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Environmental Engineering (Vol. II)

Sewage Disposal and Air Pollution Engineering

SANTOSH KUMAR GARG

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ENVIRONMENTAL ENGINEERING (Vol. II)

SEWAGE DISPOSAL
AND
AIR POLLUTION ENGINEERING

[*For Civil, Environment, and Agriculture Engineering Degree & Post Graduate Courses ; MSc (Environmental Science) Courses ; Engg. Services and Civil Services Competitive Examinations of UPSC ; GATE examinations for admissions to M. Tech. Courses ; AMIE (Section B) Examinations ; and for Professional Field Engineers*.]

By

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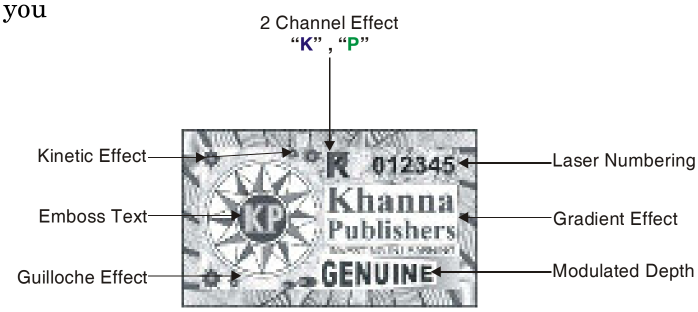

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Dedication

Dedicated to those,
who are continuing making efforts,
inspite of several odds,
for the upliftment of our beloved
and beautiful India.

PREFACE TO THE REVISED 41st EDITION

The first edition of this highly acclaimed book was published in March 1979, and contained hardly 350 pages. During the intervening period exceeding 40 years, more than 3 lakh copies have been sold through its thirty nine editions and their reprints. Additional 3300 copies are being printed for this revised 40th edition.

Due to the continuous and progressive revision and updation of the book, edition after edition, the size of the book has virtually tripled, since its first edition. In order to reduce the number of pages and to control the continuously increasing thickness of the book, we had, in its 24th edition, got the entire book recomposed into a **new size of 24 cm × 16 cm**, as against the previous size of 20 cm × 13 cm. This has helped in reducing the thickness of the book by about 20%, thereby making the book easier to handle and carry. All the drawings were also redrawn on computer to make them of better quality.

The book has been further revised continuously edition after edition. Even in the present 41st edition, large scale changes in the entire text have been carried out by deleting certain olds obsolete matter and by updating several data, particularly relating to ***Activated Sludge Process (ASP)*** in Chapter 9 and ***Noise Pollution*** (Ch. 20). The question banks of Engineering Services and Civil Services Exams have also been updated up to the year 2020.

The author is delighted to find the growing popularity of the book, not only among the average students but also among the toppers of the various engineering colleges of the country and abroad. ***It is also a matter of great pleasure to the author as well as to the students to find questions being directly set from this book year after year, in the prestigious "Civil Services" and "Engineering Services" Exams. The author expresses his gratitudes to all such learned Professors, Examiners and Paper-setters, who have valued this book worthy of such a high acclaim***.

Acknowledgements. In going through the forty editions of this book, the author has accumulated enormous amount of debt from students and teachers over the years, who had written about their satisfaction with the book, and extended suggestions for the improvement of its various editions. *If the book today is so strikingly popular, they all deserve much of the credit. The author certainly wants them to know of his gratitudes and openness to further suggestions, and is hence enlisting their names below :*

Sh. Satish Kumar Aggarwal—a student of M.R. Engineering College Jaipur, Rajasthan ; *Sh. Rajesh Gupta* and *Sh. Ajay Gupta*, students of Jabalpur Engineering College ; *Sh. Ashfaq Ahmed* of Shri Ram Rayons Kota, ***Mr. Biswaroop Ghosh***—an ex student of Bengal Engineering College, Calcutta (who handsomely contributed to the objective section) ; ***Sh. H.S. Bhatia***—Professor Delhi College of Engineering ; *Sh. A.M. Malek*—the then Lecturer S.S. College of Engineering Sidsar, Bhavnagar, Gujarat ; *Sh. Pramod Kumar Tomar* of Maharaja Surajmal Institute, New Delhi ; *Sh. A.P. Thankhavel*—lecturer A.K. College of Engg. Krishnakovil, Tamilnadu ; *Sh. Shri Ram*—lecturer Madan Mohan Malviya Engg. College Gorakhpur, U.P. ; ***Sh. Pawan Goyal***—a student of MBM Engineering College, Jodhpur, Rajasthan ; *Sh. Krishan Mohan Kansal*—a student of Delhi College of Engineering ; *Mr. Ganesh Sawleshwarkar* of victoria Jubilee Technical Insutitute Bombay ; *Mr. Pradeep Sharma*—a student of I.I.T. Delhi ; *Mr. Azmal Kamal*—a student of Jamia Millia Islamia, New Delhi ; *Mr. Ashok Kumar*—a student of BIT Sindri Dhanbad ; *Mr. R.D. Punia*—Dy Director Technical Education at Regional Engineering College, Kurukshetra, Haryana. ***Dr. V.S. Prasad***—Professor at Regional Engg. College, Calicut ; ***Mr. A.M. Malek***—Asstt. Professor at L.D. College of Engg. Ahmedabad, *Mr. B.J. Bhaskar Reddy* from Hyderabad ; *Mr. Santhanam Krishnan*—an M. Tech. student of IIT Delhi, *Mr. Bibek Bastola* of Nepal ; etc., etc.

The author also wants to thank and acknowledge the receipt of numerous sms's, showering praises on the books of Env. Engg. Vol. I and II both, from several students and teachers, like Ms Rumpa, Mr. Dilip G. Patil, Mr. Sandip Kr. Das (Lecturer), Mr. Manish Kr., Mr. Noopur, etc. etc.

The author further desires to record his special gