrosive resistant materials like PVC or ceramic for waste water lines.

5.3.2.12 Fume Hoods and Chambers

Fume hoods and chambers are necessary to prevent spreading of toxic and irritant fumes and odours into other parts of the laboratory and also to prevent condensation of walls, windows and other fixtures causing corrosion. Some analytical work needs isolated fume chambers while other could he carried out under an exhaust hood. Positive ventilation with exhaust tans are generally provided for this purpose. Hoods are designed as per standard practice to provide a minimum air velocity of 30 linear m/min.

5.3.2.13 Gas Supply

The plant should provide its own gas supply to the laboratory by installing a gas plant.

Efforts should be made to use digester gas if sludge digesters are installed. Gas should be piped to main work tables with hoods with appropriate fixture outlets. Compressed cooking gas in cylinders can also be used.

5.3.2.14 Space for Analytical Balance

The analytical balance mounted on a small rigid table to be used in sitting position may be provided in a separate cubicle or enclosure in bigger laboratories. It may also be possible to provide a masonry platform with top surface of polished stone for mounting the balance.

5.3.2.15 Constant Temperature Room

In large plants, provision is sometimes made for constant temperature rooms maintained at 20 deg C for performances of BOD and other tests. If this is not available commercial type 20 deg C BOD incubator may be used.

5.3.2.16 Sample Preparation Room

In large plants employing both primary and secondary processes where number of samples handled daily is large and so a separate sample preparation room con be very useful. Such room should have refrigerators of suitable capacities. In addition, an attached cold room with storage facilities may also be necessary particularly where bacteriological work is done.

5.3.2.17 Media Preparation and Sterilization Room

In large STPs where continuous bacteriological analysis is done, additional facilities for media preparation, centrifuging sterilization by autoclaves, etc. are necessary and additional rooms for accommodating these facilities should also be included. Such rooms are usually attached to the laboratory and are located within easy reach of the analysts.

5.3.2.18 Space for Records

Space for keeping laboratory and plant records should be provided in the laboratory office or in the plant administrative block.

5.3.2.19 Wash and Toilet Facilities

Adequate toilets and wash basins should be provided separately for men and women. Emergency showers should also be provided which can be housed in the work room itself with a curtain to provide temporary privacy. Emergency foot operated spout type eyewash should also be installed in the workroom.

5.3.3 Equipment and Chemicals

5.3.3.1 Equipment Required

The type of equipment required for sewage treatment plant laboratory depends on the type of plant, the type of analytical work to be caused out and the frequency of each test to be performed. It is advisable to make initial decisions on the specific analysis to be undertaken, the number of samples, the frequency of sampling and the staff requirement to carry out these analysis, so as to avoid unnecessary purchases and keeping of equipment idle for an indefinite period. Equipment that is not used and is kept idle is often neglected and fall into disuse. Hence, selection of equipment for the plant laboratory requires most useful and careful planning, so that each equipment bought is specifically on the basis of anticipated function and availability of trained staff.

A list of important equipments required for carrying out several analytical works in a laboratory is given in Appendix A 5.4. The list is not exhaustive, but covers most of the requirements. The quantities required have to be decided as suggested above.

The estimates of essential consumable articles such as chemicals, glassware etc. and recurring replacement in the succeeding years of operation must be worked out with utmost care on the basis of the particular treatment processes to each plant. A list of important tests is given in Appendix A 5.5 which will serve as a guideline for choosing the required glassware and chemicals for a particular STP.

Refrigerators for reagents and deep freezes provided for preserving samples should be adequate in capacity and numbers.

All equipment needs a certain amount of maintenance care, particularly those that are electrically operated. Periodic servicing of equipment and checking for their efficiency will save the loss of equipment and prevent faulty analysts leading to work interruptions.

5.3.3.2 Storage

All glassware should be stored in an orderly way and used with care to minimize loss due to breakages in handling, Glassware should he cleaned thoroughly after their use and dried before placing in the cupboards and lockets.

Chemicals should be stated in proper shelves and lockets. Toxic chemicals such as arsenic, cyanide etc. should he kept under lock and key and should be under the direct charge of a senior analyst who issues and accounts for them, Acids, bulky glassware etc. which can cause accidents and burns by dropping on the floor should not be stored on high shelves., which need ladders or high stools to reach them.

Chemicals that have a limited life should be bought in such quantities as can be used before their potency is lost.

A stock register for all equipment, chemicals and glassware should be maintained in all laboratories and kept up-to-date.

APPENDIX A 5.4
MINIMUM LABORATORY EQUIPMENTS NEEDED FOR TESTS

Equipment	Type of Plant	
	5MLD	>5 MLD
Analytical Balance	x	x
Autoclave	--	x
Centrifuge	--	x
Chlorine comparator	x	x
Colony counters	--	x
Demineraliser	x	x
Dissolved Oxygen sampler	x	x
Drying oven (hot air)	x	x
Fume cupboards	x	x
Gas liquid chromatograph	--	x
Hot plates	x	x
Incubator 20°C (BOD)	x	x
Incubator 30°C (Bacteriological)	--	x
Kjeldahl Digester Unit	x	x
Magnetic stirrers	x	x
Microscope, binocular with oil immersion and movable stage counting cell	--	x
Membrane Filter Assembly	--	x
Muffle Furnace	x	x
Orsat or equivalent gas analysis apparatus		x
pH comparator (Colorimetric)	x	x
pH meter with reference & spare electrodes	--	x

Equipment	Type of Plant	
	5MLD	>5 MLD
pH meter portable	x	x
Refrigerator	x	x
Sedwick Rafter funnel	--	x
Sludge sampler	--	x
Soxhlet extraction unit	--	x
Spectrophotometer (atomic absorption)	--	x
Spectrophotometer with or without U-V rage or photo electric colorimeter	--	x
Total organic carbon analyser	--	x
Turbidimeter	x	x
Vacuum pump	x	x
Water bath (thermostat controlled)	x	x

APPENDIX A 5.5
TESTS RECOMMENDED TO BE CARRIED OUT ON UNITS OF SEWAGE TREATMENT PLANTS

	Treatment stage/Unit	Total Suspended Solids	Settleable Solids	Dissolved Solids	Mixed Liqueur Suspended Solids (ML SS)	SVI for ML	Turbidity	pH	Alkalinity	Volatile Acids	BOD	COD	DO	ORP	Total Kjeldahl Nitrogen
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Raw sewage	x	x	x				x	x		x	x			x
2	Primary sedimentation tanks influent and effluent	x	x									x			
3	Attached/fluidized/immobilized media influent & effluent	x						x			x	x	x		x
4	Activated sludge aeration tank influent & effluent										x	x	x	x	
5	Above tank contents				x	x									
6	Effluent of secondary settling tank	x	x						x		x	x	x		x
7	Influent & effluent of septic tanks	x	x	x							x	x			
8	Above tank contents							x	x	x					
9	Digester contents							x	x	x					
10	Primary sludge														
11	Secondary settled sludge														
12	Digested sludge							x	x	x					
13	Sludge digester supernatant	x		x				x	x		x	x			x
14	Stabilization ponds influent & effluent	x					x				x	x	x		
15	Above pond contents							x	x				x	x	

APPENDIX A 5.6
EXAMPLE FOR HYDRAULIC DESIGN OF MECHANICALLY CLEANED BAR RACK AND SCREEN CHAMBER
(Retained as in 2nd edition)

1 PROBLEM STATEMENT

Design a bar rack and screen chamber for a peak design flow of 150 MLD (3×average sewage flow of 50 MLD) with the following data.

Peak design flow	=	1.736 m^3/s
Flow conditions in incoming trunk sewer		
Diameter of incoming sewer	=	1.40 m
Depth of flow in sewer at peak flow	=	1.05 m
Velocity in sewer at peak design flow	=	1.16 m/s
Drop of screen chamber floor to invert	=	0.08 m
Assumed width of rectangular bars	=	10 mm
Clear spacing between bars	=	25 mm

Sketch a hydraulic profile through bar rack under clean conditions as well as for 50 percent clogged conditions.

2 SOLUTION

2.1 DESIGN OF BAR RACK

Assume depth of flow in screen chamber	=	1.05 m
Assume velocity of flow through rack Openings	=	0.9 m/s

$$Clear\ area\ of\ openings\ through\ the\ rack = \frac{Q}{V}$$

$$= \frac{1.736}{0.9} = 1.929\ m^2$$

$$Clear\ width\ of\ openings\ through\ the\ rack = \frac{1.929}{1.05} = 1.84\ m$$

Provide 73 clear spacing of 25mm each
Number of bars = 72 of 10mm each

$$Total\ width\ of\ the\ screen\ chamber = \frac{73 \times 25}{1000} + 72 \times \frac{10}{1000} = 2.545\ m$$

2.2 ACTUAL DEPTH OF FLOW IN SCREEN CHAMBER AT PEAK FLOW

The longitudinal section of the screen chamber is divided into four sections. The section 1 is at sewer, section 2 at screen chamber u/s of bar rack, section 3 at d/s of bar rack and section 4 u/s of the outlet of screen chamber. It is assumed that the outlet channel/sewer from screen chamber discharges freely into the sump well. The definition sketch is given in Figure A5.6-1.
Applying Bernoulli's theorem between sections 1 and 2

$$Z_1 + d_1 + \left(\frac{V_1^{\;2}}{2g}\right) = Z_2 + d_2 + \left(\frac{V_2^{\;2}}{2g}\right) + h_L$$

Where,

Z_1 & Z_2	=	datum heads
d_1 & d_2	=	depths of flow at sections 1 and 2
V_1 & V_2	=	velocities of flow at sections 1 and 2
h_L	=	head loss due to sudden expansion from sewer to screen chamber
	=	$K_e\left[\frac{V_1^{\;2}}{2g} - \frac{V_2^{\;2}}{2g}\right]$

Taking floor of the screen chamber as datum (Z_2 = 0) and assuming K_e = 0.3 for coefficient of expansion,

$$0.08 + 1.05 + \left(\frac{1.16^2}{2\times 9.81}\right) = 0 + d_2 + \frac{\left(\frac{1.736}{2.545 d_2}\right)^2}{2\times 9.81} + \frac{0.3}{2\times 9.81}\times\left[1.16^2 - \left(\frac{1.736}{2.545 d_2}\right)^2\right]$$

$$d_2^{\;3} - 1.178 d_2^{\;2} + 0.0166 = 0$$

Solving by trial and error,

d_2 = 1.17 m

$$V_2 = \frac{1.736}{2.545\times 1.17} = 0.583\, m/s$$

2.3 VELOCITY THROUGH CLEAR OPENING OF BAR RACK

$$V = \frac{Flow}{Net\ area\ of\ opening\ through\ rack}$$

$$= \frac{1.736}{73\times 0.025\times 1.17} = 0.813\, m/s$$

The velocity through the bar rack was assumed to be 0.9 m/s but it is actually 0.81 m/s. If desired, the steps I, II and III can be revised to yield different values of number of bars, depth of flow and velocity of flow, etc. However as V is within range (0.6-1.2 m/s), these steps are not being revised, being acceptable.

2.4 HEAD LOSS THROUGH BAR RACK

$$h = 0.0728\left(V^2 - V_2^{\;2}\right) = 0.0728\times\left(0.813^2 - 0.583^2\right)$$

$$= 0.024\, m$$

Using Kirschmer’s Formula

$$h = \beta \left(W/b\right)^{\frac{4}{3}} h_V \sin\theta$$
$$= 2.42 \times \left(\frac{72 \times 10}{73 \times 25}\right)^{\frac{4}{3}} \times \left(\frac{0.813^2}{2 \times 9.81}\right) \sin 75°$$
$$= 0.022\, m$$

2.5 DETERMINE DEPTH AND VELOCITY OF FLOW D/S OF BAR RACK

Applying energy equation between sections 2 and 3

$$Z_2 + d_2 + \left(\frac{V_2^{\,2}}{2g}\right) = Z_3 + d_3 + \left(\frac{V_3^{\,2}}{2g}\right) + h$$

when bar rack is clean

$$0 + 1.17 + \left(\frac{0.583^2}{2 \times 9.81}\right) = 0 + d_3 + \frac{\left(\frac{1.736}{2.545 \times d_3}\right)^2}{2 \times 9.81} + 0.024$$

$$d_3^{\,3} - 1.163\, d_3^{\,2} + 0.0237 = 0$$

$$d_3 = 1.15\, m$$

$$V_3 = \frac{1.736}{2.545 \times 1.15} = 0.593\, m/s$$

2.6 HEAD LOSS THROUGH BAR RACK AT 50% CLOGGING

Assuming d_2^1 and V_2^1 as depth and velocity of flow at section 2 when bar rack is 50% clogged,

$$d_2^1 + \frac{\left(V_2^1\right)^2}{2g} = d_3 + \frac{V_3^{\,2}}{2g} + h_{50\%}$$

$$h_{50\%} = 0.0728\left(\left(Velocity\ through\ c\log ged\ rack\right)^2 - V_2^{\,2}\right)$$
$$= 0.0728\left[\left(\frac{1.736}{73 \times 0.025 \times 0.5 \times d_2^1}\right)^2 - \left(\frac{1.736}{2.545 d_2^1}\right)^2\right]$$
$$= \frac{0.23}{\left(d_2^1\right)^2}$$

Therefore,

$$d_2^1 + \frac{\left(\frac{1.736}{2.545 \times d_2^1}\right)^2}{2 \times 9.81} = 1.15 + \frac{0.593^2}{2 \times 9.81} + \frac{0.23}{\left(d_2^1\right)^2}$$

$$\left(d_2^1\right)^3 - 1.168\left(d_2^1\right)^2 - 0.206 = 0$$

$$V_2^1 = \frac{1.736}{1.30 \times 2.545} = 0.525\, m/s$$

Head loss under 50% clogging of bar rack,

$$h_{50\%} = \frac{0.23}{(1.30)^2} = 0.136\, m < 0.15\, m \quad hence \;\; OK$$

2.7 FLOOR RAISING REQUIRED IN CHANNEL BEFORE FREE FALL INTO SUMP WELL

If the flow d/s of bar rack has to be designed for free fall conditions into the adjoining sump well of pumping station, it is obvious that critical flow conditions will prevail near the outfall.

Depth of critical flow,

$$d_c = \left(\frac{Q^2}{gb^2}\right)^{\frac{1}{3}}$$

$$= \left[\frac{(1.736)^2}{9.81 \times (2.545)^2}\right]^{\frac{1}{3}} = 0.362\, m$$

Critical velocity,

$$V_c = \frac{1.736}{2.545 \times 0.362} = 1.88\, m/s$$

In order not to disturb the existing hydraulic profile at section 3 and beyond, the floor of the screen chamber has to be raised by an amount Z_c, which can be determined by applying Bernoulli's Theorem between sections 3 and 4.

$$Z_3 + d_3 + \left(\frac{V_3^{\,2}}{2g}\right) = Z_4 + Z_c + d_4 + \left(\frac{V_4^{\,2}}{2g}\right) + head \;\; loss$$

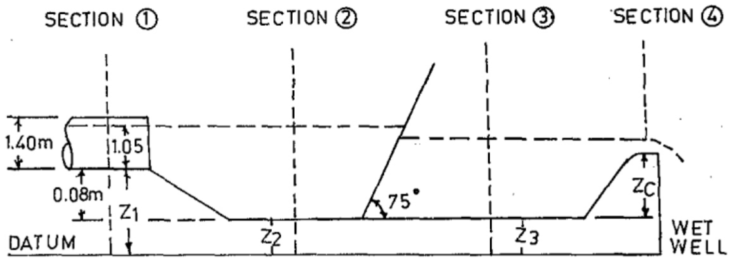
Since $Z_3 = Z_4$, $d_4 = d_c = 0.362$ m, $V_4 = V_c = 1.88$ m/s and neglecting head loss,

$$0 + 1.15 + \frac{0.593^2}{2 \times 9.81} = 0 + Z_c + 0.362 + \frac{1.88^2}{2 \times 9.81} + 0$$

$$Z_c = 0.625 \text{ m}$$

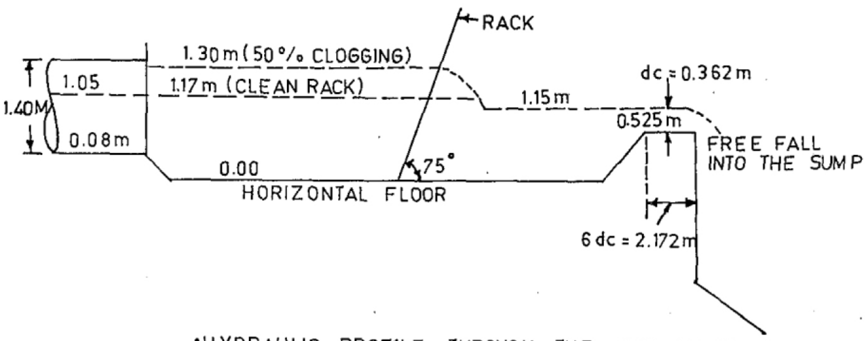
2.8 HYDRAULIC PROFILE

Hydraulic profile through the bar racks for clean conditions as well as for 50% clogged conditions is presented in the following Figure A 5.6-2.



:DEFINITION SKETCH FOR SECTIONS OF BAR SCREEN DESIGN

Figure A 5.6-1



:HYDRAULIC PROFILE THROUGH THE BAR RACK AT PEAK DESIGN FLOW WHEN RACK IS CLEAN & AT 50% CLOGGING

Figure A 5.6-2

APPENDIX A 5.7
DESIGN EXAMPLE FOR GRIT CHAMBER WITH PROPORTIONAL FLOW WEIR AS HYDRAULIC CONTROL DEVICE
(Retained as in 2nd edition)

1 PROBLEM STATEMENT

Design grit chamber to treat peak design flow of 150 MLD (3×Average wastewater flow of 50 MLD) of wastewater to remove grit particles up to a size of 0.15 mm and of specific gravity of 2.65. The minimum temperature is 15ºC. The grit chamber is equipped with proportional flow weir as control device.

2 SOLUTION

2.1 COMPUTATION OF SETTLING VELOCITY

Applying Stoke's Law,

$$V_s = \frac{g}{18}(S_s - 1)\frac{d^2}{v}$$

Given S_s = 2.65, d = 0.15×10^{-3} m

$$v = 1.14 \times 10^{-6}\ m^2/s \quad at\ 15\ °C$$

$$V_s = \frac{9.81}{18} \times (2.65 - 1) \times \frac{(0.15 \times 10^{-3})^2}{1.14 \times 10^{-6}} = 0.018\ m/s$$

Check for Reynold's Number, R

$$R = \frac{V_s d}{v} = \frac{0.018 \times 0.15 \times 10^{-3}}{1.14 \times 10^{-6}} = 2.37 > 0.5$$

Hence Stoke's law does not apply

Applying Transitions Law for 0.5 < R < 10^3

v_s = [0.7.07 (S_s - 1)$_d{}^{1.6}{}_v$ - *0.6*] 0.714

= [0.707 X (2.65-1) X (0.15 X 10^{-3}) $^{1.6}$ X (1.14 X 10^{-6})$^{-0.6}$] 0.714

= 0.0168 m /s

2.2 COMPUTATION OF SURFACE OVERFLOW RATE, SOR

The surface overflow rate for 100% removal efficiency in an ideal grit chamber

= Settling velocity of the minimum size of particle to be removed

= 0.0168 m/s

= 1451.5 m3/m2/d

However, due to turbulence and short circuiting due to several factors as eddy, wind and density currents, the actual value to be adopted has to be reduced taking into account the performance of the basin and the desired efficiency of the particles removal. To determine the actual overflow rate, the following formula may be used.

$$\eta = 1 - \left(1 + n\frac{V_s}{\frac{Q}{A}}\right)^{-\frac{1}{n}}$$

where,

η = efficiency of removal of desired particles

n = measure of settling basin performance

= 1/8 for very good performance

Assuming η = 0.75, n = 1/8

$$\frac{Q}{A} = \frac{V_s n}{(1-\eta)^{-n} - 1}$$

$$= \frac{1451.5 \times (1/8)}{(1-0.75)^{-(1/8)} - 1} = 959\ m^3/m^2/d$$

2.3 DETERMINATION OF THE DIMENSIONS OF GRIT CHAMBER

$$Plan\ area\ of\ grit\ chamber = \frac{Q}{(Q/A)}$$

$$= \frac{7.5 \times 10^3}{959} = 7.82\ m^2$$

Provide 4 channels of 0.5 m wide and 16 m long.

The critical displacement velocity to initiate re-suspension of grit is given by

$$V_c = \left[\frac{8K}{f}(S_s - 1)gd\right]^{0.5}$$

for K = 0.04, f = 0.03, S_s = 2.65, d = 0.15×10^{-3} m

V_c = 0.161 m/s

The horizontal velocity of flow V_h should be kept less than critical displacement velocity, V_c. Assuming a depth of 0.3 m,

$$V_h = \frac{7.5 \times 1000}{0.3 \times 4 \times 0.5 \times 24 \times 3600} = 0.15\ m/s < 0.161\ m/s\ \ OK$$

The hydraulic residence time at peak flow is

$$HRT = \frac{Volume}{Peak\ discharge} = \frac{4 \times 0.5 \times 16 \times 0.3}{0.087} = 110\ seconds$$

Total depth of grit chamber = Water depth + free board + grit storage space

=0.3 + 0.25 + 0.25 = 0.8 m

Provide 4 channels of grit chamber, each 16m × 0.5m ×0.8m

2.4 DESIGN OF PROPORTIONAL FLOW WEIR

There will be four proportional flow weirs, each installed at the control section of each of the four grit chambers.

Peak flow for each weir = (0.087 / 4) = 0.022 m^3/s
Flow through a proportional flow weir is givers by

$$Q = Cb\sqrt{2ag}\left[h - \left(\frac{a}{3}\right)\right]$$

For symmetrical sharp-edged weir, C = 0.61

Assuming, a = 35 mm (usually between 25-50 mm)

h = 1.1m at peak flow

$$0.022 = 0.61 \times b\sqrt{2 \times 0.035 \times 9.81} \times \left[1.1 - \left(\frac{0.035}{3}\right)\right]$$

b = 0.04 say 4 cm

To determine the coordinates (x, y) of the curve forming the edge of the weir, assume suitable four values of y and compute corresponding values of x using equation 5.14, The coordinates for

$$x = \frac{b}{2}\left[1 - \frac{2}{\pi}\tan^{-1}\sqrt{\frac{y}{a} - 1}\right]$$

proportional flow weir are listed below:

Sl. No.	y, m	x, m
1.	a = 0.035	0.400
2.	10a = 0.35	0.082
3.	20a = 0.70	0.057
4.	30a = 1.05	0.047
5.	40a = 1.40	0.040

However, with a base width (b) of 4 cm, it is not possible to have such a weir. Hence, continue the channel section itself downstream by elevating the floor level above the grit storage space of 0.25 m for a length of at least 5 times the clear width and designing the floor slope such that a minimum velocity of 0.3 m/s is obtained at least in peak flow conditions.

APPENDIX A 5.8
DESIGN EXAMPLE FOR DETRITOR

Design a detritors for a peak flow of 150 MLD and Average flow of 60 MLD

Peak design flow	= 150 MLD
Average flow	= 60 MLD
Number of units	= 2 (designer to choose)
Peak design flow for each unit	= 75 MLD
Grit particle size to be removed	= 0.15 mm
Grit particle specific gravity	= 2.65
Settling velocity as per Table 5.6	= 0.018 m/sec
Surface overflow rate as per Table 5.6	= 1555 cum / sqm / day
Plan area of each detritors at peak flow	= 150 X 1000 / 1555 / 2 = 48 sqm
One side of a square detritor	= 7 m

Critical displacement velocity to initiate resuspension of grit is calculated as in Appendix A 5.7

Critical displacement velocity	= 0.161 m / sec
Depth of flow	= assumed as 0.85 m
Horizontal velocity	= 75 x 1000 / 24 / 3600 / 7 / 0.85 = 0.145 m / sec

Less than critical displacement velocity of 0.161and hence OK
Grit storage space

Rotary speed of scraper	= say 0.25 rpm
Time between scraping	= 1 / 0.25 = 4 minutes

Grit content for domestic sewage varies from 0.05m3 to 0.15m3 per ML

Assume	= 0.1m3 per ML
Quantity of grit between scrapings	= 60 x 0.1 x 4 / 1440 = 0.017 cum
Depth of detritor needed to hold this grit	= 0.017 / 48 / 2 = negligible

Normally this is a concurrent activity and separate depth is not needed and may affect velocities Provide, 2 numbers of each 7 m x 7 m x 0.85m LD with freeboard as per equipment vendor

Appendix A 5-9
Calculating Size of Approach Channel for Parshall Plume

1	A	B	C	D	E	F	G
2							
3		choice 1		choice 2		choice 3	
4	Lower value of flow in MLD	Enter	45	Enter	45	Enter	45
5	Higher value of flow in MLD	Enter	170	Enter	170	Enter	170
6	Lower value of flow in lps	C4*1000000/24/3600	521	E4*1000000/24/3600	521	G4*1000000/24/3600	521
7	Higher value of flow in lps	C5*1000000/24/3600	1968	E5*1000000/24/3600	1968	G5*1000000/24/3600	1968
8	Throat width (W) m, from Table	Enter	0.3	Enter	0.6	Enter	0.9
9	Channel at (D) m, from Table	Enter	0.83	Enter	1.12	Enter	1.55
10	Liquid depth at low flow, m	POWER((C6/2264/C8),(1/1.5))	0.84	POWER((E6/2264/E8),(1/1.5))	0.53	POWER((G6/2264/G8),(1/1.5))	0.40
11	Liquid depth at high flow, m	POWER((C7/2264/C8),(1/1.5))	2.03	POWER((E7/2264/E8),(1/1.5))	1.28	POWER((G7/2264/G8),(1/1.5))	0.98
12	velocity at mouth, low flow, m/s	C4*1000/24/3600/C9/C10	0.75	E4*1000/24/3600/E9/C10	0.88	G4*1000/24/3600/G9/G10	0.83
13	velocity at mouth, high flow, m/s	C5*1000/24/3600/C9/C11	1.17	E5*1000/24/3600/E9/C11	1.37	G5*1000/24/3600/G9/G11	1.30
14	Approach channel width, m	C9	0.83	E9	1.12	G9	1.55
15	Approach channel, liquid depth, m	C11	2.03	E11	1.28	G11	0.98
16	Approach channel width, m	C14	0.83	E14	1.12	G14	1.55
17	Approach channel liquid depth, m	C11	2.03	E11	1.28	G11	0.98
18	Width of throat, m	C8	0.3	E8	0.60	G8	0.9

It may be seen that the velocities at low flow and high flow are met adequately in all three chosen channel widths. However, the ease of O&M also has to be considered. Choice 1 gives a very narrow width and very deep channel. This will be difficult to maintain. Between choice 2 and choice 3, both can be used. However choice 2 will give almost a square section and lesser width for easy maintenance.

APPENDIX A 5.10
DETENTION TIMES OF CLARIFIERS IN STPs EVALUATED BY NEERI

Name of STP	Q in	Primary				Secondary				
		Numbers	Diameter	SWD	HRT	Numbers	Diameter	SWD	HRT	Total HRT
	MLD		m	m	hrs		m	m	hrs	hrs
K&C Valley	163	3	39.6	3.04	1.65	3	46.5	3.6	2.70	
						1	39	3.6	0.63	3.33
Atladara	27	1	45.7	2.5	3.64	1	35	2.5	2.14	2.14
Howrah	45	2	38.1	3	3.65	2	38.1	3	3.65	3.65
Mahati	135	4	22.86	3.14	0.92	2	40	3.2	1.43	
						2	45	3.5	1.98	3.41
Jaspur	20	1	39.6	2.4	3.55	1	33.5	2.4	2.54	2.54
Kodungaiyur II	90	2	40	3	2.01	2	41.6	3	2.17	2.17
Koyambedu	34	2	36.6	2.74	4.07	2	33.5	2.44	3.03	3.03
Nesapakkam	23	2	21.2	2.4	1.77	2	24.4	3.1	3.02	3.02
Kalyani	10.8	1	23.6	4.2	4.08	1	28.3	1.6	2.24	2.24
Rithala	180	4	40	3.12	2.09	4	42.7	4.2	3.21	3.21
Kishopur	180	4	40	3	2.01	4	48	3.6	3.47	3.47
BHU	8	2	14.6	3	3.01	2	16	3.5	4.22	4.22
Maximum				4.20						4.22
Minimum				2.40						2.14

Source-Performance Evaluation of Sewage Treatment Plants in India-NEERI-February-1994

Appendix A 5-11
Illustrative Sizing of Clarifiers in Activated Sludge

1	A	B	C
2	Primary Clarifiers followed by secondary treatment		
3			
4	Average flow, MLD	Enter	23
5	Peak flow. MLD	Enter	60
6	Overflow rate for average flow from Table 5.8. m3/m2/day	Enter	35
7	Overflow rate for peak flow from Table 5.8, m3/m2/day	Enter	80
8	Surface area for average flow, sqm	C4*1000/C6	657
9	Surface area for peak flow, sqm	C5*1000/C7	750
10	Higher of the two areas, sqm	MAX(C8,C9)	750
11	Required diameter, m	SQRT(4*C10/3.14)	30.91
12	Resulting weir length, m	3.14*C10	97.06
13	Resulting weir loading rate, m3/m /day	C3*1000/C11	236.97
14	Weir loading rate in average flow from Table 5.8, m3/m / day	Enter	125.00
15	Usage of double sided weir is needed or not	Enter	Yes
16	Choose an annular space from inner sidewall of clarifier, m	Enter	0.20
17	Choose a launder width, m	Enter	0.60
18	Diameter of outer weir, m	C10-C15-C15	30.51
19	Diameter of inner weir, m	C17-C16-C16	29.31
20	Diameter of inner weir, m	3.14*(C17+C18)	187.83
21	Resulting weir loading rate, m3/m /day	C3*1000/C19	122.45
22	Weir loading is safe or not	Enter	Yes
23	Side water depth shall be to suit Table 5.8	Enter	Yes
24	In actual practice, the diameter and the size of launder will be not less than the above values		

25	Depending on the area and diameter, multiple number of these clarifiers may be designed		
26	Secondary Clarifiers for activated sludge		
27	Average flow, MLD	Enter	23
28	Peak flow. MLD	Enter	60
29	Return sludge flow, MLD	Enter	11.5
30	MLSS, mg/L	Enter	3500
31	Overflow rate for average flow from Table 5.8. m3/m2/day	Enter	25
32	Overflow rate for peak flow from Table 5.8, m3/m2/day	Enter	40
33	Surface area for peak flow, sqm	C5*1000/C7	750
34	Surface area for average flow for overflow rate, sqm	C27*1000/C31	920
35	Solids loading for average flow from Table 5.8. kg/m2/day	Enter	100
36	Solids loading for peak flow from Table 5.8, kg/m2/day	Enter	210
37	Surface area for average flow for solids loading, sqm	(C27+C29)*C30 /C35	1207.5
38	Surface area for peak flow for solids loading, sqm	(C28+C29)*C30/ C36	1192
39	Higher of the four areas, sqm	MAX(C33,C34, C37,C38)	1500
40	Required diameter, m	SQRT(4*C39/3.14)	43.71
41	Resulting weir length, m	3.14*C40	137.26
42	Resulting weir loading rate at average flow, m3/m /day	C27)*1000/C41	168
43	Weir loading rate in average flow from Table 5.8, m3/m / day	Enter	185
44	Usage of double sided weir is needed or not	Enter	No
45	Choose an annular space from inner sidewall of clarifier, m	Enter	0.2
46	Side water depth shall be to suit Table 5.8		
47	In actual practice, the diameter and side water depths will be not less than the above values		
48	Depending on the area and diameter, multiple number of these clarifiers may be designed		

APPENDIX A 5.12
ILLUSTRATIVE DESIGN OF CONVENTIONAL ASP AERATION

The MS Excel version is available in the CD version of the manual and can be easily used. In case of any difficulty, the reader may proceed as follows.

Leave 3 blank rows at the top and start from cell A4.
Copy column A as below
Paste it in column A of your computer
Then copy column C as below
Paste it in column C of your computer by prefixing =
Then wherever it says “Enter” in column C below, you can enter your choice in column B
Then copy column B as entered and paste in column D except in cell D6,
Then enter the winter temperature in cell D6

No	A	B	C	D
1				
2				
3				
4	Plant design flow, MLD	50	Enter	50
5	Elevation of site above MSL, m	30	Enter	30
6	Operating temperature in deg C	30	Enter	20
7	Primary clarifier effluent BOD, mg/l	230	Enter	230
8	Thickener overflow return as fraction of plant flow	0.15	Enter	0.15
9	Thickener overflow return, MLD	7.5	B4*B8	7.5
10	Thickener overflow return BOD, mg/l	500	Enter	500
11	Centrate from sludge dewatering as fraction of plant flow	0.006	Enter	0.006
12	Centrate from sludge dewatering return, MLD	0.3	B4*B11	0.3
13	Centrate from sludge dewatering return BOD, mg/l	380	Enter	380
14	Influent BOD to aeration tank, mg/l	266	((B4*B7)+(B9*B10)+(B12*B13))/(B4+B9+B12)	380
15	Effluent BOD	20	Enter	20

No	A	B	C	D
16	Weighted BOD to be removed in the aeration tank, mg/l	246	B14-B15	246
17	MLSS	3000	Enter	3000
18	F : M	0.35	Enter	0.35
19	F	14208	B16*(B4+B9+B12)	14208
20		40594	B19/B18	40594
21	Aeration tank volume calculated from F/M, cum	13531	(B20/B17)*1000	13531
22	Mean Cell Residence Time, Theta C, days	3	From Fig 5.31 in Chapter 5	5
23	Constant Y	0.500	Fixed value	0.500
24	constant Kd	0.060	Fixed value	0.060
25	Aeration tank volume calculated from Theta, cum	5208	B23*B4*1000*B16 *B22/(1+B24*B22)/ B17	0.006
26	HRT for average flow as per CPHEEO, hrs	5	4 to 6 in Table 5.8 in Chapter 5	5
27	Influent BOD to aeration tank, mg/l	266	((B4*B7)+(B9*B10)+ (B12*B13))/ (B4+B9+B12)	380
28	Aeration tank volume calculated from HRT, cum	10417	B4*1000*B26/24	10417
29	liquid depth, m (restrict to max of 6.5 m if air cooled)	5.50	Enter	5.50
30	BOD removed in aeration tank, kg/day	14208	(B4+B9+B12)*B16	14208
31	Kg oxygen / Kg of BOD removed	0.9	0.8 to 1.0 in Table 5.8 in Chapter 5	0.9
32	Kg of Oxygen needed per day	12787	B30*B31	12787
33	Residual D. O. in aeration	2.0	Fixed value	2.0
34				
35	**If surface aerators are used**		5412.4	

No	A	B	C	D
36	Alpha value	0.83	0.8 to 0.85 as in Equation 5.31 in Chapter 5	0.83
37	Beta value	0.95	As in clause 5.8.1.7.5.3	0.95
38	D O at operating temperature	7.43	14.42+(0.003*B6*B6)-(0.323*B6)	9.16
39	D O at operating elevation	7.41	(1-(B5/152)*0.017)*B38	9.13
40	Oxygen tension, mg/l	5.03	(B39*B37)-B33	6.67
41	Oxygen gradient, mg/l	0.55	B40/9.17	0.73
42	Temperature difference	10.0	B6-20	0.0
43	Temperature Co-efficient	1.03	Fixed Value	1.03
44	Temperature correction factor	1.3	Power(B43,B42)	1.0
45	Conversion factor to standard conditions	0.61	B41*B36*B44	0.60
46	Oxygen needed under standard conditions, kg / day	20879	B32/B45	21172
47	Provide factor of safety for intangibles	1.1	--	1.1
48	Oxygen needed after factor of safety , kg/ day	22967	B45*B46	23289
49	Oxygen transfer capacity of aerator Kg/Kwhr in aeration tank, kg/day	1.8	1.2 to 2.4 in clause 5.8.1.7.5.3	1.8
50	Kw of aerator needed	532	B48/24/B49	532
51				
52	If diffused aeration is used			
53	Factor for temperature power 3	0.027	POWER(B6,3)/(POWER(10,6))	0.008
54	Factor for temperature power 2	0.001	(POWER(B6,2)/(POWER(10,5))/7)	0.001

No	A	B	C	D
55	Factor for temperature power 1	0.090	0.003*B6	0.060
56	Density of air at operating temperature	1.221	1.285+B53-B54-B55	1.232
57	Content of oxygen in air	0.23	Fixed value	0.23
58	Kg of oxygen needed for residual D O per day	100	B4*B33	100
59	Total kg of oxygen needed per day	12887	B32+B58	12887
60	Air needed in cum / day	45505	B59/B56/B57	45072
61	Transfer efficiency of diffuser system per m depth (*)	0.05	Fixed	0.05
62	Transfer efficiency at design depth	0.28	B29*B61	0.28
63	diffuser fouling factor per year	0.04	Enter	0.04
64	Diffuser life cycle, years	3.00	--	3.00
65	Diffuser fouling factor for its life cycle	1.12	POWER((1+B63), B64)	1.12
66	Provide factor of safety for intangibles	1.10	B47	1.10
67	Air needed for oxygenation in cum / day	204747	B60*B65*B66/B62	163899
68	Air needed for oxygenation in cum / hour	8531	B67/24	6829
69	Air mixing criteria cum /minute / 1000 cum of tank	16	As in clause 5.8.1.7.5.6	16
70	Air needed for mixing as per manual cum / hr	12990	B28*B69*60/1000	12990
71	Air needed for mixing as per manual in cum / hr	2.7	1.8 to 2.7 as per US EPA, 625/8-85/0100, p 38	2.7
72	Surface area of aeration tank, sqm	2460	B28/B29	2460
73	Air needed for mixing as per US EPA guidelines in cum / hr	6643	B71*B72	6643
74	Maximum of air needed for mixing in cum / hr	12990	MAX(B70,B73)	12990
75	Air needed as higher of oxygenation and mixing cum / hr	12990	MAX(B68,B74)	12990

No	A	B	C	D
76	Air needed as under standard conditions, cum / hr	21210	B75/B45	21508
77	Friction and other losses as fraction of depth	0.2	Enter by Designer	0.2
78	Liquid depth as water column for air pressure	6.6	B29*(1+B77)	6.6
79	Kw of needed compressor at 1400 rpm	486.6	0.746*((0.03*B76) +16)	493.3
80	For DPR purpose, equation for Compressor Kw at 1400 rpm for 7 m water column can be taken as BHP = 0.03*(cum / hr)+16			
81	For DPR purpose, equation for Compressor Kw at 1400 rpm for 6 m water column can be taken as BHP = 0.025*(cum / hr)+13			
82	For DPR purpose, equation for Compressor Kw at 1400 rpm for 5 m water column can be taken as BHP = 0.02*(cum / hr)+14			
83	**Sludge Flows**			
84	Y0bs=Y/(1+Kd*ThetaC)	0.42	(B23)/(1+B24*B22)	0.38
85	Excess Sludge mass wasted Kg/day	5208	B84*B16*B4	4727
86	Kgd of excess sludge / Kg of BOD removed	20879	B32/B45	21172
87	Kg of excess sludge from thumb rule per day	4916	B4*B16*B86	4916
88	Excess sludge as higher of the two values, Kg/ day	5208	MAX(B85,B87, D85, D87)	5208
89	Concentration factor for MLSS in return / excess sludge	3.3	Enter by Designer	3
90	Return / excess sludge MLSS concentration, mg/l	9900	B17*B89	9900
91	Cells in aeration, kg	40594	B17*B28/1000	40594
92	Cells wasting from system kg / day	5208	B88	5208
93	Volume of excess sludge, cum / day	526	B92*1000000/B90 /1000	526
94	Resulting Theta C	7.8	B91/B92	7.8

No	A	B	C	D
95	Least Theta C in design	0.3	MIN(B22,D22)	0.5
96	Volume of excess sludge for least Theta C	1367	B93*B94/B95	820
97	Excess sludge pump set duty as cum / day	1367	MAX(B93,B96,D93,D96)	1367
98	Recirculation ratio	0.8	0.25 to 0.8 as per Table 5.8	0.8
99	Return sludge pump set duty as MLD	40	B4*B98	40
100	Motors of both the return sludge and excess sludge pump sets will be provided with VFD to downsize actual pumpage as needed			

Note.

For incorporating anoxic tank before aeration tank, the design criteria of the Bangalore K&C Valley STP as given in Table 5.32 may be followed.

APPENDIX A 5.13
DESIGN EXAMPLE OF FACULTATIVE AERATED LAGOON
(Retained as in 2nd edition)

1 PROBLEM

Design a facultative aerated lagoon to serve 40,000 people. Sewage flow @ 180 lpcd = 7200 cum/day, Raw BOD_5 = 50 gcd or 277 mg/l and final BOD_5 is not to exceed 30 mg/l in winter. Average ambient air temperature in January is 18ºC and in summer 37ºC.

2 SOLUTION

2.1 LAGOON SIZE

Assume detention time	=	5 days
Lagoon volume	=	7,200×5 = 36,000 cum.
Let Lagoon dimensions be		70 m×130 m×4 m deep

2.2 LAGOON WINTER TEMPERATURE

Use Eq. (5.34) to determine TL. Assume Ti = 23°C

Hence, Hence,

$$\frac{5\ days}{4\ m} = \frac{(23 - T_L)}{0.49\,(T_L - 18)}$$

TL = 21ºC

2.3 ESTIMATION OF K

Assume K at 20ºC	=	0.7 per day
Hence, K at 21°C	=	0.7×1.035 = 0.724/day,

2.4 D/UL ESTIMATION

Keep lagoon geometry such that flow conditions are plug-flow type (i.e. D/UL = 0.2 approx.). This will be possible if a long and narrow lagoon (23 m×390 m) is provided (see Table 5.12) or baffles are provided within the rectangular lagoon of 70 m×130 m to give a winding flow with the same effect. (See Figure 5.42).

2.5 BOD_5 REMOVAL EFFICIENCY (IN WINTER)

K×Θ = 0.724×5	=	3.62
See Figure (5.41) at K×Θ = 3.62 and D/UL	=	0.2
Soluble BOD removal efficiency	=	92%
Namely, soluble BOD in effluent	=	22 mg/l
SS likely to flow out in effluent	=	35 mg/l (say)

BOD of VSS = 0.77×(0.6×35) = 16 mg/l
Hence, BOD of effluent = 22 + 16 = 38 mg/l
Overall efficiency in winter = 86%

In other months of the year, the efficiency will be higher and effluent BOD will be less than the above value.

2.6 POWER REQUIREMENT

When efficiency = 86% and all BOD is removed aerobically,
O_2 required/day = 0.86 (1.4×2000 kg/d)
= 2,408 kg/d = 100kg/hr

$$Power\ needed = \frac{100\ kg/hr}{0.8 \times 2\ kgO_2/kWh}$$

= 62.5 kW (i.e. about 80 HP)

$$Power\ level\ in\ Lagoon = \frac{62.5kW \times 1{,}000}{36{,}000}$$

= 1.7 W/cum (acceptable)

2.7 LAND REQUIREMENT

Net lagoon area = 9,000 sqm
Area including embankments and slopes = 13,500 sqm (approximately)
Area/person = 0.337 sqm/person

NOTE)

If the lagoon was kept as a square shaped unit or a rectangular unit with say W:L = 1:2, the D/UL value would have been between 3.0 and 4.0 (namely, approaching completely - mixed conditions) and soluble effluent BOD would have increased to 49 mg/l, thus giving a total final effluent of about 65 mg/l instead of 38 mg/l seen above. Thus, lagoon geometry plays an important part in determining efficiency.

APPENDIX A 5.14
DESIGN EXAMPLE OF FACULTATIVE STABILIZATION POND
(Retained as in 2nd edition)

1 PROBLEM

Design a facultative stabilization pond to treat 5,000 m3/d municipal wastewater, BOD5 230 mg/l from a town (population 25,000 persons) located in Central India, latitude 22ºN, elevation 100 m above sea level. The average temperature in January is 18°C. The effluent from the pond is to be used for irrigation.

2 SOLUTION

2.1 POND SIZE

Permissible organic load according to temperature correlation	= 20×18 – 120
	= 240 kg BOD/ha/d
Permissible organic load according to latitude and elevation	= 235/(1 + 0.003×1)
	= 180 kg BOD/ha/d
Adopt a conservative loading rate of 200 kg BOD/ha/d	
BOD load from the town	= 5,000×0.23 = 1,150 kg/d
Therefore pond area	= 1,150/200 = 5.75 ha
Adopt an average depth of 1.5 m	
Therefore pond detention time	= 5.75×104×1.5/5,000
	= 17.25 d

Provide three ponds of equal volume and surface area; two primary ponds in parallel and one secondary pond in series receiving the effluent of the two primary ponds. Use of multiple ponds improves performance from viewpoints of stability, efficiency of treatment and maintenance. However, it requires greater land area for the same pond surface area.

2.2 CHECK FOR DETENTION TIME

For 90% BOD reduction, the BOD reaction rate constant = 0.2/d for plug flow condition. The total overall detention time, Θ, is given by:
$0.1 = \exp - 0.2\,(2\times\Theta/3 + \Theta/3)$, or $\Theta = 11.5$ d

For a conservative estimate, for completely mixed condition in all three ponds, the total overall detention time is given by:
$0.1 = 1/(1+0.2\times 2\Theta/3)\,(1 + 0.2\times\Theta/3)$, or $\Theta = 22.5$ d

In actual conditions, the hydraulic regime in the ponds is going to be between the two ideal conditions of plug flow and completely mixed flow. The detention time of 17.25 d is therefore acceptable.

2.3 CHECK FOR MICROBIAL QUALITY FOR IRRIGATION

WHO guidelines recommend sewage retention in stabilization ponds for 8-10 days for irrigation of cereal, fodder and industrial crops and trees. This assures removal of intestinal nematodes from sewage. The design meets this requirement.

For irrigation of crops likely to be eaten uncooked, the guidelines recommend a faecal coliform limit of 1,000 organisms/100 ml. For microbial reduction rate constant of 2.0/d at 20°C or 1.4 at 18°C, and influent faecal coliform concentration = 107/100 ml, the effluent concentration N is
given by

N = 107/ (1+1.4×2×17.25/3) (1+1.4×17.25/3)
or,
N = 64,600/100 ml

Therefore the design does not meet the criteria of irrigation water quality for crops likely to be eaten uncooked. If two maturation ponds, each of 17.25/3 d detention time are provided in series after the secondary pond, the effluent concentration is expected to be:

N = 107/ [(1 + 1 4×2×(17.25/3)] (1+1.4×17.25/3)3
= 788/100 ml

The above calculations are based on assumption of complete mixing. In actual condition the performance is likely to be better.

2.4 SLUDGE ACCUMULATION

Most of the sludge will accumulate in primary ponds. Assuming 0.75 m deep allowable sludge deposition, capacity available = 0.75 × (2/3) × 5.75 × 104 = 28,750 m3. For 0.07 m3/person/year sludge accumulation rate,

Desludging frequency = 28,750/(0.07 × 25,000) = 16 years.
Because of non-uniform deposition of sludge, a desludging frequency of once in 10 years is recommended.

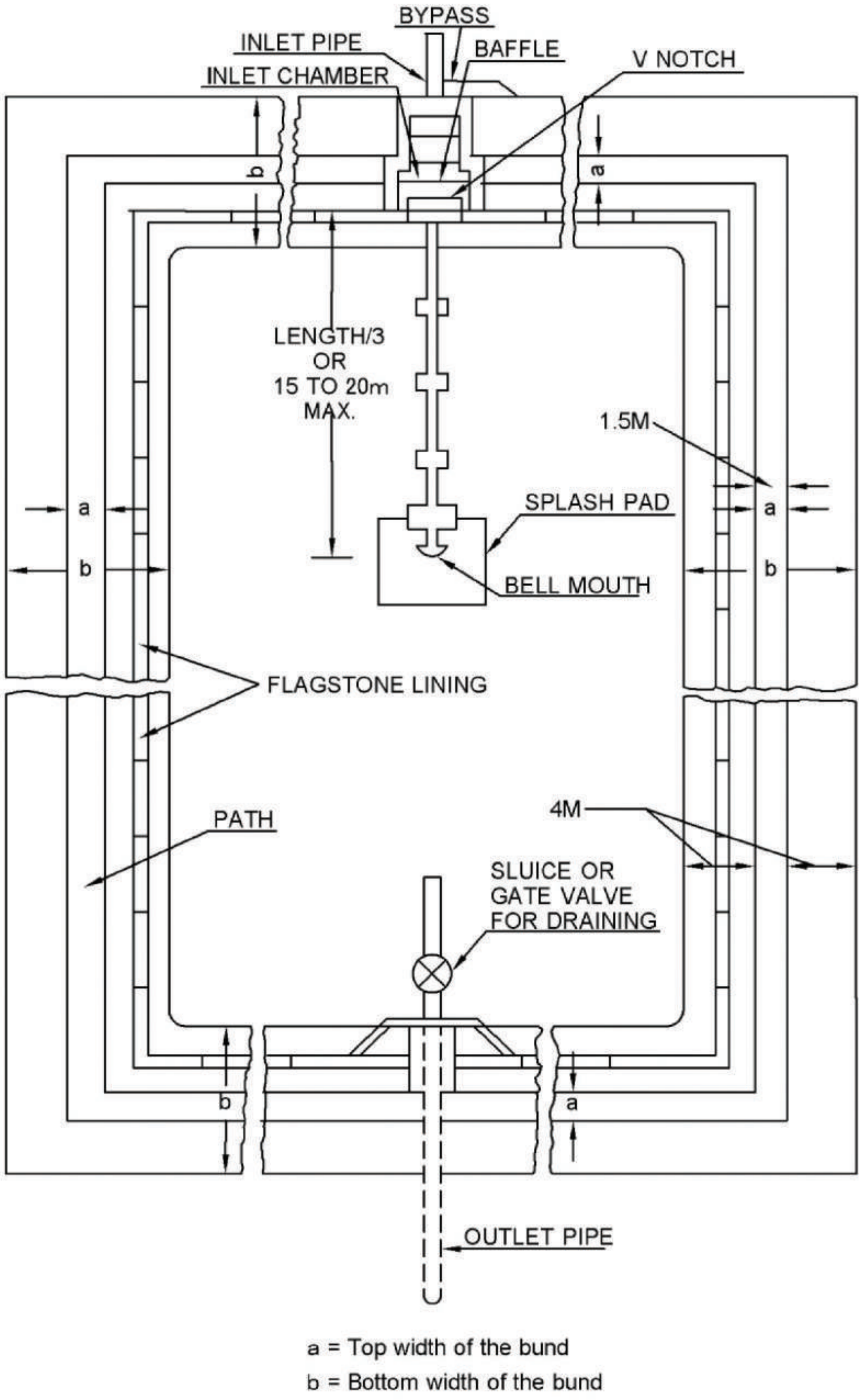


Figure A5.14-1 Typical plan of a waste stabilization pond

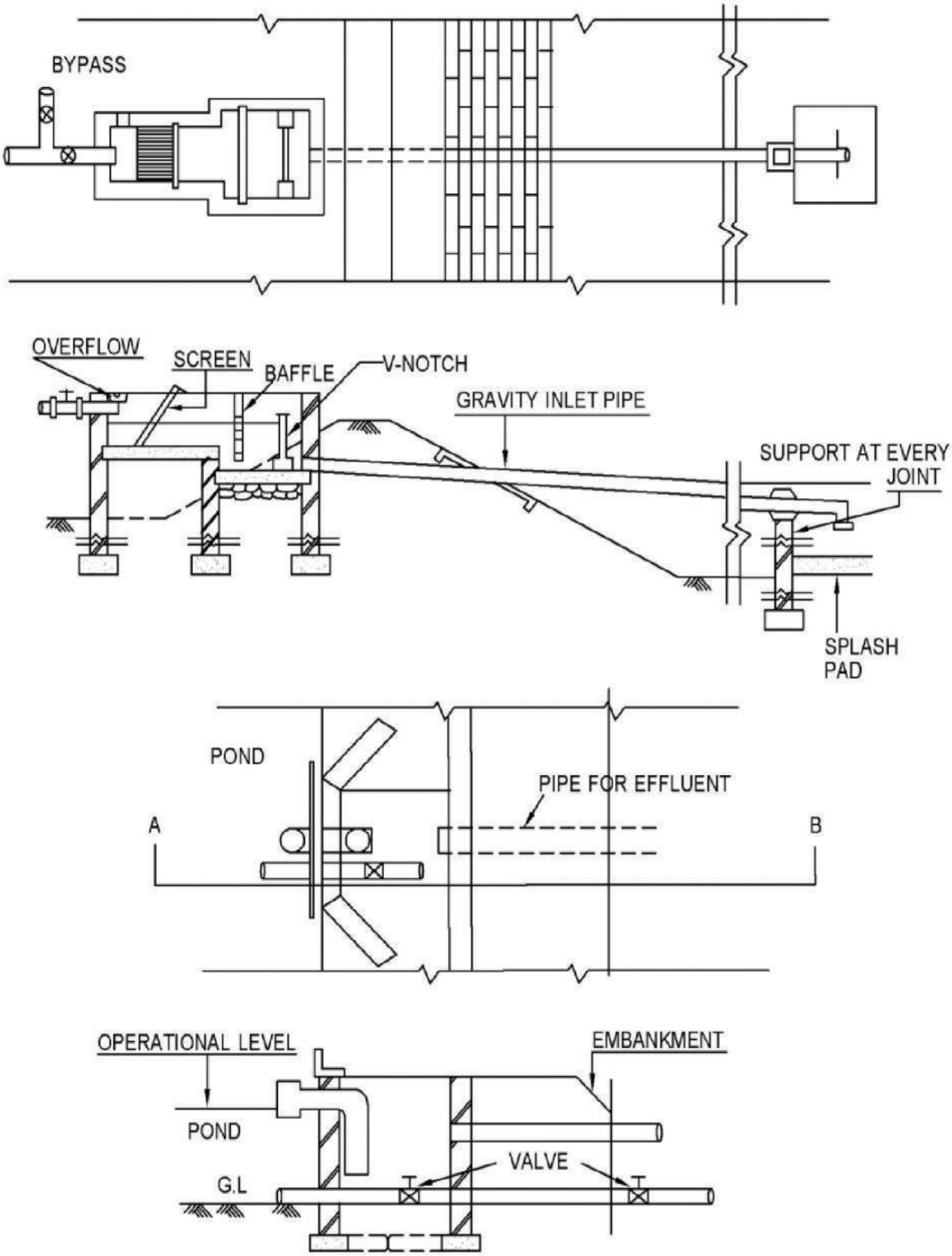


Figure A5.14-2 Typical details of inlet and outlet chamber for facultative waste stabilization pond

APPENDIX A 5.15
DESIGN EXAMPLE FOR UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR
(Retained as in 2nd edition)

1 PROBLEM

Design an upflow sludge blanket reactor for an average flow of 5 MLD of wastewater with the following data:

1. COD of wastewater	=	400 mg/l
2. Design hydraulic residence time	=	6 hrs
3. Design COD loading	=	1 - 2 kg COD/m^3d
4. Velocity of rise of wastewater in the reactor through sludge bed	=	0.75 m/hr
5. Velocity of wastewater in settling chamber	=	< 1.5 m/hr
6. Flow area covered by each inlet	=	1 - 2 m^2

2 SOLUTION

2.1 DETERMINE THE DIMENSIONS OF UASBR

Volume of UASBR = 5,000 × (6/24) = 1,250 m^3

Actual volumetric organic loading = [(5×400)/1,250] kg COD/m^3d

= 1.6 [OK as it is between 1-2 kg COD/m^3d]

Height of wastewater in reactor = Rise velocity×HRT

= 0.75×6 = 4.5 m

Area of Reactor = [1250/4.5] = 277.8 m^2

Provide two reactors of 11.8 m×11.8 m×5.25 m (height)

2.2 NO. OF INLETS

Assume that each inlet can serve 2.0 m^2 of flow area

Number of inlets in each reactor = [138.9/2] = 70

2.3 AREA OF SETTLING CHAMBER

Assuming a velocity of 1.2 m/hr in the settling zone

Area of settling chamber in each reactor = [5,000/(2×24×1.2)] = 86.8 m^2

APPENDIX A 5.16
DESIGN EXAMPLE FOR ANAEROBIC FILTER
(Retained as in 2nd edition)

1 PROBLEM

Design anaerobic filters to treat an average flow of 5 MLD of wastewater with the following assumptions:

1.	COD of the wastewater	=	400 mg/l
2.	Design COD Loading	=	1.0 kg COD/m^3d
3.	Depth of media	=	1.2 m

2 SOLUTION

2.1 DIMENSIONS OF ANAEROBIC FILTER

Total COD load	= 5×400	=	2,000 kg COD/d
Volume of anaerobic filters for media	= [2,000/1.0]	=	2,000 m^3
Plan Area of filters	= [2,000/1.2]	=	1,666.7 m^2

Provide two filters of diameter 32.6 m and height 1.5 m including free board and bottom zone for dispersion of wastewater and supporting media.

2.2 HRT FOR FILTERS

HRT = [2,000/5,000] d
= 9.6 hrs

APPENDIX A 6.1
ILLUSTRATIVE COMPUTATION OF SLUDGE WEIGHTS AND VOLUMES FROM ASP

No	A	B	C	D
1	Appendix 6-1			
2	Illustrative Computation of Sludge weights and volumes from ASP			
3	Raw sewage flow in MLD	Enter		10
4	Raw sewage BOD in mg/l	Enter		250
5	Raw sewage SS in mg/l	Enter		400
6	Raw sewage VSS in percent	Enter		60
7	Raw sewage ISS in percent		100-D6	40
8	Secondary clarifier effluent BOD in mg/l	Enter		10
9	Consider Primary Clarifier alone			
10	BOD removal in percent	Enter		30
11	Effluent BOD in mg/l		D4*(100-D10)/100	175
12	ISS removal in percent	Enter		60
13	VSS removal in percent	Enter		60
14	TSS removal in percent	Enter	100*((D6*D12/100)+(D7*D13/100))/(D6+D7)	60
15	VSS removed in kg / day		D3*D5*D6*D13/100/100	1440
16	ISS removed in kg / day		D3*D5*D7*D12/100/100	960
17	TSS removed in kg / day		SUM(D15:D16)	2400
18	% solids in primary sludge	Enter		4
19	Specific gravity of primary sludge	Enter		1
20	Sludge removed in Kld		D17*100/D18/D19/1000	60
21	BOD removed in kg / day		D3*D4*D10/100	750
22	Kg VSS / kg BOD removed		D15/D21	1.9

No	A	B	C	D
23	Kg ISS / kg BOD removed		D16/D21	1.3
24	Kg TSS / kg BOD removed		D17/D21	3.2
25	ISS carry over in kg / day		(D3*D5*D7/100)-D16	640
26	Consider conventional secondary stage alone			
27	Clarifier effluent BOD in mg/l	Enter		10
28	Secondary clarifier VSS in percent	Enter		85
29	Secondary clarifier ISS in percent		100-D28	15
30	Aeration kd in per day	Enter		0.06
31	Aeration Y	Enter		0.5
32	Aeration SRT in days			5
33	Kg VSS / kg BOD removed, Y observed = Y/(1+ (kd)*(SRT))	Enter	D31/(1+(D30)*(D32))	0.38
34	BOD removed in kg / day		D3*(D11-D27)	1650
35	Kg VSS removed per day		D33*D34	635
36	SS removed in kg / day		D35*100/D28	747
37	Inert sludge carry over in kg/day		(D3*D5*D7/100)	1600
38	Kg TSS carried over per day		SUM(D36:D37)	2347
39	% solids in sludge		Enter	0.75
40	Specific gravity		Enter	1.00
41	Sludge removed in Kld		D38*100/D39/D40/1000	313
42	Kg VSS / kg BOD removed		D35/D34	0.4
43	Kg TSS / kg BOD removed		D38/D34	1.42
44	Consider extended aeration alone			
45	Clarifier effluent BOD in mg/l	Enter		10
45	Aeration kd in per day	Enter		0.06

No	A	B	C	D
46	Aeration kd in per day	Enter		0.06
47	Aeration Y	Enter		0.5
48	Aeration SRT in days	Enter		15
49	Kg VSS / kg BOD removed, Y observed = Y/(1+ (kd)*(SRT))	Enter	D47/(1+(D46)*(D48))	0.26
50	BOD removed in kg / day		D3*(D4-D45)	2400
51	Kg VSS removed per day		D49*D50	632
52	Inert sludge carry over in kg/day		D3*D5*(D7)/100	1600
53	Kg TSS removed per day		SUM(D51:D52)	2232
54	% solids in sludge		Enter	0.75
55	Specific gravity		Enter	1.00
56	Sludge removed in Kld		D53*100/D54/D55/1000	298
57	Kg VSS / kg BOD removed		D51/D50	0.26
58	Kg TSS / kg BOD removed			0.93
59				
60	Rule of Thumb for Design Purposes for parameters as above.			
61	For other parameters please rework in the M S excel			
62			Kg Sludge / Kg BOD removed	
63	Process	as VSS	as TSS	
64	Primary alone	1.92	3.20	
65	Primary & secondary as conventional ASP	0.86	1.31	
66	Extended aeration ASP	0.26	0.93	

APPENDIX A 6.2
ILLUSTRATIVE CALCULATION OF SLUDGE WEIGHTS

Calculation example of Figure 6.1.

1) Set influent solid as 100 and Design sludge generation, D as 90.
2) Assume solids recovery rate or reduction rate of each treatment stage as under.

Table A6.2-1

Solids recovery rate, etc.	Figure 6.1, a	Figure 6.1, b
Solid recovery rate in Thickening, γ^1	90 %	90 %
Solid reduction rate in Digestion, γ^2	-	40 %
Solid recovery rate in Dewatering, γ^3	95 %	90 %
Coagulant dosing rate in Dewatering, γ^4	0.8 %	1.0 %
Solid reduction rate in Incineration, γ^5	70 %	-
Solid recovery rate in Incineration, γ^6	80 %	-

3) In case of Figure 6.1, a

Solid of return flow from sludge treatment facilities, R, is calculated as under assuming all solids are returned to the sludge treatment facilities.

$$R = (D + R) \{(1 - \gamma^1) + \gamma^1(1 + \gamma^4)(1 - \gamma^3) + \gamma^1(1 + \gamma^4)\, \gamma^3\, (1 - \gamma^5)(1 - \gamma^6)$$
$$= (90 + R) \{(1 – 0.9) + 0.9(1 + 0.008)(1 – 0.95) + 0.9(1 + 0.008)\, 0.95\, (1 – 0.7)(1 – 0.8)$$
$$= (90 + R) \times 0.197$$
$$R = 22.1$$

Calculation of Solid in each treatment stage

Thickener: X1 = D + R = 90 + 22.1 = 112.1

Centrifugal dewatering machine: $X_2 = X_1 \times \gamma^1 = 112.1 \times 0.9 = 100.9$

Coagulant dosing: $C = X_2 \times \gamma_4 = 100.9 \times 0.008 = 0.8$

Incinerator: $X_3 = X_2 \times (1 + \gamma_4) \times \gamma_3 = 100.9 \times (1+0.008) \times 0.95 = 96.6$

Solid reduction in Incinerator: $G = X_3 \times \gamma_5 = 96.6 \times 0.7 = 67.6$

Incineration ash: $X_4 = (X_3 - G) \times \gamma^6 = (96.6 - 67.6) \times 0.8 = 23.2$

4) In case of Figure 6.1, b

Solid of return flow from sludge treatment facilities, R, is calculated as under assuming all solids are returned to the sludge treatment facilities as in case of Figure 6.1, a.

$$R = (D + R) \{(1 - \gamma^1) + \gamma^1(1 + \gamma^4)(1 - \gamma^3) + \gamma^1(1 + \gamma^4)\, \gamma^3\, (1 - \gamma^5)(1 - \gamma^6)$$
$$= (90 + R) \{(1 – 0.9) + 0.9(1 + 0.008)(1 – 0.95) + 0.9(1 + 0.008)\, 0.95\, (1 – 0.7)(1 – 0.8)$$

$= (90 + R) \times 0.197$

$R = 22.1$

Calculation of Solid in each treatment stage

Thickener: $X1 = D + R = 90 + 22.1 = 112.1$

Centrifugal dewatering machine: $X_2 = X_1 \times \gamma_1 = 112.1 \times 0.9 = 100.9$

Coagulant dosing: $C = X_2 \times \gamma_4 = 100.9 \times 0.008 = 0.8$

Incinerator: $X_3 = X_2 \times (1 + \gamma_4) \times \gamma_3 = 100.9 \times (1+0.008) \times 0.95 = 96.6$

Solid reduction in Incinerator: $G = X3 \times \gamma 5 = 96.6 \times 0.7 = 67.6$

Incineration ash: $X_4 = (X_3 - G) \times \gamma_6 = (96.6 - 67.6) \times 0.8 = 23.2$

APPENDIX A 6-3
FRICTION LOSSES IN SLUDGE PIPELINES UNDER GRAVITY AND PUMPED CONDITIONS

1	A	B	C
2	Calculation of Friction Losses in Sludge Pipelines		
3	for Gravity conditions and pumped conditions		
4	For Gravity Conditions		
5	Pipe material considered is UPVC		
6	value of Manning's n	Enter from Table 3.11	0.0100
7	Discharge rate m^3/day	Enter by Designer	500
8	Discharge rate in litres per sec	C7*1000/24/3600	5.79
9	Required velocity, m/sec	Enter by Designer	1.20
10	Required area in sqcm	(C8/C9/1000)*100*100	48.23
11	diameter in mm	10*SQRT(4*C10/3.14)	78.38
12	Hydraulic mean radius R in m	C11/4/1000	0.0196
13	diameter in mm power 0.67	POWER(C11,0.67)	18.5830
14	Gradient power 0.5	C9*C6*1000/3.968/C13	0.1627
15	Gradient	C14*C14	0.026
16	Length of pipeline, m	Enter by Designer	100
17	Friction loss, m	C15*C16	2.6484
18	Solids content of sludge in percent	Enter by Designer	4
19	Friction compounding factor	2.88+(0.176*C18*C18)-0.866*C18	2.2320
20	Total friction head, m	C17*C19	5.9113
21	Add safety factor at percent	Enter by Designer	10
22	Design friction head, m	C20*(1+(C21/100))	6.502
23			

24	For Pumped Conditions of raw sludge		
25	Pipe material considered is UPVC		
26	Solids in sludge as percent	Solids in sludge as percent	4
27	Value of Hazen C	Value of Hazen C	53
28	Discharge in cum / day	Discharge in cum / day	75
29	Discharge rate in litres per second	Discharge rate in liters per second	0.87
30	Required velocity, m/sec	Required velocity, m/sec	1.50
31	Required area in sqcm	Required area in sqcm	5.79
32	diameter in mm	diameter in mm	27.15
33	diameter in mm power 0.67	diameter in mm power 0.67	9.13
34	Gradient power 0.54	Gradient power 0.54	0.678
35	Gradient	Gradient	0.488
36	Length of pipeline, m	Length of pipeline, m	15
37	Friction loss, m	Friction loss, m	7.314
38	Friction compounding factor	Friction compounding factor	3
39	Total friction head, m	Total friction head, m	21.94
40	Add safety factor at percent	Add safety factor at percent	10
41	Design friction head, m	Design friction head, m	22.3
42	Number of tees	Number of tees	2
43	Friction factor for tee	Friction factor for tee	1.5
44	Number of valves	Number of valves	2
45	Friction factor for valve	Friction factor for valve	1.4
46	Total friction co-efficient	Total friction co-efficient	6
47	velocity head, m	velocity head, m	0.11
48	Friction loss in bends & tees	Friction loss in bends & tees	0.67
49	Other Losses, m	Other Losses, m	0.33
50	Total friction loss, m	Total friction loss, m	23.27

APPENDIX A 6.4
DESIGN EXAMPLE OF SLUDGE DIGESTERS
(Retained as in 2nd edition)

Design low rate and high rate digesters for digesting mixed primary and activated sludge from a 50,000 m3/day capacity activated sludge Wastewater Treatment Plant.

1 GIVEN

a) Raw effluent suspended solids (SS) concentration = 400 mg/l

b) SS removal efficiency in the primary sedimentation tank = 75 %

c) Therefore, quantity of primary sludge generated
(0.4 kg/m^3 × 50,000 m^3/day × 0.75) = 15,000 kg/day

d) At 4% consistency or 40 kg/m3 SS concentration,
primary sludge volume (15,000 kg/day ÷ 40 kg/m^3) = 375 m^3/day

e) The excess activated sludge generated = 2,630 kg/day

f) At 1% consistency or SS concentration of 10 kg/m^3 the excess
activated sludge volume (2,630 kg/day ÷ 10 kg/m^3) = 263 m^3/day

g) Total volume of the raw mixed sludge (375 + 263) = 638 m^3/day

h) Total quantity of the raw mixed sludge (15,000 ÷ 2,630) = 17,630 kg/day

i) SS concentration of the raw mixed sludge
(17,630 kg/day ÷ 638 m^3/day) = 27.6 kg/ $m^{3]}$

j) The approximate percentage of volatile matters (VM)
in the mixed sludge = 70 %

k) Quantity of VM in the raw mixed sludge (0.7 × 17,630) = 12,341 kg/day

l) Quantity of Non-VM or inorganic (0.3 × 17,630) = 5,289 kg/day

* 1% consistency = 10,000 mg/l = 10 kg/m^3

2 LOW RATE DIGESTER

a) Approximate percentage destruction of VM
(design value) = 50%

b) For achieving 50 % VM destruction, under mesophilic
conditions, the HRT required (from Figure.6.5) = 40 day

c) Quantity of VM in the digested sludge (0.5 × 12,341) = 6,170 kg/day

d) Quantity of non-volatile matters or inorganic matters
in the digested sludge = 5,289 kg/day

e) Total quantity of solids in the digested sludge
(6,170 + 5,289) = 11,459 kg/day

f) Percentage of VM in the digested sludge
(6,170 + 11,459) = 53.80 %

g) Percentage of inorganic matter in the digested sludge
(5,289 + 11,459) = 46.20 %

h) Depending on the frequency of sludge withdrawal the consistency of the digested sludge withdrawn from the low rate digester is expected to be in the range of 4 - 6 %.

i) For an average consistency of 5 % (or 50 kg/ m^3),
the volume of digested sludge (11,459 ÷ 50) = 229 m^3/day

j) Therefore the volume of digester
$V = [V_f – 2/3 (V_f - V_d)]$ T1
= [638 – 2/3 (638 – 229)] × 40
= 14,624 m^3
Check for volatile solids loading rate kg VSS/day/m^3
= 12,341 ÷ 14,624 = 0.84 kg VSS/day/m^3
(The VSS loading is within the permissible range - 0.6 to 1.6 kg VSS/day/m^3)

3 GAS GENERATION

a) Gas production per kg of VM destroyed = 0.9 m^3
b) Total gas generation (0.9m^3/kg VM × 6,170 kg VM/day) = 6,039 m^3
c) To avoid foaming, the minimum surface area required to meet the condition - 9 m^3 of gas generated per day per m2 surface area, will be (6,039 ÷ 91) = 617 m^2
d) For operational flexibility and constructional reasons, it is suggested to install two digesters of the following dimensions.
e) Volume of each digester (14,624 m^3 ÷ 2) = 7,312 m^3
f) Minimum surface area of each digester (617 m2 ÷ 2) = 309 m^2
g) Choosing the digester shape as a low, vertical cylinder and for a diameter of 34 m, the surface area of each digester will be = 908 m^2
h) Therefore the effective digester depth will be (7,312 m3 ÷ 908 m^2) = 8.0 m

4 ADDITIONAL VOLUME

a) Volume for sludge storage during the monsoon period –when the sludge drying bed option is used for sludge dewatering = Vd × T2
b) For a storage period of 12 days (229 m^3/day × 12 days) = 2,748 m^3
c) Equivalent to 2,748 m^3 ÷ 908 m^2 = 3.0 m
d) Additional allowance for grit and scum Accumulation = 0.6 m
e) Free board = 0.6 m
f) Therefore total additional depth = 4.2 m

Two digesters – each of 34 m diameters & 12.2 m depth

5 HIGH RATE DIGESTERS

a) For a sludge temperature of 24°C, the Solids Retention Time (SRT) required for 50% VSS destruction (refer Table 6.10) = 20 days
b) Therefore the digester volume will be = 638 × 20
c) (Volume of fresh sludge × Retention time) = 12,760 m^3
d) Choosing two digesters, the capacity of each digester will be:
Volume (12,760 m3 ÷ 2) = 6,380 m^3

e) Choosing a diameter of 27 m, the effective depth will be = 11.2 m
f) Additional allowance for grit accumulation = 0.5 m
g) Free board = 0.6 m
h) Total additional depth = 1.1 m

Two digesters of 27 m diameter and 12.3 m depth

Additional, separate sludge holding facility for storage during monsoon period (when sludge drying bed option is used for dewatering) is to be computed as before.

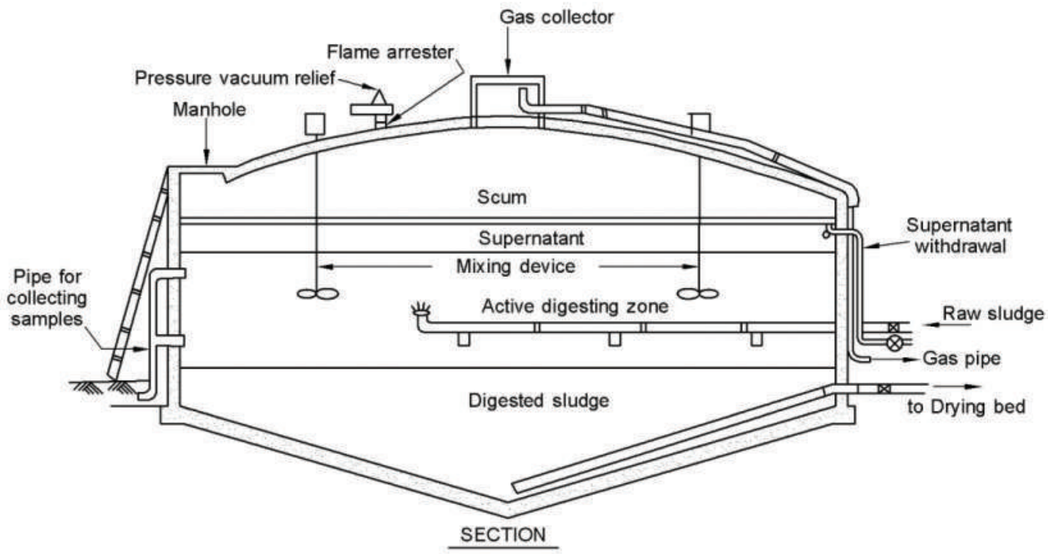


Figure A6.4-1 Typical Details of Low rate Sludge Digester

APPENDIX A 6.5
DESIGN EXAMPLE OF SLUDGE DRYING BEDS
(Retained as in 2nd edition)

1 PROBLEM STATEMENT

Design sludge drying beds tor digested sludge obtained from low rate anaerobic digesters for digesting a mixture of primary and excess activated sludge. The capacity of activated sludge plant is 50,000 m^3/d and following data is assumed:

i) Volume of digested sludge (Refer to design example on low rate anaerobic digester in Appendix 6.4) = 229 m3/day

ii) Dewatering, drying and sludge removal cycle = 10 d

iii) Depth of application of sludge = 0.3 m

2 SOLUTION

i) Total plan area of sludge drying $= \frac{229 \times 10}{0.3}\ m^2 = 7{,}633\ m^2$

ii) Number of beds is assumed to be = 30

iii) If per capita wastewater flow is assumed as 150 lpcd

Contributory design population $= \frac{50{,}000 \times 10^3}{150} = 3{,}33{,}333$

Plan area of sludge drying bed = 7,633 ÷ 3,33,333 = 0.023 m^2/capita

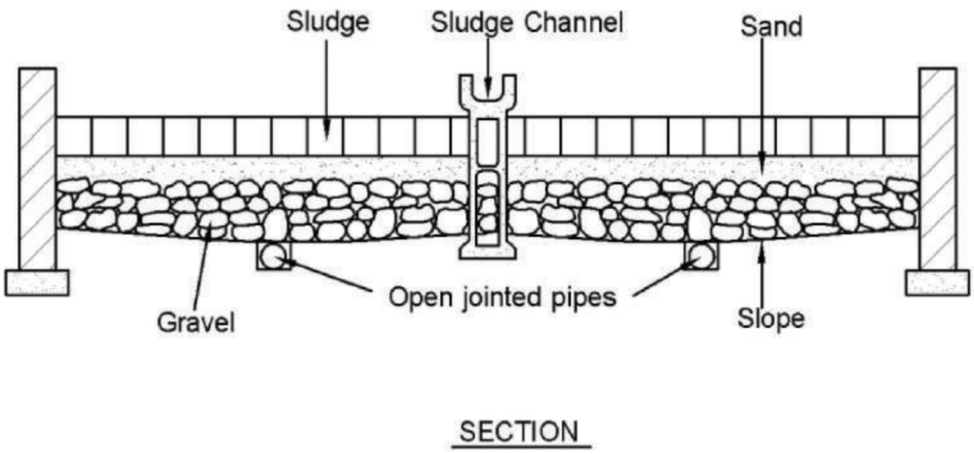


Figure A6.5-1 Typical details of sludge drying bed

Appendix A 7-1

Table of Micro Nutrients to be added to biological systems per month till MLSS builds up to 3000 mg/l for continuous flow reactors (Source, Eckenfelder)

A	B	C	**D**	E	**F**	G	H	I	J	K
Sewage in MLD			**4**	BOD at Inlet	**300**					
		Atomic	mg per mg of BOD	Market Chemical	Chemical Formula	Molecular	mg per mg of BOD	Kg	Rs	Cost
		Weight	as element			Weight	as compound	per month	per Kg	per month
									(may vary)	
Calcium	Ca	40	0.0062	Calcium carbonate	CaCo3	100	0.0155	18.60	120	2232.00
Cobalt	Co	58	0.00013	Cobaltic chloride	CoCl2(6H2O)	238	0.000533448	0.64	3400	2176.47
Copper	Cu	64	0.00015	Cupric sulphate	Cu(SO4)	160	0.000375	0.45	340	153.00
Iron	Fe	56	0.012	Ferrous ammonium sulphate	FeSO4 (NH4)2(SO4) (6 H20)	392	0.084	100.80	260	26208.00
Magnesium	Mg	24	0.003	Magnesium chloride	MgCl2	95	0.011875	14.25	200	2850.00
Manganese	Mn	55	0.0001	Manganese chloride	MnCl2(4H2O)	198	0.00036	0.43	280	120.96
Molybdenum	Mo	96	0.00043	Molybdic acid	MoS2	106	0.000474792	0.57	3500	1994.13
Potassium	K	39	0.0045	Potassium chloride	KCl	75	0.008653846	10.38	240	2492.31
Selenium	Se	79	0.0014	Selenium chloride	SeCl4	228.825	0.004055127	4.87		
Sodium	Na	23	0.00005	Sodium chloride	NaCl	59	0.000128261	0.15	120	18.47
Zinc	Zn	66	0.00016	Zinc oxide	ZnO	82	0.000198788	0.24	300	71.56
									Rs/Kl	0.32

The values in column (I) are for the indicated feed raw sewage of 4 MLD and feed raw BOD of 300 mg / I, For other values, it will be prorate.
For example, if raw sewage is 20 MLD and raw BOD is 450 mg/l, Ca need will be 18.6 * (20*450) / (4*300) = 140
These can be added even in shorter intervals than a month if the need arises. Cost of chemicals as given is only for illustrative calculations.

Appendix A7-2

Table of Micro Nutrients to be added to biological systems per month till MLSS builds up to 3000 mg/l for batch flow reactors

A	B	C	D	E	F	G	H	I	J	K
volume of reactor in cum			**1500**	BOD of feed	**200**					
		Atomic	mg per mg of BOD	Market Chemical	Chemical Formula	Molecular	mg per mg of BOD	Kg	Rs	Cost
		Weight	as element			Weight	as compound	per month	per Kg	per month
									(may vary)	
Calcium	Ca	40	0.0062	Calcium carbonate	CaCo3	100	0.0155	4.65	120	558.00
Cobalt	Co	58	0.00013	Cobaltic chloride	CoCl2(6H2O)	238	0.000533448	0.16	3400	544.12
Copper	Cu	64	0.00015	Cupric sulphate	Cu(SO4)	160	0.000375	0.11	340	38.25
Iron	Fe	56	0.012	Ferrous ammonium sulphate	FeSO4 (NH4)2(SO4)(6 H20)	392	0.084	25.20	260	6552.00
Magnesium	Mg	24	0.003	Magnesium chloride	MgCl2	95	0.011875	3.56	200	712.50
Manganese	Mn	55	0.0001	Manganese chloride	MnCl2(4H2O)	198	0.00036	0.11	280	30.24
Molybdenum	Mo	96	0.00043	Molybdic acid	MoS2	106	0.000474792	0.14	3500	498.53
Potassium	K	39	0.0045	Potassium chloride	KCl	75	0.008653846	2.60	240	623.08
Selenium	Se	79	0.0014	Selenium chloride	SeCl4	228.825	0.004055127	1.22		
Sodium	Na	23	0.00005	Sodium chloride	NaCl	59	0.000128261	0.04	120	4.62
Zinc	Zn	66	0.00016	Zinc oxide	ZnO	82	0.000198788	0.06	300	17.89
									Rs/day	1368

The values in column (I) are for the indicated feed volume of reactor of 1500 cum & feed raw BOD of 200 mg / l. For other values, it will be prorate. For example, if volume of reactor is 2500 cum and raw BOD is 450 mg/l, Ca need will be 4.65*2500*450/1500 / 200 = 17.44
These can be added even in shorter intervals than a month if the need arises.

APPENDIX A 7.3
CASE STUDIES IN RECYCLING AND REUSE OF SEWAGE

A complete documentation of all the technologies, design basis and engineering practices will be not only voluminous but also not directly applicable in every other place and as such, only the key issues are brought out here and a reference is available in the end for a detailed learning of these comprehensively. The case studies are arranged in the following order:

1. Agriculture
2. Farm Forestry
3. Horticulture
4. Toilet flushing
5. Industrial and commercial
6. Fish culture
7. Groundwater recharge
8. Indirect recharge of impoundments

1 AGRICULTURE

The risk in using inadequately treated sewage in agriculture in general poses the health hazards as enunciated by the WHO and extracted hereunder.

Table A7.3- 1 Health hazards of inadequately treated sewage in agriculture

Type of pathogen / infection	Relative excess of frequency of infection or disease
Intestinal nematode infections (*Ascaris lumbricoidus, Trichuris trichiura*, hookworm)	High
Bacterial infections Bacterial diarrheas (e.g. cholera, typhoid)	Lower
Viruses Viral diarrheas Hepatitis A	Lowest

Source: World Health Organization 1989

These infections can virtually reduce the effective man days by as much as even 50 % especially in rural habitations where neither prophylaxis not cure is easily accessible and if at all, financially in out of reach unless subsidized. It is not that sewage cannot be used at all. It only requires appropriate treatment. The reported specific experiences are hereunder.

1.1 ISRAEL

There are approximately 200 numbers of deep surface reservoirs in operation throughout the country with a total storage capacity of 150 Mm^3 that are used to store treated sewage during the winter season and the water is then used during the summer season for irrigation crops and animal fodder thus reusing nearly 70% of the treated sewage which equates to nearly 400 Mm^3 per year. The Dan Region reuse system serves the Tel Aviv metropolitan area treats 120 Mm^3/year of Tel Aviv sewage which is stored in recharge aquifer basins and then pumped from recovery wells and conveyed to irrigation. The Kishon facilities treat 32 Mm^3/year of sewage from the Haifa metropolitan area and the treated sewage is conveyed beyond 30 km where it is blended with local storm water and stored in a 12 Mm^3 reservoir for irrigation of 15,000 ha of cotton and other non-edible crops. There are 3 other similar reuse projects in the Jeezrael Valley for 8 Mm^3/year, Gedera for 1.5 Mm^3/year and Getaot Kibbutz for 0.14 Mm^3/year. This emphasises the importance of reuse projects.

1.2 TALLAHASSEE, FLORIDA, US

The Tallahassee agricultural reuse system is a cooperative operation where the city owns and maintains the irrigation system, while the farming service is under contract to commercial enterprise. The reuse dates back to 1966 and until 1980, was limited to irrigation of 50 ha of land used for hay production. Based upon success of the early studies and experience, new spray field has been expanded to approximately 840 ha with an application rate of 8 cm per week on the soils of 95% sand and interspersed clay layer at a 10 m depth and the field is sloping from 21m to 6m above sea level. The treated sewage meets BOD of 20 mg/l for BOD and TSS and MPN of 200 per 100 ml for faecal Coliform and is pumped over 13 km and distributed via 16 centre-pivot irrigation units. Major crops are corn, soybeans, coastal Bermuda grass, and rye with the rye and Bermuda grass being grazed by cattle, though some of the Bermuda grass is harvested as hay and haylage.

1.3 AFRICA

Raw sewage farming for vegetables is used in Eritrea in Northeast Africa in an area of 124,320 km^2 and a 3.5 million population set at 1,700 m above sea level with water scarcity which forces the crudely treated sewage use for vegetables. The pathogens detected in the vegetables are shown hereunder:

Table A7.3- 2 Pathogen detected in vegetables grown from crudely treated sewage at Eritrea, Africa

Types of vagetables grown	Sampling sites	No. of sample	Faecal coliform		E. Coli		Giardia	
			No. + ve	%. + ve	No. + ve	%. + ve	No. + ve	%. + ve
Cabbage	4	8	6	75	6	75	4	50
Lettuce	4	12	11	96.6	6	96.6	6	50
G.vegetable	4	12	12	100	11	100	3	25
Tomatoes	3	9	9	100	12	100	2-	22.0
Carrots	3	9	6	66.6	9	66.6	ND	-
Cucurbits	3	6	6	100	6	100	ND	-
Total	16	62						

ND indicates not dctocted.
Note: No Salm onclla was detected, Shigclla was detocted in one let tuce sample.

The faecal Coliforms in the sewage used for irrigation was 4×10^4 to 13×10^9 per litre as compared to a limit of 1,000 per 100 ml and in the vegetables it was 2×10^3 to 4×10^6 per kg. Among the local farmers in the field, out of a sample of 75 persons, 34 had Giardia Lamblia. But there was surprisingly no detection of round worm or hook worm, Shigella or Salmonella. This might have been due to the combination of prophylactic methods in treading on farm soil and drinking water sources were not affected by sewage but eating green salad as a standard practice.

1.4 FINDINGS BY THE LONDON SCHOOL OF TROPICAL MEDICINE & INTERNATIONAL WATER MANAGEMENT INSTITUTE, HYDERABAD, INDIA

An evaluation of the situation at Hyderabad when the city sewage was not treated and used for irrigation of nearly 3,100 hectares of land downstream of the discharge river course and the quality issues are hereunder:

Table A7.3- 3 Effect of exposure to untreated sewage and partially treated sewage on Ascaris Lumbricoides, Hookworm, Heavy hookworm and Trichuris Trichiura infection at Hyderabad

Characteristic		Water quality, ova/liter	OR*1	95%CI	P
A. lumbricoides *2					
	River water	0	1.0		
	Partially treated wastewater	12	3.2	1.2-8.6	0.02
	Untreated wastewater	70	5.3	2.0-14	0.001
Hookworm*3					
	River water	0	1.0		
	Partially treated wastewater	15	0.7	0.4-1.1	0.11
	Untreated wastewater	76	3.5	2.2-5.5	<0.001
Hookworm (epg > 160)*4					
	River water	0	1.0		
	Partially treated wastewater	15	0.8	03-2.2	0.65
	Untreated wastewater	76	3.9	1.5-9.9	0.004
*T. trichiura**5					
	River water	0	1.0		
	Partially treated wastewater	0.3	0.6	02-2.5	0.53
	Untreated wastewater	4	5.6	1.8-18	0.003

*1 OR = odds ratio, CI = confidence interval: epg = eggs per gram (of feces).
*2 Controlled for age. sex. education, and household clustering,
*3 Controlled for age. education, caste, latrine presence, and household clustering.
*4 Controlled for age. sex. education, type of water supply, agricultural activities involved in. and household clustering.
*5 Controlled for sex. education, and household clustering.

Although this study was unable to provide conclusive evidence about the validity of the current WHO wastewater nematode guideline, the findings suggest that for A lumbricoides and T trichiura infection, the WHO nematode guideline of less than or equal to one ova per litre is appropriate but the nematode guideline of less than or equal to one per litre when exposed to children is too strict. No increased risk of hookworm infection was detected when wastewater with a mean concentration of

15 ova per litre was used, which would suggest that at least for the risk of hookworm infection, the WHO nematode guideline is too strict and a more lenient guideline can be set if hookworm species is the predominant ova in wastewater. However, more studies are needed to confirm this suggestion.

1.5 FINDINGS OF THE INSTITUTE OF PUBLIC HEALTH LAHORE AND INTERNATIONAL WATER MANAGEMENT INSTITUTE, LAHORE, PAKISTAN

The study was carried out around the town of Haroonabad a small town with about 80,000 inhabitants in the southern part of the Punjab Province in Pakistan. Around this town agricultural areas are irrigated with untreated urban wastewater for about 30 years for vegetables sold in the city. In the middle of this main site there is a colony and most farmers live here. There are two peri-urban settlements and all three settlements are connected with the municipal relative reliable water supply. There is an organized system for disposal of sewage water in a pond, either by drains or pipes or by carts. The farmers in the villages use canal or tube well water. This provides as ideal setting for a relative evaluation of farm workers from sewage farm and fresh water farm. The findings of incidence of diseases related to the practices are extracted hereunder:

Table A7.3- 4 Prevalence of diseases by exposure to wastewater with odds ratio and 95% confidence interval

Disease	Exposed		Unexposed		OR	96% CI
Diarrhea	11 7%	(23)	6.2%	(17)	2.00	1.04-3.85
Diarrtea complicated with fever	56%	(11)	1.8%	(5)	3.18	1. 09-9.31
Dysentery	0.5%	(1)	0		-	-
Skin problems	30%	(6)	5.8%	(16)	0.51	0.20-1.32
Nail problems	7 1%	(14)	2.2%	(6)	3.42	1.29-9.05
Typhoid	0		0.7%	(2)	-	-
Fever/cold	11 7%	(23)	11.7%	(32)	1.00	0.57 – 1.77
Total number of health questionnaires	197		274			

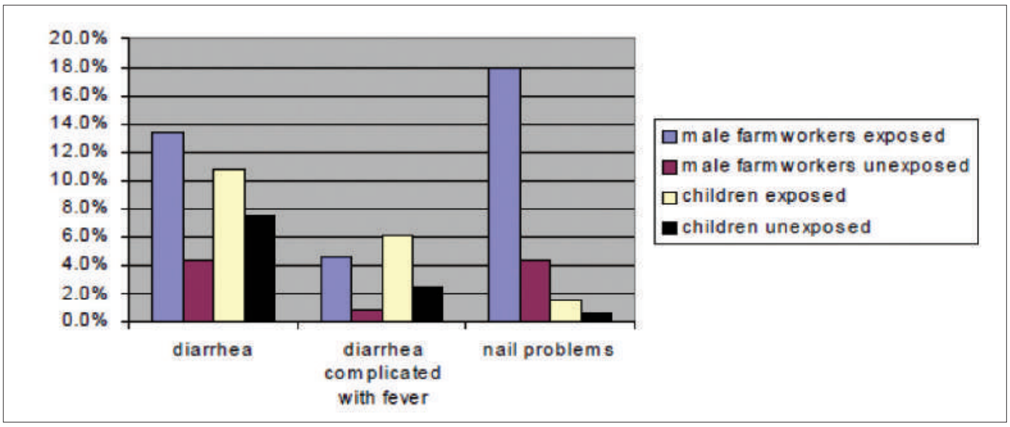


Figure A7.3- 1 Prevalence of diseases in male adult farm workers and children by exposure to wastewater

The classical finding of this study was the health guidelines for faecal coliform bacteria in wastewater from the WHO seem difficult to realize in the tropical climate of the Punjab Province, since canal water also exceeds the guidelines regularly. However, an appropriate form of treatment of wastewater for helminth eggs and faecal coliform bacteria before application to the fields is highly recommended. If treatment is not possible because of the high costs, other protective measures should be taken. Low cost interventions could include information on hygiene behaviour for farmers, wearing of shoes and gloves while working in wastewater irrigated fields, regular treatment of farmers and their families with anti-helminthic drugs and crop restrictions in wastewater irrigated fields.

1.6 FINDINGS OF THE UNIVERSITY OF JERUSALEM

Though this study covers an outdated period of early 20th century, the lessons there from are worth learning for posterity. Some the extracts from this study are shown hereunder:

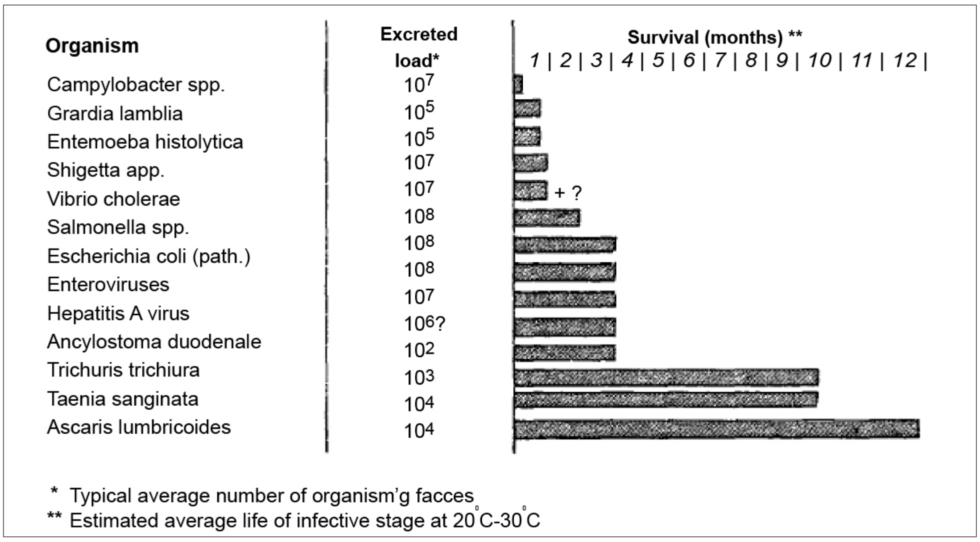


Figure A7.3- 2 Persistence of selected enteric pathogens in water, wastewater, soil and crops

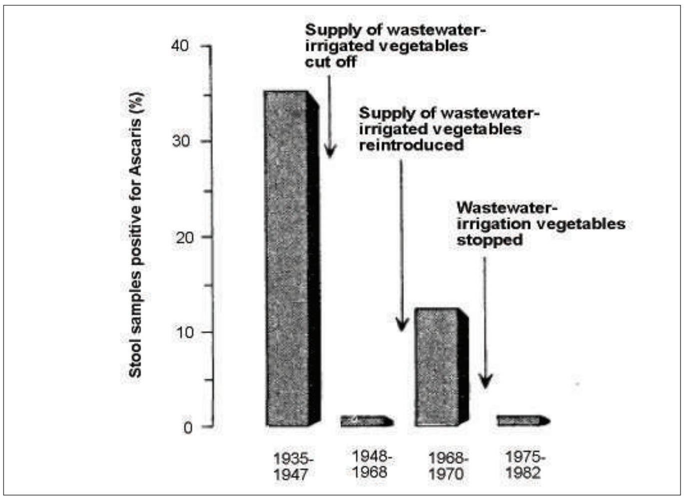


Figure A7.3- 3 Relationship between Ascaris-positive stool samples in the population of western Jerusalem and supply of vegetable and salad crops irrigated with raw wastewater in Jerusalem, 1935-1982

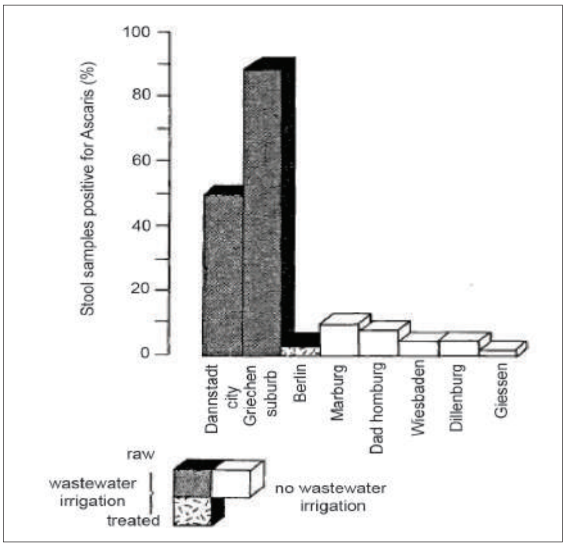


Figure A7.3- 4 Wastewater irrigation of vegetable and Ascaris prevalence in Darmstadt, Berlin and other German cities, 1949

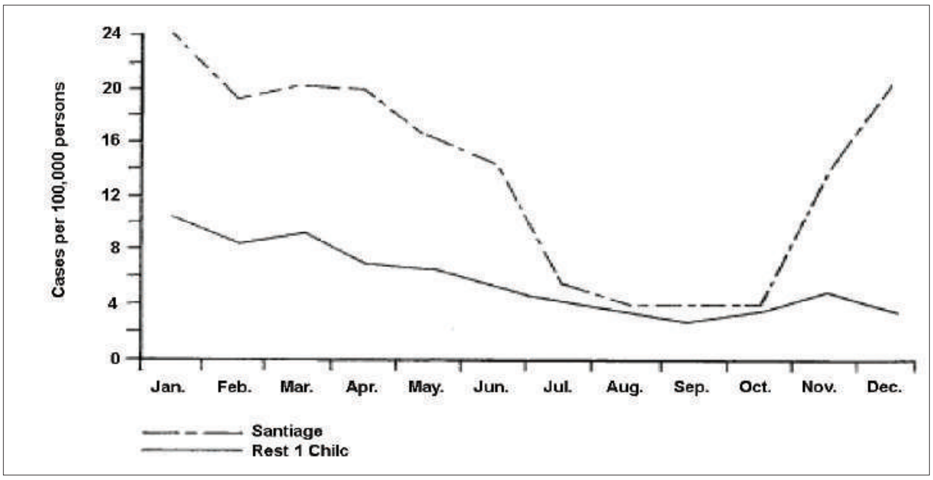


Figure A7.3- 5 Seasonal variation in typhoid fever cases in Santiago and the rest of Chile (average rates, 1977-1983)

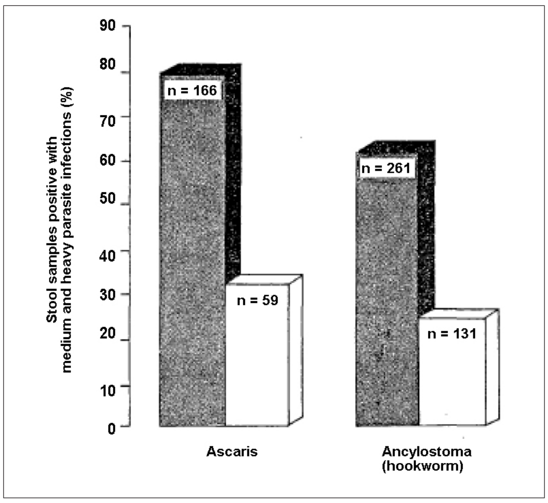


Figure A7.3- 6 Intensity of parasitic infection in sewage farm workers and controls in various regions of India

Their findings concluded that the WHO guidelines for crops eaten uncooked (and on pasture land where farm animals are grazed) that an effluent must contain one or fewer helminth eggs per litre, with a geometric mean of faecal coliforms not exceeding 1,000/100 ml can be readily achieved with low-cost, robust stabilization pond systems which are particularly suited to developing countries and high levels of pathogen removal can be achieved by such low-cost systems as shown hereunder.

Table A7.3- 5 WHO Recommended microbiological quality guidelines for wastewater use in agriculture

Category	Reuse conditions	Exposed group	Intrstinal Nematodes (b) (arithmetic Mean no. of Eggs per litre)	Faecal Coliforms (geometric Mean no. per 100ml) ©	Wastewater Treatment expected to Achieve the required microbiological quality
A	Irrigation of crops Likely to be eaten Uncooked, sports Fields, public Parks (d)	Workers, Consumers, Public	<1	< 1,000(d)	A series of tabilisation Ponds desigied to achieve The microbik equivalent indicated, or equivalent Treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees (e)	Workers	<1	No standard recommended	Retention in stabilisation ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localised Irrigation Of crops in category B If exposure of workers and the public Does not occur	None	Not applicable	Not applicable	Pre - treatment as required by the irrigation technology, but not less than primary sedimentation

A) In specific cases, local epidemiological, socio – cultural and environmertal factors should be taken into account, and guidelines modified accordingly
b) Ascaris and Trichuris species and hookworms
c) During the irrigation Period
d) A more stringent guidetion (<200 faecal coliforms /100ml) is appropriate for public lawns, such as hotel lawns, with the public may come into direct contact
e) In the case of fruit Lees , irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler

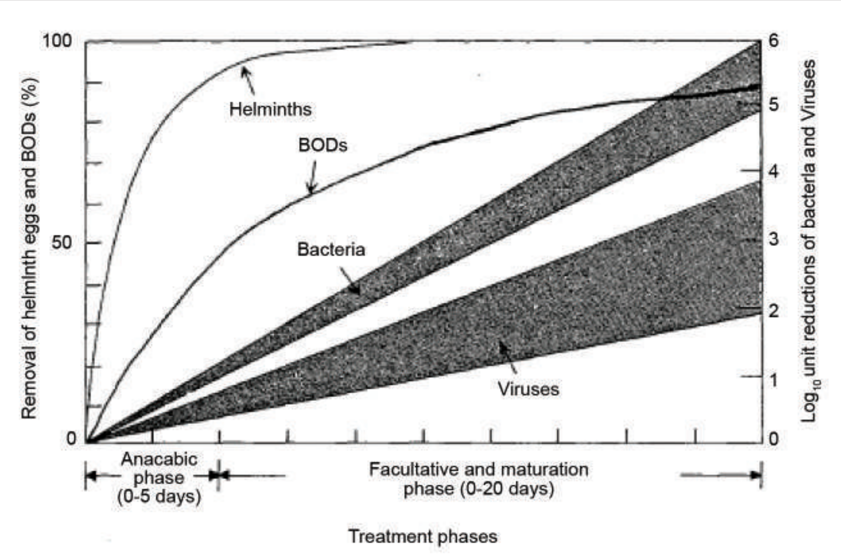


Figure A7.3- 7 Generalized removal curves for BOD, helminth eggs, excreted bacteria and viruses in waste stabilization ponds at temperatures above 20ºC

This study is of great relevance to India in appropriately treating the sewage of rural habitations by such natural pond systems without complicating sophisticated treatment technologies and ensuring the safe reuse of pond effluents for potential agriculture of non-edible crops. In 1970, an outbreak of cholera of some 200 cases occurred in Jerusalem and investigation provided a strong evidence that the main route of transmission was through the consumption of vegetables, including lettuce and cucumbers illegally irrigated with untreated sewage from Jerusalem and which villagers sold door-to-door throughout the city.

1.7 FINDINGS OF NEERI IN INDIA

A study of stool examinations of workers at five large sewage farms at Jaipur, Madras, Hyderabad, Trivandrum and Pune in India during 1973 revealed that out of 466 samples from sewage farm workers compared with 432 samples from a control population for the presence of Ancylostoma duodenale (hook worm), Ascaris lumbricoides (round worm), Trichuris trichiura (whip worm), Enterobius vermicularis (pin worm), Hymenolepis nana (dwarf tapeworm), Entamoeba histolytica and Giardia intestinalis, the incidence and multiplicity of infection was greater in sewage farm workers.

1.8 GUANAJUATO RIVER BASIN, MEXICO, SEWAGE RIGHTS ISSUES

The total sewage generated in Guanajuato's 46 municipalities is 567 MLD and could be used for agricultural of 20,000 ha. There is little or no expected impact on the nutrient value resulting from treatment, given that the nutrient requirements of the principal crop, alfalfa, would continue to be met even after treatment. Additionally, other sources of untreated urban wastewater enter the river down-stream of the treatment plant, entailing sufficiently high nutrient loads that little effect of treatment was perceptible to the farmers. The benefits from the waste solid sludge are being lost because these go directly to a landfill instead of being spread on agricultural land. The areas of further study are (a) the conditions required for wastewater markets to function, specifically commercial feasibility for irrigation use of treated vs. untreated wastewater, pricing and supply mechanisms, etc. (b) water rights conflicts, (c) hydrological impact of selling the treated water outside the sub-basin, (d) water quality assessment of the final use, e.g. at the farm level for irrigation and (e) accounting for the nutrients lost in the treatment process. This is a classical case of inter basin rights of treated sewage.

1.9 TYPHOID FEVER OUTBREAK IN SANTIAGO, CHILE

In 1978 and 1983, the outbreak of typhoid fever in Santiago has been reported due to the use of untreated sewage for the irrigation of 13,500 ha of tomatoes, lettuce, cabbage, celery and cauliflower that were consumed raw.

1.10 THE SULAIBIA REUSE FACILITY, KUWAIT

By far the world's largest of its kind, this facility extends the secondary sewage treatment beyond the conventional limits to nutrients removal, ultra filtration and reverse osmosis to a mammoth scale of 375 MLD with provision to expand to 600 MLD and when commissioned in 2004, it won 'Wastewater Project of the Year' in the 2005 Global Water Awards and described by the judges as a "Powerful statement of the future of water resources across the whole Middle East and North Africa region". The agriculture and industry demands were met till then by brackish ground water which slowly increased in its salt concentration and this project seeks to reverse it by substituting the agriculture and industry demands and aquifer recharge as well. The sale price for kilolitre was $ 0.60 for freshwater, 0.08 for secondary sewage and 0.15 for RO treated sewage it being colourless, clear and sparkling.

2 FARM FORESTRY

2.1 ABU DHABI

It is extensively practiced since 1976. The system, designed for 190 MLD is a dual distribution network for irrigation of 15,000 ha of urban forests, public gardens, trees, shrubs, and grassed areas along roadways. Secondary treated sewage is further provided tertiary treatment with rapid sand filtration, chlorination and ozonation. The infra-structure is painted purple and labelled to avoid any cross-connections.

2.2 EGYPT

Egypt exports some fruits and vegetables and hence use of treated sewage is impossible in this segment. However, considering the barren sandy terrain, the ministry promulgates a policy of "Treated sewage + sandy desert soil = Green Trees" and already 1,800 hectares are under cultivation with Eucalyptus, Mahogany, African Mahogany, Terminalia, Acacia and Neem trees with irrigation by modified flood or drip irrigation.

2.3 WOODBURN, OREGON, USA

In 1999, Woodburn was ready to discharge 6 MLD of treated sewage through micro-spray sprinklers into its newly developed 40 hectare poplar tree plantation. Sewage is treated using a biological nutrient removal aeration basin, a clarifier, sand filters, disinfection in an ultraviolet unit, chlorination and is pumped into a manifold system to the plantation through an underground piping system where micro-spray sprinklers are used and there is a 10 m offset to the property line where irrigation does not occur. In addition, the plantation is completely fenced and surrounded by signs warning intruders that treated effluent is being discharged. The irrigation system can be shut down in 2.5 hectare blocks, providing the capability for spot irrigation and operated from a microcomputer. The field was ploughed, levelled, and then grass and 10 cm cuttings were planted into the bare ground and when irrigated, they had a weed control problem and had to manually remove the grass from around the cuttings. This would condition the soil and there wouldn't be any weeds. Then they would plant the trees in the stream lines and rows without disturbing the soil. This way, grass was already growing and weeds were not a big problem. This natural system creates an attractive habitat for wildlife, provides 30 to 50% more evapotranspiration capacity than would a different crop of equal size, and provides a new source of revenue. Trees can be harvested every 7 to 12 years, and revenue from the sale of woodchips can be used to offset a portion of the capital and operation and maintenance costs of the system. The city plans to expand the facility every 5 years to match population growth. By 2020, the site will cover 140 hectares acres and will reuse 20 MLD of treated sewage.

2.4 WIDE BAY WATER CORPORATION, QUEENSLAND, AUSTRALIA

Wide Bay Water Corporation has come up with a winning solution for the dispersal of their treated sewage by recycling it onto a timber plantation of 300,000 trees on 220 hectares as of 2008 with expansion plans to a million trees by 2010 by a centrally controlled automated drip irrigation system from two sewage treatment plants. A 130 micron disc filtration technology was used to pre filter the treated sewage before putting into the drip irrigation. The monitoring consisted of a central base unit which is interfaced to a PC for ease of programming, viewing system status, water usage, graphing and SMS alarming, as well as graphical mapping and additional management programs. Currently, the base unit manages the RF communications to three, UHF radio linked field units which are installed at each of the main pumping sites. Additional sensors were installed to monitor water flow, pH and dam levels. The remote infield valve control and water meter monitoring was automated by Piccolo XR's. The Piccolo XR's utilize a low power licensed UHF radio, latching output technology and store & forward (repeater) communications. This combination allows low cost, yet simple and reliable communication to the remote fields. A wireless monitoring system was also installed at the site to record local environmental factors, such as a weather station to monitor temperature, humidity, solar radiation, wind speed, rainfall and ET. Soil moisture probes were installed at keys sites to monitor the effects of irrigation, localized rainfall, drainage and plant uptake in the soil profile. The plantation is stated to have won a Federal Government for Innovation in Irrigation, were both financial and environmental.

2.5 AL BIREH, PALESTINE

The sewage treatment facility is designed for 5.7 MLD with extended aeration followed by gravel media filtration for turbidity reduction, a chlorine-dosing unit calibrated to inject chlorine at a rate of 2 mg/l and 400 L vessel that retained the chlorinated water for 30 minutes. No fertilizer was applied in addition to the nutrients presents in the reclaimed wastewater. A nursery of 600 m^2 for annual cultivation of 80,000 seedlings of indigenous trees and cooked vegetables with irrigation system of micro-drippers was opted for. The eggplants were sterilized to ensure a safe distance of 50 cm from the drip lines. Two types of effluents are used being high quality effluent with drip irrigation and very high quality effluent with subsurface irrigation. The regulations, applications and achievements are shown hereunder.

Table A7.3- 6 Summary of Al-Bireh WWTP reclaimed water use achievements

Effluent Type	Regulation	Application	Achievements
High quality	BOD/TSS less than 20/30 mg/l, Faecal Coliform less than 1,000 MPN/100 ml	Orchard, olives, Ornamentals Grape stocks Processed vegetables Restricted area landscaping	High growth High yield
Very high quality	F.C non-detectable Effluent polishing	Cooked vegetables Nursery (eggplants)	High yield No contamination

Regular basis of the reclaimed water, soil and microbiological quality were tested. The test results show that the tertiary treatment generates reclaimed water suitable for unrestricted agriculture reuse application according to Israeli and US EPA guidelines. Crop quality tests showed that eggplants irrigated with reclaimed water were not contaminated with faecal coliform and intestinal viruses. In the nursery, seedling germination rates were high (>90%) and seedlings irrigated with the reclaimed water showed high vegetative growth. The nursery and Alfalfa plantation are shown hereunder.

Figure A7.3- 8 Nursery and Alfalfa plantation at Al-Bireh facility

2.6 SEWAGE SUSTAINED VERMICOMPOSTING

In the matter of producing vermin compost for tree plantations, a study by University of Agricultural Sciences, Dharwad, Karnataka found that sewage could be used in vermicomposting provided its details with respect to composition of toxic substances are known.

3 HORTICULTURE

3.1 EL PASO TEXAS, USA

Because of declining reserves of fresh groundwater and an uncertain supply of surface water, the El Paso Water Utilities has adopted a strategy to curtail irrigation use of potable water by substituting reclaimed municipal effluent. This strategy has been implemented in stages, starting with irrigation of a county-operated golf course using secondary effluent from the Haskell Plant, and a city-owned golf course with tertiary treated effluent from the Fred Hervey Plant. The reuse projects were expanded to use secondary effluent from the Northwest Plant to irrigate a private golf course, municipal parks, and school grounds. Reclaimed water use from the Haskell Plant is also expanded to include parks and school grounds. In these cases, the salinity of reclaimed water ranges from 680 to 1,200 ppm as total dissolved salts (TDS) depending on the plant. Reclaimed water from the Hervey Plant has the lowest salinity (680 ppm), and a large portion of it is now being injected into an aquifer for recovery as potable water.

3.2 DURBIN CREEK (WESTERN CAROLINA)

The Durbin Creek Wastewater Treatment Facility located near Fountain Inn, South Carolina, discharges to Durbin Creek, a relatively small tributary of the Enoree River. Average flow from the Durbin Creek Plant is 5,200 m^3/day with a peak flow of 22,700 m3/day during storm events. The plant is permitted for an average flow of 12,500 m^3/day. The Durbin Creek plant is located on an 81 ha site, half of which is wooded and the remaining half cleared for land application of bio solids. Hay is harvested in the application fields. Much of the land surrounding the plant site is used as a pasture and for hay production without the benefit of bio solids applications.

3.3 CHANDIGARH

Chandigarh is perhaps the first city to have developed infrastructure with pipe lines for a tertiary treatment plant to cover the horticulture needs of its vast 1,500 hectares by nearly 90 MLD out of which 45 MLD capacity is in place and another 45 MLD is under completion.

3.4 DELHI

With the sewage volume at about 4,400 MLD, planned reuse of treated sewage for designated institutional centres have been put in place as (a) Luytens at 90 MLD, (b) Japanese park at 35 MLD, (c) minor irrigation department at 350 MLD totalling 475 MLD.

4 TOILET FLUSHING

4.1 JAPAN

Because of the country's density and limited water resources, water reclamation and reuse programs are not new to Japan. By 1995, 89.6% of cities larger than 50,000 people were sewered, and 72% of the inhabitants of these cities were served with a sewage collection system. Therefore, buildings being retrofitted for flush toilets and the construction of new buildings offer excellent opportunities for reuse. Initially, the country's reuse program provided reclaimed water to multi-family, commercial, and school buildings, with a reclamation plant treating all of the wastewater for use in toilet flushing and other incidental non-potable purposes. Later, municipal treatment works and reclaimed water systems were used together, as part of a dual system, providing more effective and economical treatment than individual reclamation facilities.

In 1998, reclaimed water use in Japan was 130 Mm^3/year, with distribution as shown in Table A7.1- 7. At that time, about 40% of the reclaimed water was being distributed in dual systems. Of this more than 1/3 was being used for toilet flushing, and about 15% each for urban irrigation and cleansing. A wide variety of buildings were fitted for reclaimed water use, with schools and office buildings being most numerous. In Tokyo, the use of reclaimed water is mandated in all new buildings that have floor area larger than 30,000 m^2. Japan offers a very good reuse model for cities in developing countries because its historical usage is directly related to meeting urban water needs rather than only agricultural irrigation requirements. In addition, the reclaimed water quality requirements in Japan are different from the U.S., as they are more stringent for coliform counts for unrestricted use, while being less restrictive for other applications.

Examples of large area water reclamation systems in Japan can be found in Chiba Prefecture, Kobe City, and Fukuoka City. Outside the city limits of each of these urban areas, streams have been augmented, parks and agricultural areas have been irrigated, and greenbelts established with reclaimed water. The price of reclaimed water in these cities ranges from $0.83/m^3 for residential use to $2.99/m^3 for business and other uses. This compares with a potable water price range of $1.08 to $3.99/m^3 (USEPA, 2004).

Table A7.3- 7 Uses of reclaimed water in Japan

Use	Percent	Mm^3/year
Environmental Water	54%	63.9
Agricultural Irrigation	13%	15.9
Snow Melting	13%	15.3
Industrial Water	11%	12.6
Cleansing Water	9%	11.2

4.2 INDIAN SCENARIO

Reuse of treated sewage for toilet flush has been recognized as a means of water conservation especially in high rise apartments, office complexes, multiplexes, etc. Generally, this flushing consumes about 3 to 4 flushes per day per person and its volume will be about 20 to 30 litres daily. When a 135 lpcd is supplied, by reusing these 30 litres per day per person, we still have to deal with 110 litres per capita daily and this has to be disposed outside the house. But then, the entire 135 lpcd has to be treated before we can recover the 30 lpcd for toilet flush. Alternatively, there has to be twin sewerage within the house so that milder grey water can be separately collected and treated with less strenuous effort before reuse for flush. Such a system is least advisable especially in modern urban habitations where the potential dangers of cross connection in plumbing and nuisance value of dealing with a STP within the dwelling boundary are matters of great reluctance either to be enforced or to be embraced by the occupants. That brings matters to two options namely, condominiums to have such a facility as a centralized option for the entire condominium or a habitation to have a dual pipeline from the STP back all the way to the dwellings supplying such toilet flush grade water.

Obviously, such a new dual pipeline all over the habitation is almost next to impossible to be designed, implemented and attended to in O&M because, here is a system that will deliver as little as 30 lpcd and its design as a gravity pipeline discharging in short stints for rare timings in a 24 hours cycle calls for a pressurized system. The net result of all this is the fact that these are possible only in the case of condominiums and entirely new layouts. In India, the rule of culture far more outweighs the practicalities and culturally, no one can be forced to avail a water supply originating from the refuse of the neighbour and receive it into his habitation. The Karnataka State Pollution Control Board (KSPCB) has laid down that new layouts shall provide their own STPs by new urban standards juxtaposed with the erstwhile standards prescribed by MoEF/CPCB, and followed by KSPCB as well. An extract of the same along with remarks thereon is furnished hereunder.

Table A7.3- 8 Discharge standards for surface water Vs urban reuse standards by KSPCB

No	Parameters as per BIS	Values as per BIS	Proposed by KSPCB
1	pH	6.5-8.5	6.0 -9.0
2	BOD	< 20	< 10
3	TSS	< 30	Not specified
4	Oil & Grease	<10	Not specified
5	Turbidity	Not specified	< 2 NTU
6	E. Coli	Not specified	NIL
7	Res. Chlorine	Not specified	> 1 PPM
All Units except pH and NTU in mg/l			

Considering the E coli issue alone, total coliform is not addressed and thus, enteric viruses which are specific for water borne epidemics through unintentional portals of entry are left out. Thus total coliforms have to be not detected. The technology for this in the condominium scale can be the ultrafiltration membranes which can function under low pressure and trap the viruses as shown in Figure A7.3- 9 overleaf.

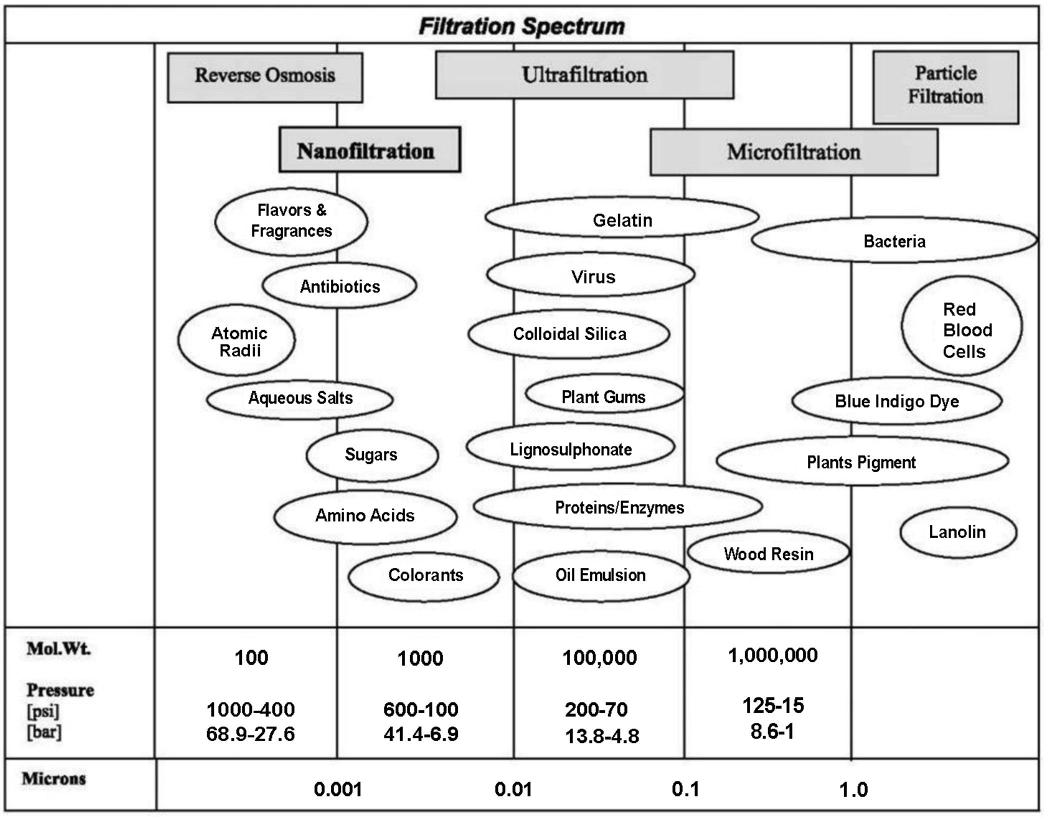


Figure A7.3- 9 Membrane filtration spectrum

5 INDUSTRIAL AND COMMERCIAL

5.1 SAKAIHAMA TREATED WASTEWATER SUPPLY PROJECT, JAPAN

To ensure sustainable water supply in Sakaihama district advanced treatment process was established at 3 STPs. Two types of advanced treatment processes are applied to the effluent obtained from step-feed multistage biological nitrogen removal facilities: 33,000 m^3/day of water is produced using fibre filtration to be used for purposes (cooling water in large industries) in which there is no contact with the human and 1,000 m3/day of water is produced using ozonation for uses in which human contact is expected. Reclaimed water is supplied to large-scale company groups, and small and medium-sized enterprises which include National Soccer Training Centre (NTC), disaster prevention base, Sakai solid waste disposal plant, and local industries. In these facilities, the reclaimed water is used for variety of purposes. In large-scale industries, it is mainly used for cooling purposes, and in small industries it is used for toilet flushing and watering plants through sprinkler. The use also includes sprinkling water over the football ground, and for fire extinguishing in emergency cases. Some hydrants are installed on transmission pipelines for this purpose.

Sakai city depends on water supplies from Osaka Prefecture, for which the main source is Yodogawa River. Considering increase in demand, it became important to secure additional water resources. To ensure sustainable water supply in Sakaihama district (covering area of about 300 ha) and to restore the environment in existing rivers, reuse of treated wastewater (advanced level) came into practice.

For this purpose, advanced treatment process was established at 3 STPs. To achieve the objectives, two types of advanced treatment processes are applied: 33,000 m^3/day of water is produced using fibre filtration to be used for purposes (cooling water in large industries) in which there is no contact with the human and 1,000 m^3/day of water is produced using ozonation for uses in which human contact is expected.

The facilities used for supplying treated water in this project are as follows:

- One water supply pumping station
- 2 satellite treatment plants (ozonation)
- About 12 km of transmission pipelines

Reclaimed water is supplied to large-scale company groups, and small and medium-sized enterprises which include National Soccer Training Centre (NTC), disaster prevention base, Sakai solid waste disposal plant, and local industries. In these facilities, the reclaimed water is used for variety of purposes. In large-scale industries, it is mainly used for cooling purposes, and in small industries it is used for toilet flushing and watering plants through sprinkler. The use also includes sprinkling water over the football ground, and for fire extinguishing in emergency cases. Some hydrants are installed on transmission pipelines for this purpose.

Table A7.3- 9 Treated wastewater supply

User	Quantity (m^3/day)	Proposed by KSPCB
Sakai National Training Centre (NTC)	400	Sprinkling on football ground
Disaster prevention base	500	Sprinkling
Solid waste disposal plant	20	Sprinkling
Local industry business cluster	80	Toilet flushing, Sprinkling
Large companies	33,000	Coolant
Total	34,000	

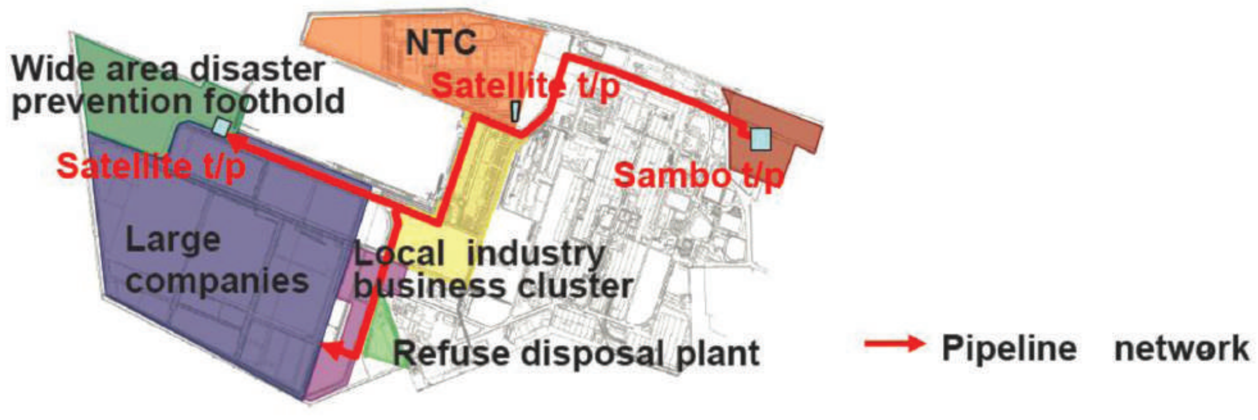


Figure A7.3- 10 Sakaihama treated wastewater reuse scheme

Table A7.3- 10 Quality of supplied treated wastewater

Parameter	Fibre filtration water	Ozonation water
E. Coli	-	Not detected
pH	5.8-8.6	5.8-8.6
Odour	Not unpleasant	Not unpleasant
Residual chlorine	-	Maintained
Appearance	Not unpleasant	Not unpleasant

Source: http://water.city.sakai.lg.jp/torikumi/file/konwakai4-03.pdf

5.2 BETHLEHEM STEEL MILLS, USA

Perhaps the first industrial use of treated sewage for industrial purpose was initiated here by Abel Wolman. One of the largest reclaimed water user is the Bethlehem Steel Sparrows Point steel mill in Baltimore. For many years, the plant used about 100 MGD of reclaimed water from the Back River Wastewater Treatment Plant. The reclaimed water was used for contact cooling of steel and for other process purposes in the mill.

5.3 HAWAII

The Sewage Treatment facility produces two grades of high-quality recycled water whereby the R-1 water is used for landscape, agriculture, and golf course irrigation, R-2 water which is the reverse osmosis permeate is used for industrial purposes such as boiler feed water and ultra-pure process water. The switching to RO water with only 1 ppm of silica turned into a savings for industrial users, as the ground water arising from filtering of rain water through the lava structure in the ground it picks up between 60 to 70 ppm of silica which scales up the boilers costing the power

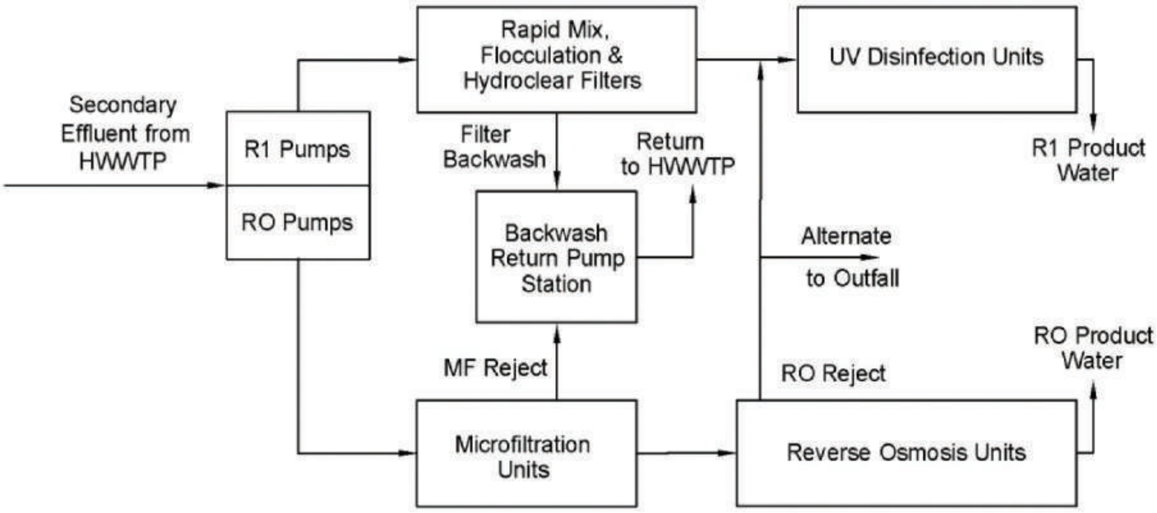


Figure A7.3- 11 Hawaii sewage reuse facility schematic

5.4 DURBAN, SOUTH AFRICA

Durban Metro experienced considerable pressure to provide basic services, including water, to its growing domestic and industrial customers. The natural water resources were not sufficient to meet the increasing demand. As a solution, the KwaZulu Natal pilot project was launched to install and operate a new affordable distribution network for the townships under successful tri-sector partnership (public-private-NGOs). Durban Metro decided to go further by implementing a public-private partnership water reuse project: the Durban Water Recycling project (DWR). The project included treating primary sewage and re-purifying the reclaimed water to the capacity of 47,500 m^3/d. As a result, about 7% of Durban's wastewater is reclaimed as high quality water supplied to the Mondi Paper Mill and SAPREF Refinery at a cost 25% lower than potable water instead of being discharged to the sea. The purification of the wastewater is handled by the newly refurbished wastewater treatment plant applying tertiary treatment using dual media filtration, ozonation, granulated carbon filters and chlorination.

The municipal authority, called "Durban Metro", experienced a dramatic population increase and customers increased from 1 million to nearly 3 million due to the incorporation of 30 local authorities and surrounding townships into the metropolitan area. As a result, Durban Metro experienced considerable pressure to provide basic services to its growing domestic customers, among whom 26% lived in the townships and relied on standpipes for clean drinking water. Moreover, several industries located in this area, such as Mondi Paper Mill and SAPREF refinery needed continuous supply of high quality water for process and cooling purposes. Average rainfall in the region is 200 mm/year, and suffers from periodic droughts. Hence, the natural water resources are not sufficient to meet the increasing demand.

In order to develop a workable solution to the water and sanitation problems, the KwaZulu Natal pilot project was launched as a part of the Worldwide “Business Partners for Development” (BPD) programme created by the World Bank in 1998. This project allowed Durban Metro to install and operate a new affordable distribution network for the townships through innovations in service delivery and tariff structures – first 200 l/day of water was free for domestic customers. This was the result of a successful tri-sector partnership (public-private-NGOs).

Considering the success of this first initiative, Durban Metro decided to go further by implementing a public-private partnership water reuse project: the Durban Water Recycling project (DWR). The project included treating primary sewage and re-purifying the reclaimed water to the capacity of 47,500 m^3/d. As a result, about 7% of Durban’s wastewater is reclaimed as high quality water supplied to the Mondi Paper Mill and SAPREF Refinery at a cost 25% lower than potable water instead of being discharged to the sea. The purification of the wastewater is handled by the newly refurbished wastewater treatment plant which includes tertiary treatment including dual media filtration, ozonation, granulated carbon filters and chlorination. (Mediterranean Wastewater Reuse Working Group, 2007).

6 FISH CULTURE

6.1 HANOI, VIETNAM

Hanoi, the capital of Vietnam has a major system of wastewater reuse involving vegetables, rice as well as fish in low lying Tranh Tri district which lies to the south of the city. Wastewater and storm water are discharged untreated, to four small rivers which play a dual role: drainage of wastewater from the city; and wastewater supply for reuse in agriculture and aquaculture. The system of waste-water reuse has largely been developed by the district farmers and local community over the past 40 years. After 1960s, land use stabilized into vegetable cultivation on higher land, rice/fish cultivation on medium level land, and year-round pond fish culture on deeper land adjacent to the main irrigation and drainage canals. Wastewater-fed aquaculture became the major occupation of cooperatives with easy access to wastewater.

The local aquaculture research institute provided seed of exotic fish species, and fish hatcheries and nurseries were developed by farmers. Farmers also learnt how to regulate the introduction of waste-water to produce fish. The major species are silver carp, rohu, and tilapia. Yields of fish of 3-8 tonnes/ha are harvested annually, lower yields from rice/fish and higher from pond culture.

Hanoi, the capital of Vietnam has a major system of wastewater reuse involving vegetables, rice as well as fish in low lying Tranh Tri district which lies to the south of the city. Produce from the reuse system provides a significant part of the diet of the city’s people.

Wastewater and storm water are discharged untreated, about 320,000 m^3/day, to four small rivers that play a dual role: drainage of wastewater from the city; and wastewater supply for reuse in agriculture and aquaculture. In 2009, only one wastewater treatment plant was reported to be operational and 3 treatment plants under construction. About one-third of the city is sewered. The wastewater is 75-80% domestic and 20-25% industrial.

Source: UNEP webpage: http://www.unep.or.jp/ietc/publications/techpublications/techpub 15/2-9/9-3-1.asp

Figure A7.3- 12 Raw wastewater being pumped into wastewater-fed fish ponds in Hanoi

The system of wastewater reuse has largely been developed by the district farmers and local community over the past 30 years. Before 1960 the area was a sparsely populated swamp where rice was grown but with low yields and frequent flooding. Following the formation of cooperatives in 1967, land use stabilized into vegetable cultivation on higher land, rice/fish cultivation on medium level land, and year-round pond fish culture on deeper land adjacent to the main irrigation and drainage canals. Wastewater-fed aquaculture became the major occupation of 6 cooperatives with easy access to wastewater and a minor occupation of 10 others out of the total of 25 district communes.

The local aquaculture research institute provided seed of exotic fish species, and fish hatcheries and nurseries were developed by farmers. Farmers also learned how to regulate the introduction of wastewater to produce fish. The major species are silver carp, rohu, and tilapia. Rohu and Tilapia has been the most popular species in recent years. Yields of fish of 3-8 tonnes/ha are harvested annually, lower yields from rice/fish and higher from pond culture.

An on-going project to improve the wastewater and drainage system of Hanoi has had only marginal impact on the wastewater-fed fish ponds through loss of a small area to construct a reservoir. A new industrial development area is being established outside the drainage area of the district so fish being cultured on city wastewater should be relatively free of contamination. However, the change in land use policy since the 1980s from cooperative to individual household management has adversely affected wastewater fed aquaculture. Over the decade since 1985 the area of wastewater fed aquaculture (essentially the rice/fish system) has declined in area by 36% from a total of 750 to 480 ha.

6.2 BANGLADESH

In Bangladesh, the development of the first duckweed, conventional wastewater treatment system began, in 1989 at the KHC in Mirzapur. The facility consists of one duckweed covered, 0.7 ha plug flow lagoon constructed as a 500 m long serpentine channel with seven bends. It is fed with a mixture of hospital, school and domestic wastewater from some 2,350 people. The plug flow wastewater-fed duckweed pond is preceded by a 0.2 ha anaerobic pond with a hydraulic retention time (HRT) of 2-4 days. HRT in the plug flow pond is estimated as 21-23 days. Duckweed harvested from the 0.7 ha wastewater treatment pond is fed daily to three adjacent fish ponds, each 0.2 ha.

The duckweed removes nutrients and the plant cover suppresses phytoplankton growth. Average removal efficiencies for BOD5, N and P, and faecal coliforms are 90-97%, 74-77%, and 99.9%, respectively. Effluent turbidity is always below 12 NTU. The effluent is used to top up the water level of the adjacent fish ponds. The wastewater treatment system produces from 220 to 400 tonnes fresh weight duckweed/ha/year (about 17 to 31 tonnes dry weight/ha/year). The fish ponds are stocked with Indian major carps (rohu, mrigal and catla), Chinese carps (grass carp and silver carp), and common carp. Fish production varies from 10 to 15 tonnes/ha/year, yield being relatively high because of frequent harvesting and addition of other feed besides duckweed such as oil cake and rice bran.
Duckweed based wastewater treatment and reuse, Mirzapur

PRISM (Project in Agriculture, Rural Industry Science and Medicine), a non-government organization (NGO) in Bangladesh, has carried out a research and development programme with duckweed based, wastewater treatment and reuse through fish culture. There are systems fed with conventional wastewater or sewage in three districts, the largest being at the Kumudini Hospital Complex (KHC), Mirzapur, Tangail district.

Source: UNEP webpage; http://www.unep.or.jp/ietc/publications/techpublications/techpub 15/2-9/9-3-3.asp

Figure A7.3- 13 A duckweed based wastewater treatment system at Mirzapur, Bangladesh

The development of the first duckweed, conventional wastewater treatment system began, in 1989 at the KHC in Mirzapur. The facility consists of one duckweed covered, 0.7 ha plug flow lagoon constructed as a 500 m long serpentine channel with seven bends. It is fed with a mixture of hospital, school and domestic wastewater from some 2,350 people (per capita estimated sewage generation 100 l/day). The plug flow wastewater-fed duckweed pond is preceded by a 0.2 ha anaerobic pond with a hydraulic retention time (HRT) of 2-4 days. HRT in the plug flow pond is estimated at 21-23 days. Duckweed harvested from the 0.7 ha wastewater treatment pond is fed daily to three adjacent fish ponds, each 0.2 ha.

The duckweed removes nutrients and the plant cover suppresses phytoplankton growth. Average removal efficiencies for BOD5, N and P, and faecal coliforms are 90-97%, 74-77%, and 99.9%, respectively. Effluent turbidity is always below 12 NTU. The effluent is used to top up the water level of the adjacent fish ponds.

The wastewater treatment system produces from 220 to 400 tonnes fresh weight duckweed/ha/year (about 17 to 31 tonnes dry weight/ha/year). The fish ponds are stocked with a polyculture of Indian major carps (rohu, mrigal and catla), Chinese carps (grass carp and silver carp), and common carp. Tilapia is not stocked, but fingerlings enter the ponds incidentally. Fish production varies from 10 to 15 tonnes/ha/year, about 40% of which is tilapia. Fish yields are relatively high because of frequent harvesting and addition of other feed besides duckweed such as oil cake and rice bran.

Over the last two years the wastewater-fed duckweed-fish system has generated a net profit of almost US$3,000/ha/year. This is about three times that of the major agricultural crop of the area, rice.

7 GROUNDWATER RECHARGE

7.1 SOIL AQUIFER TREATMENT

7.1.1 DESCRIPTION

Soil aquifer treatment (SAT) makes use of the natural chemical and biological processes within soil (unsaturated zone) to "polish" treated sewage. Soil aquifer treatment is most commonly used to remove residual organic material, nitrogen and pathogenic microorganisms.

The most common SAT solution is infiltration ponds. After conventional sewage treatment, the water is discharged into infiltration ponds and then reused via recovery wells. Infiltration ponds are used in cycles: Sewage is treated during wet cycle; sludge is dried and solids are removed during dry cycle.

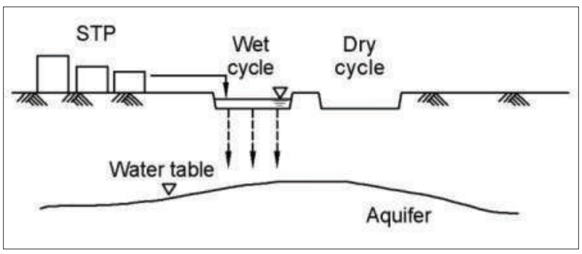


Figure A7.3- 14 Soil aquifer treatment

7.1.2 APPLICATION EXAMPLES

a. Sweetwater SAT Treatment Plant in Tucson, Arizona, USA

It was built in year 1989, and consists of 8 recharge basins and 2 wetland basins. The total size is 17 ha, the design percolation rate is 70 cm/day and the amount of water reclaimed per year is 1,233.5 m3 per year. The area is used also for wildlife protection.

Figure A7.3- 15 Sweetwater SAT treatment plant, Tucson, AZ

b. Rio Hondo Spreading Grounds, Montebello Forebay, California, USA

Table A7.3- 11 Site characteristics

Rio Hondo	
Year when initially started using	1937/38
Size (ha)	230
# of Sub-Basins	20
Percolation Rate (m^3/sec)	11
Water Storage (103 m^3)	4,557

Source: http://www.wrd.org/engineering/groundwater-replenishment-spreading-grounds.php [Accessed 20 Oct. 2011]

Figure A7.3- 16 Rio Hondo Spreading Grounds, Montebello Forebay, CA

c. Phoenix, Arizona, USA

d. Orange County, California, USA

e. Israel

7.1.3 ADVANTAGES AND DISADVANTAGES

The advantages and disadvantages of this process are as follows:

a. Advantages

i. No requirement of energy and mechanical equipment for aeration
ii. Natural process and virtually maintenance free
iii. System can provide renewed water sources
iv. It protects against sea water intrusion, when practiced in coastal areas.
v. It helps in the protection of wildlife

b. Disadvantages

i. Large areas of land are used
ii. Odours, mosquitoes and flies can be a problem if they are not properly controlled

7.1.4 TYPICAL DESIGN PARAMETERS

Table A7.3- 12 Typical design parameters

Parameter	Value
Sewage loading rate	<15cm/d
Total nitrogen loadings	56 to 67 kg/ha/d
BOD to Nitrogen ratio	>3:1
BOD removal	around 90%
SS in the percolate	1 to 2 mg/L

Source: Sherwood C. Reed, Ronald W. Crites, E. Joe Middlebrooks, 2006

Table A7.3- 13 Hydraulic loading cycles for soil aquifer treatment

Loading Objective	Wastewater Applied	Season	Application Period (d)	Drying/Resting Period (d)
Maximize infiltration rates	Primary	Summer	1-2	6-7
		Winter	1-2	7-12
	Secondary	Summer	2-3	5-7
		Winter	1-3	6-10
Maximize nitrification	Primary	Summer	1-2	6-9
		Winter	1-2	7-13
	Secondary	Summer	2-3	5-6
		Winter	1-3	6-10
Maximize nitrogen removal	Primary	Summer	1-2	10-13
		Winter	1-2	13-20
	Secondary.	Summer	6-7	9-12
		Winter	9-12	12-16

Source: Adapted from Crites, R.W. and Tchobanoglous, G., Small and Decentralized Wastewater Management Systems, McGraw-Hill. New York. 1998.

Important considerations related to design and maintenance of this process is as follows

A. The minimum pre-treatment is secondary or the equivalent. For small systems, a short detention-time pond is recommended. If facultative or stabilization ponds are to be used, it is recommended that a constructed wetland system be used between the pond and the infiltration point to reduce TSS levels.

B. High loadings of BOD and TSS from industrial activity will require careful management to avoid odour production and to avoid plugging of the soil.

7.1.5 APPLICABILITY

Soil aquifer treatment is an effective process for polishing BOD, TSS, and pathogen removal. Removal of phosphorus and metals depends on travel distance and soil texture. Nitrogen removal can be significant when systems are managed for that objective: ammonia is retained in the soil long enough for biological conversion through ammonia adsorption and the absence of available oxygen and the existence of carbon sources facilitates denitrification. Pathogens are filtered out by the soil and adsorbed onto clay particles and organic matter.

7.1.6 GUIDING PRINCIPLES

A. This technology is used as a method of conserving sewage without wasting it.

B. This technology can be considered where area is available.

C. In coastal cities where ground water is used, this can be a long term solution against sea water intrusion. This requires a separate study needs to be carried out at each location before its application in the field.

7.2 ORLANDO AND ORANGE COUNTY, FLORIDA, USA

The City of Orlando and Orange County, Florida, were mandated to cease discharge of effluent into Shingle Creek, which flows into Lake Tohopekaliga. To overcome this issue, a reuse project was constructed in West Orange and Southeast Lake counties along a high, dry, and sandy area known as the Lake Wales Ridge, called Water Conserv II. Water Conserv II is the largest reuse project of its type in the world, a combination of agricultural irrigation and rapid infiltration basins (RIBs). It is also the first reuse project in Florida to irrigate crops produced for human consumption with reclaimed water. Water Conserv II began operation on December 1, 1986. The project is designed for average flows of 50 mgd (2,190 l/s) and can handle peak flows of 75 mgd (3,285 l/s). Approximately 60% of the daily flows are used for irrigation, and the remaining ± 40% is discharged to the RIBs for recharge of the Floridan aquifer.

Citrus growers participating in Water Conserv II benefit from using reclaimed water. Citrus produced for fresh fruit or processing can be irrigated by using a direct contact method. Growers are provided reclaimed water 24 hours per day, 7 days per week at pressures suitable for micro-sprinkler or impact sprinkler irrigation. By providing reclaimed water at pressures suitable for irrigation, costs for the installation, operation, and maintenance of a pumping system can be eliminated.

Water Conserv II: City of Orlando and Orange County, Florida, US

As a result of a court decision in 1979, the City of Orlando and Orange County, Florida, were mandated to cease discharge of their effluent into Shingle Creek, which flows into Lake Tohopekaliga, by March 1988. To overcome this issue, the decision was made to construct a reuse project in West Orange and Southeast Lake counties along a high, dry, and sandy area known as the Lake Wales Ridge, and the project was named Water Conserv II. The primary use of the reclaimed water would be for agricultural irrigation. Daily flows not needed for irrigation would be distributed into rapid infiltration basins (RIBs) for recharge of the Floridan aquifer.

Water Conserv II is the largest reuse project of its type in the world, a combination of agricultural irrigation and RIBs. It is also the first reuse project in Florida permitted by the Florida Department of Environmental Protection to irrigate crops produced for human consumption with reclaimed water. The project is best described as “a cooperative reuse project by the City of Orlando, Orange County, and the agricultural community.”

The project is designed for average flows of 50 mgd (2,190 l/s) and can handle peak flows of 75 mgd (3,285 l/s). Approximately 60% of the daily flows are used for irrigation, and the remaining ±40% is discharged to the RIBs for recharge of the Floridan aquifer. Water Conserv II began operation on December 1, 1986.

At first, citrus growers were reluctant to sign up for reclaimed water being afraid of potential damage to their crops and land from the use of the reclaimed water. Study was carried out on the use of reclaimed water as an irrigation source for citrus. Later on, the Mid Florida Citrus Foundation (MFCF), a non-profit organization was created for conducting research on citrus and deciduous fruit and nut crops. Goals of the MFCF are to develop management practices that will allow growers in the northern citrus area to re-establish citrus and grow it profitably, provide a safe and clean environment, find solutions to challenges facing citrus growers, and promote urban and rural cooperation. All research conducted by the MFCF is located within the Water Conserv II service area. Reclaimed water is used on 163 of the 168 acres of research. MFCF research work began in 1987.

Research results to date have been positive. The benefits of irrigating with reclaimed water have been consistently demonstrated through research since 1987. Citrus on ridge (sandy, well drained) soils respond well to irrigation with reclaimed water. No significant problems have resulted from the use of reclaimed water. Tree condition and size, crop size, and soil and leaf mineral aspects of citrus trees irrigated with reclaimed water are typically as good as, if not better than, groves irrigated with well water. Fruit quality from groves irrigated with reclaimed water was similar to groves irrigated with well water. The levels of boron and phosphorous required in the soil for good citrus production are present in adequate amounts in reclaimed water. Thus, boron and phosphorous can be eliminated from the fertilizer program. Reclaimed water maintains soil pH within the recommended range; therefore, lime no longer needs to be applied.

Citrus growers participating in Water Conserv II benefit from using reclaimed water. Citrus produced for fresh fruit or processing can be irrigated by using a direct contact method. Growers are provided reclaimed water 24 hours per day, 7 days per week at pressures suitable for micro-sprinkler or impact sprinkler irrigation. At present, local water management districts have issued no restrictions for the use of reclaimed water for irrigation of citrus. By providing reclaimed water at pressures suitable for irrigation, costs for the installation, operation, and maintenance of a pumping system can be eliminated. This means a savings of $317 per hectare per year. Citrus growers have also realized increased crop yields of 10 to 30% and increased tree growth of up to 400%.

The increase is not due to the reclaimed water itself, but the availability of the water in the soil for the tree to absorb. Growers are maintaining higher soil moisture levels.

Citrus growers also benefit from enhanced freeze protection capabilities. The project is able to supply enough water to each grower to protect his or her entire production area. Freeze flows are more than 8 times higher than normal daily flows. It is very costly to the City and County to provide these flows (operating costs average $15,000 to $20,000 per night of operation), but they feel it is well worth the cost. If growers were to be frozen out, the project would lose its customer base. Sources of water to meet freeze flow demands include normal daily flows of 30 to 35 MGD (1,310 to 1,530 l/s), 38 million gallons of stored water (143,850 m^3), 80 MGD (3,500 l/s) from twenty-five 16-inch diameter wells, and, if needed, 20 MGD (880 l/s) of potable water from the Orlando Utilities Commission.

Water Conserv II is a success story. University of Florida researchers and extension personnel are delighted with research results to date. Citrus growers sing the praises of reclaimed water irrigation. The Floridan aquifer is being protected and recharged. Area residents view the project as a friendly neighbour and protector of the rural country atmosphere (USEPA, 2004).

7.3 PHOENIX (ARIZONA), USA

Water reclamation and reuse have become an important part of Phoenix Water Services Department's operational strategy. In 2001, Cave Creek Reclaimed Water Reclamation Plant (CCWRP), in northeast Phoenix, began operation which uses an activated sludge nitrification / denitrification process along with filtration and ultraviolet light disinfection to produce a tertiary-grade effluent that meets the Arizona standards. CCWRP is currently able to treat 8 MGD (350 l/s) and has an expansion capacity of 32 MGD (1,400 l/s). The Phoenix reclamation plant delivers reclaimed water through a nonpotable distribution system to golf courses, parks, schools, and cemeteries for irrigation purposes. The reclaimed water is sold to customers at 80% of the potable water rate.

CCWRP's sister facility, North Gateway Water Reclamation Plant (NGWRP), will serve the northwest portion of Phoenix. The design phase has been completed. The NGWRP will have an initial treatment capacity of 4 MGD (175 l/s) with an ultimate capacity of 32 MGD (1,400 l/s). The plant is modelled after the Cave Creek facility using the "don't see it, don't hear it, don't smell it" design mantra. Construction will be performed using the construction manager-at-risk delivery method.

Groundwater recharge and recovery is a key component of the water reuse program. Phoenix is currently exploring the use of vadose zone wells because they do not require much space and are relatively inexpensive to construct. This method also provides additional treatment to the water as it percolates into the aquifer. A vadose zone recharge facility along with a recovery well is being designed for the CCWRP site.

Water Reclamation and Reuse: Integrated Approach to Wastewater Treatment and Water Resources Issues in Phoenix, Arizona

The rapidly developing area of North Phoenix is placing ever-increasing demands on the city's existing wastewater collection system, wastewater treatment plants, and potable water resources.

As an integrated solution to these issues, water reclamation and reuse have become an important part of Phoenix Water Services Department's operational strategy.

Cave Creek Reclaimed Water Reclamation Plant (CCWRP), in northeast Phoenix, began operation in September 2001. The facility uses an activated sludge nitrification/denitrification process along with filtration and ultraviolet light disinfection to produce a tertiary-grade effluent that meets the Arizona standards. CCWRP is currently able to treat 8 MGD (350 l/s) and has an expansion capacity of 32 MGD (1,400 l/s). The Phoenix reclamation plant delivers reclaimed water through a non potable distribution system to golf courses, parks, schools, and cemeteries for irrigation purposes. The reclaimed water is sold to customers at 80% of the potable water rate.

CCWRP's sister facility, North Gateway Water Reclamation Plant (NGWRP), will serve the northwest portion of Phoenix. The design phase has been completed. The NGWRP will have an initial treatment capacity of 4 MGD (175 l/s) with an ultimate capacity of 32 MGD (1,400 l/s). The plant is modelled after the Cave Creek facility using the "don't see it, don't hear it, don't smell it" design mantra. Construction will be performed using the construction manager-at-risk delivery method.

Phoenix is using geographic information system (GIS) technology to develop master plans for the build out of the reclaimed water distribution system for both the Cave Creek and North Gateway reclamation plants. Through GIS, potential reclaimed water customers are easily identified. GIS also provides information useful for determining pipe routing, reservoir, and pump station locations. The goal is to interconnect the 2 facilities, thus building more reliability and flexibility into the system. The GIS model is dynamically linked to the water system, planning, and other important databases so that geospatial information is constantly kept up to date. A hydraulic model is being used in conjunction with the GIS model to optimize system operation.

Irrigation demand in Phoenix varies dramatically with the seasons, so groundwater recharge and recovery is a key component of the water reuse program. Phoenix is currently exploring the use of vadose zone wells because they do not require much space and are relatively inexpensive to construct. This method also provides additional treatment to the water as it percolates into the aquifer.

A pilot vadose zone well facility has been constructed at the NGWRP site to determine the efficacy of this technology. A vadose zone recharge facility along with a recovery well is being designed for the CCWRP site.

Nonpotable reuse and groundwater recharge with high quality effluent play an important role in the City's water resources and operating strategies. The North Phoenix Reclaimed Water System integrates multiple objectives, such as minimizing the impact of development in the existing wastewater infrastructure by treating wastewater locally and providing a new water resource in a desert environment. By using GIS, Phoenix will be able to plan the build out of the reclaimed water system to maximize its efficiency and minimize costs (USEPA, 2004).

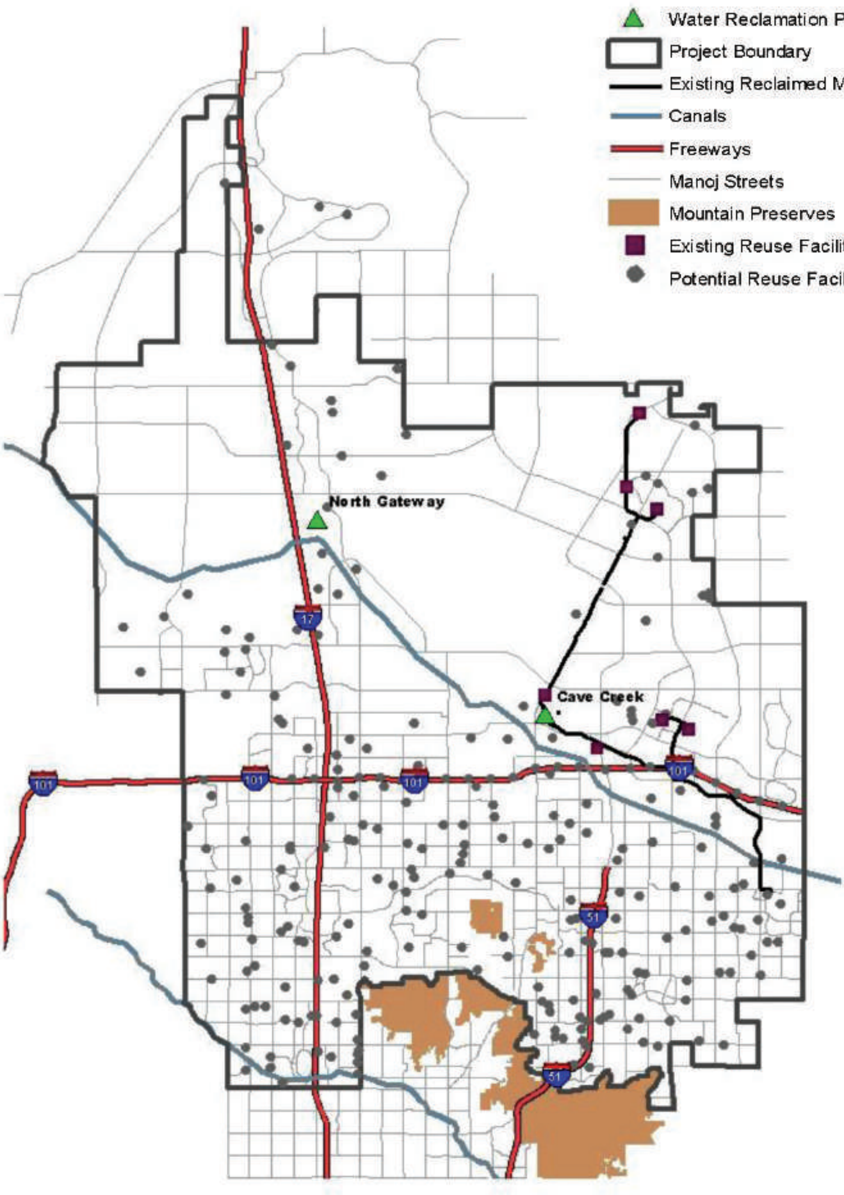


Figure A7.3- 17 North Phoenix reclaimed water system

7.4 SANTA ROSA (CALIFORNIA) RECHARGE PROJECT, USA

Since early 1960s, the Santa Rosa Subregional Water Reclamation System has provided reclaimed water for agricultural irrigation in the Santa Rosa Plain, and later on for irrigating golf courses, and local parks. The remaining reclaimed water not used for irrigation was discharged to the Laguna de Santa Rosa. Growing concerns over water quality impacts in the Laguna de Santa Rosa pressured the system to search for a new and reliable means of reuse.

In the northwest quadrant of Sonoma County lies the Geysers Geothermal Steamfield, a super-heated steam resource used to generate electricity. Due to overexploitation, the electricity generation has declined from 2,000 MW (1987) to about 1,200 MW. As a result, the operators are seeking a source of water to recharge the deep aquifers that yield steam.

In 1998, the Santa Rosa Sub-regional Reclamation System decided to build a conveyance system to send 11 MGD (480 l/s) of tertiary-treated water from the Laguna treatment plant to the northwest Geysers steam field for recharge and it began operations in in November 2003.

About 100 megawatts of additional power is generated each day by the Geysers Recharge Project. In January 2008, the delivery went up to 12.62 MGD and helped generate enough electricity for 100,000 households in Sonoma and other North Bay counties.

The conveyance system to deliver water to the steamfield includes 40 miles (64 km) of pipeline, 4 large pump stations, and a storage tank located high in the Mayacmas Mountains. The system requires a lift of 1,005 meters. Distribution facilities within the steamfield include another 29km of pipeline, a pump station, and tank, plus conversion of geothermal wells from production wells to injection wells.

Geysers Recharge Project: Santa Rosa, California, USA

The cities of central Sonoma County, California, have been growing rapidly, at the same time regulations governing water reuse and discharge have become more stringent. Since the early 1960s, the Santa Rosa Subregional Water Reclamation System has provided reclaimed water for agricultural irrigation in the Santa Rosa Plain, primarily to forage crops for dairy farms. In the early 1990s, urban irrigation uses were added at Sonoma State University, golf courses, and local parks. The remaining reclaimed water not used for irrigation was discharged to the Laguna de Santa Rosa. But limited storage capacity, conversion of dairy farms to vineyards (decreasing reclaimed water use by over two-thirds), and growing concerns over water quality impacts in the Laguna de Santa Rosa, pressured the system to search for a new and reliable means of reuse.

In the northwest quadrant of Sonoma County lies the Geysers Geothermal Steamfield, a super-heated steam resource used to generate electricity since the mid-1960s. At its peak in 1987, the field produced almost 2,000 megawatts (MW). Geysers operators have mined the underground steam to such a degree over the years that electricity production has declined to about 1,200 MW. As a result, the operators are seeking a source of water to recharge the deep aquifers that yield steam.

Geothermal energy is priced competitively with fossil fuel and hydroelectric sources, and is an important "green" source of electricity. In 1998, the Santa Rosa Sub-regional Reclamation System decided to build a conveyance system to send 11 MGD (480 l/s) of tertiary-treated water from the Laguna treatment plant to the northwest Geysers steamfield for recharge and in November 2003 it began operating. About 100 megawatts of additional power is generated each day by the Geysers Recharge Project. In January 2008, the delivery went up to 12.62 MGD and helps generate enough electricity for 100,000 households in Sonoma and other North Bay counties.

The conveyance system to deliver water to the steamfield includes 40 miles (64 km) of pipeline, 4 large pump stations, and a storage tank located high in the Mayacmas Mountains. The system requires a lift of 1,005 meters. Distribution facilities within the steamfield include another 29 km of pipeline, a pump station, and tank, plus conversion of geothermal wells from production wells to injection wells.

One of the major benefits of the Geysers Recharge Project is the flexibility afforded by year-round reuse of water. The system has been severely limited because of seasonal discharge constraints and the fact that agricultural reuse is not feasible during the wet winter months. The Geysers steam-field will use reclaimed water in the winter, when no other reuse options are available. However, during summer months, demand for reuse water for irrigation is high. The system will continue to serve agricultural and urban users while maintaining a steady but reduced flow of reclaimed water to the Geysers.

In addition to the benefits of power generation, the Geysers Recharge Project will bring an opportunity for agricultural reuse along the Geysers pipeline alignment, which traverses much of Sonoma County's grape-growing regions (USEPA, 2004).

7.5 UNDP STUDY AT CHENNAI

A study by UNDP in the 1970's identified a sand basin on the coast of Bay of Bengal where secondary treated sewage of the Chennai city can be infiltrated through percolation ponds and extracted for specific industrial use in the nearby petro-chemical complex. However, the public acceptance of this project has not been forthcoming.

8 INDIRECT RECHARGE OF IMPOUNDMENTS

8.1 WINDHOEK (NAMIBIA)

The Windhoek reclamation plant has been in operation since 1968 with an initial production rate of 4800 m^3/d. This operation is the only existing example of direct potable water production. The plant has since been upgraded in stages to its present capacity of 21,000 m^3/d.

The wastewater from residential and commercial settings is treated in the Gammans treatment plants by trickling filters (6,000 m^3/d) and activated sludge (12,000 m3/d), with enhanced phosphorus removal. The effluents from these processes go to 2 separate maturation ponds (4 to 12 days retention). Only the polished effluent from the activated sludge system is directed to the Windhoek reclamation facility added with water from the Goreangab Dam (blending ratio 1:3.5), where it is treated to drinking water standards. After tertiary treatment, reclaimed water is blended again with bulk water from different sources.

Advanced treatment processes (including ozonation and activated carbon) have been added to the initial separation processes of dissolved air flotation, sedimentation, and rapid sand filtration. A chlorine residual of 2 mg/l is provided in distribution systems. Membrane treatment has been considered, as well as additional 140 days storage of the secondary effluent from the maturation ponds in the Goreangab Dam.

Windhoek, the capital of Namibia, has a population of 200,000 and is located in the desert. In 1960, low rainfall (below 300 mm/year) caused the necessary water supply to fall short of the water demand. To meet this need, the country's water supply master plan included the long distance transport of 80% of its water supply from the Eastern National Water Carrier, extensive aquifer withdrawals from around the city, the development of a local surface reservoir, and the construction of a reclamation plant. The Windhoek reclamation plant has been in operation since 1968 with an initial production rate of 4,800 m3/d. This operation is the only existing example of direct potable water production. The plant has since been upgraded in stages to its present capacity of 21,000 m^3/d.

The wastewater from residential and commercial settings is treated in the Gammans treatment plants by trickling filters (6,000 m^3/d) and activated sludge (12,000 m3/d), with enhanced phosphorus removal. The effluents from each of these processes go to 2 separate maturation ponds for 4 to 12 days of polishing. Only the polished effluent from the activated sludge system is directed to the Windhoek reclamation facility added with water from the Goreangab Dam (blending ratio 1:3.5), where it is treated to drinking water standards. After tertiary treatment, reclaimed water is blended again with bulk water from different sources.

Advanced treatment processes (including ozonation and activated carbon) have been added to the initial separation processes of dissolved air flotation, sedimentation, and rapid sand filtration. Residual chlorine of 2 mg/l is provided in distribution systems. Membrane treatment has been considered, as well as additional 140 days storage of the secondary effluent from the maturation ponds in the Goreangab Dam.

Risk studies and evaluations of toxicity and carcinogenicity have demonstrated that reclaimed water produced at the Windhoek facility is a safe and acceptable alternative water resource for potable purposes. Treatment capacity at the Windhoek treatment plant is currently being increased to 40,000 m^3/d (USEPA, 2004).

Source: USEPA, 2004

Figure A7.3- 18 Goreangab Dam, adjacent to the Windhoek reclamation plant in Namibia.

8.2 GERMANY

The Berlin water works are located near the surface water system. The water works' wells are drilled mostly at short distance from the rivers and lakes near the bank, from where water is abstracted. One of the largest water works of Berlin (Tegel) abstracts lake water (80%) via bank filtration and artificial groundwater recharge. In Tegel drinking water, advanced treated wastewater portions have been calculated to be 14-28%.

In order to study the properties and consequences of artificial recharge, a research and development project, namely Project Natural and Artificial Systems for Recharge and Infiltration (NASRI), was initiated in 2002. The NASRI project indicates that aquifer recharge offers great potentials in the future of integrated water management, provided that the necessary precautions are taken.

The Berlin water works are located near the surface water system. The waterworks' wells are drilled mostly at short distance (1-600 m) from the rivers and lakes near the bank. From here bank-filtered surface water is abstracted.

One of the largest waterworks of Berlin (Tegel) abstracts lake water (80%) via bank filtration and artificial groundwater recharge. In Tegel drinking water, advanced treated wastewater portions have been calculated to be 14-28%.

The climatic water balance is approaching a negative value with transpiration equalling precipitation. Even in the near future an equalised water balance is not expected. Since 1997, part of the advanced treated wastewater is discharged into former drainage ditches to redress the disturbed water balance in the lowland which had resulted in a 0.15 to 0.50 m reduction in the low moors thickness over 50 years. This beneficial reuse has increased the water table, restored the ecology and increased the grass yields from the meadows to 4-5 harvest per year instead of 2.

In order to study the properties and consequences of artificial recharge, a research and development project, namely Project Natural and Artificial Systems for Recharge and Infiltration (NASRI), was initiated in 2002. Their purpose was to study: physical, chemical and biological processes; transport processes; the long-term sustainability of bank filtration; models of transport processes; water managing scenarios; the development of guidelines for the optimised operation of existing bank filtration and groundwater recharge scheme.

The NASRI project provided valuable data concerning artificial aquifer recharge. This project indicates that aquifer recharge offers great potentials in the future of integrated water management, provided that the necessary precautions are taken. It is a process of high value for the future of Berlin's drinking water supply. Mechanisms governing the removal of impurities and chemical reactions were better understood (Mediterranean Wastewater Reuse Working Group, 2007).

APPENDIX A 8.1
DESIGN EXAMPLE OF INTERCEPTOR TANK

The following design criteria are extracted from the publication "The Design of Small Bore Sewer Systems" by the World Bank indexed as TAG 14 available from website *http://www-wds.worldbank.org/* and authorised for public use.

Design of an interceptor tank to pre-treat the sewage from a household of 8 persons at 70 lpcd of sewage and desludging every 3 years

(i) Minimum hydraulic retention time is given by the following equation:

$t_h = 1.5 – 0.3 \log (Pq)$

Where,

t_h = minimum mean hydraulic retention time, days
P = contributing population
q = sewage flow, lpcd

Hence, minimum hydraulic retention time = $1.5 - 0.3 \log (8 \times 70) = 0.68$ day

(ii) Volume required for sedimentation is given by the following equation:

$V_h = 10^{-3} (Pq)$ th

Where,

V_h = volume required for sedimentation, m^3
Hence, volume required for sedimentation = $8 \times 70 \times 0.68 /1000 = 0.39\ m^3$

(iii) Combined solids digestion and storage volume is given by equation:

$V_s = 70 \times PN / 1000$

Where,

V_s = combined solids digestion and storage volume, m^3
N = desired interval between successive desludging operations, years

Hence, solids digestion and storage volume = $70 \times 8 \times 3/1000 = 1.68\ m^3$
Assume a tank of 3 m × 1 m in plan area (A)

(iv)	Maximum depth of sludge	=	Vs/A = 1.68/3 = 0.56 m
(v)	Maximum submerged scum depth (d_{ss})	=	0.7/A = 0.7/3 = 0.23 m
(vi)	Minimum sludge clear space	=	0.82 − 0.26 A
			= 0.82 − (0.26 × 3) = 0.04 m

Minimum to be provided is 0.3 m
Minimum height between bottom of scum and invert of the outlet pipe must be 75 mm

Clear height above invert of outlet pipe	= 0.3 + (75/1000) = 0.375 m
Diameter of outlet pipe	= 75 mm = 75 / 1000 = 0.075 m
Effective depth	= 0.56 + 0.375 + 0.23 = 1.165 m
Freeboard	= 0.3 m
Overall inner dimensions	= 3 m × 1 m × 1.5 m height

APPENDIX A 9.1
DESIGN EXAMPLE OF LEACH PIT
(Retained as in 2nd edition)

Design example : Twin Leach Pits (Dry conditions) for 5 users :

1 ASSUMPTIONS

a) litres of wastewater is generated per capita per day
b) litres of water is used per day for floor washing and pan cleaning
c) The water table remains 2 meters or more below ground level through out the year for dry pit and 50 cm below for wet conditions
d) The local soil is porous silty loams and
e) The pits are designed for 2 year sludge accumulation capacity.

2 SOLUTION 1

a) Calculate the total waste water flow (Q) in litres per day
   Q = 9.5 l/d × 5 users + 5 litres for floor wash etc.
   = 52.5 liters per day

b) Assuming a pit of 800 mm internal diameter (inside lining 75 mm thick with brick on edge and effective depth 800 mm, check for infiltrative surface area (At); this is given by :
   At = π d h

   Where d is the external diameter and h is the effective depth of the pit.
   At = π × 0.95 × 0.8 = 2.39 m^2

c) If the soil is porous silty loams, the infiltrative area required is 52.5/20 = 2.6 m^2 ; hence the infiltrative area provided is insufficient, Therefore by choosing a depth of 0.9 m ; the infiltrative area At will be
   = π × 0.95 × 0.9 = 2.69 m^2, which is sufficient.

d) Check for the required solid storage volume (V) for a solids accumulation rate of 0.04 m^3 per capita per year, (Table 9.2) for a dry pit with water being used for anal cleansing and for a dislodging interval of 2 years and a household size of 5 persons
   V = 0.04 × 2 × 5 = 0.40 m^3
   Whereas, the volume of proposed pit is :

$$\frac{\pi \times 0.8 \times 0.8 \times 0.9}{4} = 0.45\, m^3$$

Hence pit proposed has the sufficient storage capacity.

e) Allowing a free space of say 0.225 m, the dimensions of the pit are as follows:
   Internal diameter 800 mm
   Total depth 1,125 mm (900 mm + 225 mm free board)

Since the pit bottom is more than 2 m above the maximum ground water table, the pit will function in dry condition.

3 SOLUTION 2

The ground water table is 50 cm below the ground surface, but all other assumptions are the same as in the above example.

The pit size is determined by taking the sludge accumulation rate from Table 9.2, Assuming the pit desludging period as 2 years.

Volume of the pit = $0.095 \times 2 \times 5$

= $0.95\ m^3$

Allowing a free board of 0.225 m. Pit dimensions come as follows :

Internal diameter 1,100 mm

Total depth 1,225 mm (1,000 mm + 225 mm free board)

APPENDIX A 9.2
SOIL PERCOLATION TEST
(Retained as in 2nd edition)

To design a suitable soil absorption system for disposal of effluent from septic tanks, percolation test shall be carried out, on the proposed site for location of the absorption system, in the following manner.

Six or more test holes spaced uniformly over the proposed absorption field shall be made.

A square or circular hole with side width of diameter of 10 cm to 30 cm and vertical sides shall be dug or bored to the depth of the proposed absorption trench. The bottom and sides of the holes shall be carefully scratched with a sharp-pointed instrument to remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate, the holes shall be filled for a depth of 5 cm with loose material to protect the bottom from scouring and settling.

Before the actual readings for percolation tests are taken, it is necessary to ensure that the soil is given ample opportunity to swell and approach the condition it will be in during the wettest season of the year, This is done by pouring water in the hole up to a minimum depth of 30 cm over the grave! and allowed to soak for 24 hours. If the water remains in the test hole after the overnight swelling period, the depth of water shall be adjusted to 15 cm over the gravel. Then from a fixed reference point, the drop in water level shall be noted over a 30 minute period. This drop shall be used to calculate the percolation rate.

If no water remains in the hole, at the end of 30 minute period, water shall be added to bring the depth of the water in hole 15 cm over the gravel. From a fixed reference point, the drop in water level shall be measured at 30 minute intervals for 4 hours, refilling to 15 cm level over the grave! as necessary. The drop that occurs during the final 30 minute period shall be used to calculate the percolation rate. The drop during the earlier periods provide information for the possible modification of the procedure to suit local circumstances.

In sandy soils or other porous soils in which the first 15 cm of water seeps away in less than 30 minutes after overnight swelling period, the time interval between measurements shall be taken as 10 minutes and the test run for one hour. The drop that occurs in the final 10 minutes shall be used to calculate the percolation rate.

Based on the final drop, the percolation rate, which is the time in minutes required for water to fall 1 cm, shall be calculated.

APPENDIX A 9.3
EXAMPLE OF DESIGN OF MINI-PACKAGED TREATMENT PLANT (ON-SITE CONSTRUCTION-TYPE)

The following shows an example of designing an on-site construction-type sewage treatment system - for 500 persons in Japan.

Basic settings

Number of users: 500

Sewage generation rate: 200 L/day

BOD concentration of sewage: 200 mg/L

- Inflow rate of sewage [Q]

Q [m^3/day] = 500 [persons] × 200 [L/person/day]/1,000 = 100 [m^3/day]

First flow equalization tank

Sewage inflow time [T]: 16 hours (per day)

Peak time [Tm]: 2 hours (per day)

Peak factor [Km] (maximum flow rate/mean flow rate): 3.0

Flow adjustment ratio (margin) [Kc]: 1.3

The necessary capacity [V] is given by the following formula:

V [m^3] = [(Km/T) - (Kc/24)] × Tm × Q

= [(3.0/16) - (1.3/24)] × 2 × 100 = 28 m^3

- Contact aeration tank

This tank shall meet all the following requirements:

Requirement 1: The retention time shall exceed 8 hours.

Requirement 2: BOD volume load shall be less than 0.3 [kg/m^3/day].

Requirement 1: V1 [m^3]

V1 [m^3] = Q × (8/24) = 34 [m^3]

Requirement 2: V2 [m^3]

Assuming that the inflow BOD concentration is 200 [mg/L],

V2 [m^3] = (200 × Q/1,000)/0.3 = 67 [m^3]

Accordingly, the capacity meeting both requirements is V [m3] = 67 [m^3].

- Sedimentation tank

Assuming that the retention time [T] is 3 hours,

V [m^3] = Q × (3/24) = 12.5 [m^3]

- Second flow equalization tank

Assuming that the retention time [T] is 2 hours,

V [m^3] = Q × (2/24) = 8.4 [m^3]

- Flocculation tank

Assuming that the retention time [T] is 30 minutes,

V [m^3] = Q × (1/24) × (30/60) = 2.1 [m^3]

- Flocculation sedimentation tank

Assuming that the retention time [T] is 3 hours,

V [m^3] = Q × (3/24) = 12.5 [m^3]

- Disinfection tank

Assuming that the retention time [T] is 15 minutes,

V [m^3] = Q × (1/24) × (15/60) = 1.1 [m^3]

- Sludge storage tank

Assuming that the BOD reduction ratio is 90% (raw sewage: 200 mg/L and treated sewage: 20 mg/L) and 100% of removed contaminants are converted to sludge, the sludge generation (dry substance) rate [Sq(DS)] is given by the following formula:

Sq(DS) [kg-DS/day] = (200 × Q/1,000) × (90/100) × (100/100)
= 18 [kg-DS/day]

Assuming that the sludge concentration is 15,000 mg/L (1.5%),

Sq [m^3/day] = 18 [kg-DS/day]/(1.5/100)/1,000 = 1.2 [m^3/day]

Assuming that the retention period is one week, the capacity of the sludge storage tank [V] is given by the following formula:

V [m^3] = 1.2 [m^3/day] × 7 [day/week] = 8.4 [m^3]

Table A9.3-1 Example of designing a on-site construction-type treatment system

Capacity	500 Persons (100 m^3/day)		
Tank Volume	Tank Name	Effective Volume	Setting Value
	Flow equalization tank (1st)	28 m^3	Peak coefficient:3.0 Inflow time:16hr/24 hr Flow adjustment ratio:1.3 Peak time:2hr/24 hr
	Contact aeration tank	67 m^3	Retention time:8 hr BOD volumetric loading :0.3 kg/m^3/day
	Sedimentation tank	12.5 m^3	Retention time:3 hr
	Flow equalization tank (2nd)	8.4 m^3	Retention time:2 hr
	Flocculation tank	2.1 m^3	Retention time:30 min
	Flocculation sedimentation tank	12.5 m^3	Retention time:3 hr
	Disinfection tank	1.1 m^3	Retention time:15 min
	Sludge storage tank	8.4 m^3	Gross yield coefficient:100% Sludge concentration:15,000 mg/L Storage days:1 week

REFERENCES

(1) A K Dhussa and V K Jain, “Biomethanation”, Newsletter, National Bioenergy Board, MNRE, March, (2002)

(2) Akepati S. Reddy, Thapar Centre for Industrial Research & Development,

(3) Arceivala. S. J., “Wastewater Treatment for Pollution Control”, Tata McGraw-Hill Publishing Company Limited, (2000)

(4) BIS: 10500 of 1991

(5) BWSSB, Correspondence at various times.

(6) Chartered Institution of Water and Environmental Management (CIWEM) webpage http://www.ciwem.org/policy-and-international/current-topics/water-management/water-reuse/potable-water-reuse/planned-indirect-potable-reuse.aspx

(7) Christine deBarbadillo et al, “Practical Considerations for Design of a Step-Feed Biological Nutrient Removal System”, Florida Water Resources Journal, (2002)

(8) CMWSSB, Correspondence at various times

(9) CPCB, “Status of Water Supply, Wastewater Generation and Treatment in Class-I Cities and Class-II Towns of India. New Delhi, (2009)

(10) CPCB, MoEF, GOI, “General Standards for Discharge of Environmental Pollutants Part-A: Effluents”, (1986)

(11) CPHEEO, MoUD, “Manual on Municipal Solid Waste Management”,(2000)

(12) CPHEEO, MoUD, “Manual on Sewerage and Sewage Treatment”, (1993)

(13) CPHEEO, MoUD, “Manual on Water Supply & Treatment”, (1999)

(14) CSE, Policy Paper on Septage Management in India, India, (2011)

(15) Daniel Sztruhar, et al., “Combined sewer overflow assessment in Slovakia”, Slovak Technical University, Department of Sanitary Engineering, Slovakia, http://www.kzdi.sk/osobne/sztruhar/icudi2000/icudi%202000.htm.

(16) Dhinadhayalan, M. and Nema, A K, “Decentralized Wastewater Management – New Concepts and Innovative Technological Feasibility for Developing Countries”, Sustainable Environment Research, 22(1), p. 39-44, (2012)

(17) Ebara Engineering Service Co., Ltd.,http://www.jiwet.or.jp/english/gcus/pdf/gcus02.pdf

(18) Environmental Operators Certification Program homepage. http://dns2.eocpsearch.org/Wordpress/wp-content/uploads/2012/10/plants-Kelowna.pdf

(19) EPA, U. “Process Design Manual for Land Application of Municipal Sludge”, EPA 625/1-83/016, (1983)

(20) Esrey, S.A., Potash, J.B., Roberts, L., Shiff, C. “Effects of improved water supply and sanitation on Ascariasis, Diarrhea, Dracunculiasis, Hookworm infection, Schistosomiasis, and Trachoma”, Bull. WHO 69(5), p. 609-621, (1991)

(21) Harrison. D., et. al., “The use of Computational Fluid Dynamics in the Optomisation of Sludge Process” ,Technical Paper 37.pDf, Monsal, http://www.monsal.com/documents/technical%20paper%2037.pdf

(22) Hickman Jr., H. Lanier, “The Principles of Integrated Solid Waste Management”, American Academy of Environmental Engineers, Annapolis, MD, (1999).

(23) Hitachi Plant Technologies, Ltd. (2010), http://www.hitachi-pt.com/products/es/water/wastewater/pegasus.html

(24) http://water.city.sakai.lg.jp/torikumi/file/konwakai4-03.pdf

(25) http://www.ariakeebb.com/

(26) http://www.ciwem.org/policy-and-international/current-topics/water-management/water-reuse/potable-water-reuse.aspx.

(27) http://www.gesui.metro.tokyo.jp/english/c40/img/Seoul.pdf

(28) http://www.ittwww.com.au/brochures/abj_brochures.pdf

(29) http://www.kaldnes.com

(30) http://www.stowa-electedtechnologies.nl/

(31) http://www.unep.or.jp/ietc/publications/techpublications/techpub-15/2-9/9-3-1.asp)

(32) http://www.unep.or.jp/ietc/publications/techpublications/techpub-15/2-9/9-3-3.asp

(33) http://www.veoliawaterst.com/solia/en/

(34) http://www.yokogawa.co.jp/an/faq/oxy/oxy_general.htm

(35) http://www.yokogawa.com/an/faq/do/do_general.htm

(36) Indira Gandhi International Airport, New Delhi, Correspondence, (2011)

(37) IS2470 (Part1):“Code of Practice for installation of septic tank”, (1985)

(38) ISHIGAKI COMPANY, LTD. http://www.ishigaki.co.jp/english/Products/Filter/Detail/ISGK3.html

(39) J Marsalek, “Technique for Flow Measurements in Urban Runoff Studies”, Proceedings of the International Seminar and Exposition on Water Resources Instrumentation by International Water Resources Association and American Society of Civil Engineers at Chicago, (1974)

(40) Japan Sewage Works Association (2011). “Draft Guideline on design and execution management in sewer rehabilitation method, and others”, JSWA, Tokyo,(2011)

(41) Japan Sewage Works Association, “Guideline and Manual for Planning and Design in Sewerage Systems”, JSWA, Tokyo, (2009)

(42) Japan Sewage works Association, “Manual on design of sewer facilities”, JSWA, Tokyo, (1991)

(43) JICA Press Release-NR/2007-2 April 2, (2007).

(44) JSWA , “The Technical Evaluation Report on MBRs”, (2003)

(45) Kajima Corporation, http://www.kajima.co.jp/gallery/civil_kajima/kurasi/kurasi01.html

(46) Knatz.et.al.”Using CFD to Select Anaerobic Digestion Mixing Systems”, WEFTEC, Session 41 Through 50, pp. 2750-2758(9), (2010)

(47) Kruger, Scada System Development and Upgrades, http://www.krugerusa.com/medias/files/scada

(48) L&T Shipbuilding Limited, Kattupalli..(Correspondence, 2011)

(49) Lambert, J et. al.,“Water Jetting Code of Practice 2nd Ed”. WRC, UK, (2005)

(50) M/s Kottar Social Service Society, Nagercoil & M/s Caritas India & M/s Caritas Germany. (Correspondence)

(51) M/s. HANNA, http://www.hannainst.com/usa/prods2.cfm?id=004002&ProdCode=HI 98186

(52) M/s. YSI, http://www.ysi.com/productsdetail.php?ProODO-19; http://www.ysi.com/productsdetail.php?5000-5100-30

(53) Mara, D., Sleigh, A and Tayler, K.,”PC-based Simplified Sewer Design”, University of Leeds, England, (2001)

(54) Mediterranean Wastewater Reuse Working Group, “Mediterranean Wastewater Reuse Report”, (2007)

(55) Metcalf & Eddy, Inc. “Wastewater Engineering: Treatment and Reuse” McGraw-Hill, New York, (2003)

(56) MoEF, Government of India, “National Urban Sanitation Policy”, (2008)

(57) Moreau, A, Filterability Assessment of Membrane Bioreactors at European Scale, ISBN/EAN: 9789089570147, (2010)

(58) Moriyama, K. et al., “A study on Nitrification-Denitrification Process Using endogenous Respiration for Denitrification”, Proceedings of Environmental and Sanitary Engineering Research, Vol.24, (1988)

(59) MoUD, “Handbook on Service Level Benchmarking”,(2011)

(60) MoUD, Advisory, “Recent Trends in Technologies in Sewerage System”, (2012)

(61) MoUD, UNDP, World Bank, “Technical Guideline on Twin Pit Pour Flush Latrine”, (1992)

(62) Murata, T., “Advanced Treatment Technology of Wastewater”, Rikou-toshyo, (1992)

(63) National Academy of Engineering, Environmental Studies Board, Ad Hoc Committee on Water Analysis Criteria, WQC, (1972)

(64) NISHIHARA Environment Co. Ltd., LINPOR®-CN, LINPOR®-NP, Advanced Treatment by Employing Media Nishihara's Technology in SBR process, IC Process, http://www.nishihara.co.jp/

(65) NRCD, MoEF, GOI, "Status Paper on River Ganga", (2009)

(66) OCWD home page, http://www.ocwd.com/

(67) Ohio Department of Natural Resources, Dam Safety, "Design and Maintenance of Trash racks for Pipe and Riser Spillways", Fact Sheet 96-38, (2007)

(68) Pamphlet issued by DJB.

(69) Pennsylvania Department of Environmental Protection, Wastewater Treatment Plant Operator Certification Training, Module 18, The Activated Sludge Process Part IV, (2013)

(70) Regional Sewerage Centre of Nara Prefecture, Annual Report of Water Quality Management, (2009)

(71) Renata Tomczak-Wandzel, et.al., "Effect of Disintegration Pre-treatment of Sewage Sludge for Enhanced Anaerobic Digestion" The 8th International Conference, May 19–20, 2011, Vilnius, Lithuania,

(72) Rongjing Xie, et. al., Full-scale demonstration of an ultrasonic disintegration technology in enhancing anaerobic digestion of mixed primary and thickened secondary sewage sludge, Journal of Environmental Engineering and Science, Volume 6, Issue 5, September 2007 pages 533 –541

(73) Robbins, D.M. ,"Septage Management Guide for Local Governments", RTI International, USA, (2007)

(74) S. Churchhouse, Long term operating experience of membrane bioreactor. School of Water Science, 1 day conference on MBR, 9 April 2003, Cranfield, UK, (2003)

(75) Saktheeswaran. S, "Resurrection of an Abandoned 23 MLD Sewage Infested Surface Water Treatment Plant by Disinfection at High Lime and Neutralization by Carbon Di Oxide at Hosur, India", International Workshop on Advances in Disinfection Technologies, NEERI, Nagpur, February, (2011)

(76) Sanki Engineering Co., Ltd., http://www.sanki.co.jp/product/lineup/images/panel_03/03_rotary-press.pdf

(77) SEKISUI AQUA SYSTEMS Co., Ltd., http://www.sekisuia.co.jp/english/tanks/product/bps/index.html

(78) Septage Management in Asia-USAID, http://www.slideshare.net/OswarMungkasa/regional-septage-study-usaid-eco-asia-15361249

(79) Spellman, F. R., "Handbook of Water and Wastewater Treatment Plant Operations", Lewis Publishers, (2009)

(80) Sundaramoorthy S and Nambi Ayyadurai, S., “Experiences in Use of Renovated Sewage as Industrial Cooling Water at Madras, India”, Proceedings of the Water Environment Federation, 66th Annual Conference & Exposition, Anaheim, California, USA, pp 402-414, (1993)

(81) Than Khin, Ajit P. Annachhatre, “Novel microbial nitrogen removal processes”, Biotechnology Advances 22, 519-532, (2004)

(82) The Indian Agricultural Research Institute at Karnal, http://www.icar.org.in/en/image/tid/109

(83) The Puducherry Public Works Department. Correspondence, (2011)

(84) Thomas P. Gilligan, Manfred Morper., “A Unique Process for Upgrading conventional activated Sludge Systems for Nitrogen Removal”, California Water Environment Association,73rd Annual Conference, April, (2001)

(85) Tilley et al., “Compendium of Sanitation Systems and Technologies. Duebendorf and Geneva”, Swiss Federal Institute of Aquatic Science and Technology (EAWAG), (2008)

(86) Tokyo Metropolitan Government. http://nett21.gec.jp/GESAP/themes/themes2.html.

(87) Turovskiy, I. S, “Wastewater Sludge Processing”, John Wiley & Sons, Inc, (2006)

(88) TWAD Board webpage

(89) U.S. Environmental Protection Agency, “Guidelines for Water Reuse”, EPA/625/R-04/108, (2004)

(90) UN Centre for Human Settlements (HABITAT), “The Design of Shallow Sewer Systems. Nairobi, Kenya”, (1986)

(91) UNDP, World Bank, “The Design of Small Bore Sewer Systems”, TAG Technical Note No. 14, Washington, USA, (1985)

(92) UNICEF “Community Approaches to Total Sanitation”, New York, USA, (2009)

(93) US Federal Emergency Management Agency, ”Special Events Contingency Planning, Job Aids Manual”, (2005)

(94) USAID, “A Rapid Assessment of Septage Management in Asia”, (2010)

(95) USAID, “Developing Comprehensive Septage Management Programmes in Asia”, (2009)

(96) USEPA, “Decentralized Systems Technology Fact Sheet – Septage Treatment/Disposal”,EPA – 832-F-99-068. Washington, USA, (1999)

(97) USEPA, “Handbook: Septage Treatment and Disposal”, EPA – 625/6-84-009. Ohio, USA, (1984)

(98) USEPA, “Summary Report for In-Vessel Composting of Municipal Wastewater Sludge”, EPA/625/8-89/016, (1989)

(99) USEPA.“Design Manual-Municipal Wastewater Disinfection”, EPA/625/1-86/021, (1986)

(100) WEPA,”State of Technology for Rehabilitation of Wastewater Collection Systems”, EPA/600/R-10/078/July, 2010.

(101) WEF, “Manual of Practice No.8”, WEF Press, (2010)
(102) WERF. “Fact sheet C2, Pressure Sewer Systems”
(103) WERF. “Fact sheet C4, Vacuum Sewer Systems”
(104) WHO/IRC (2004). “Linking Technology Choice with Operation and Maintenance” .
(105) World Bank, “Water and Sanitation Program”, (2006)
(106) World Bank, “World Development Report”, (1993)
(107) WPCF, MOP – FD-5 Chapter 4, Table 4-2
(108) WRC, UK, “Water Jetting Code of Practice”, (2005)
(109) WSP, South Asia, “Hoshangabad: Towards City-wide Sanitation”, http://www.wsp.org/sites/wsp.org/files/publications/EEMP_TSSM.pdf, (2008)
(110) WSP, South Asia, “Technology Options for Urban Sanitation in India”, (2008)
(111) Yamada, K., Matsushima, O., and K. Sone, “Reclaimed Wastewater Supply Business in Tokyo and Introduction of new Technology”, http://www.gesui.metro.tokyo.jp/ english/tec_papers/tec_papers.htm)
(112) Yamagata, H., Nasu, M., Yoshizawa, M., Miyamoto, A., and M. Minamiyama, “Heat Island Mitigation using Water Retentive Pavement Sprinkled with Reclaimed Wastewater”, Water Science and Technology, Vol. 57.5, p.763-771,(2008)

सत्यमेव जयते

Government of India

Ministry of Urban Development

Nirman Bhawan, New Delhi 110 011, India

http://moud.gov.in

http://cpheeo.nic.in/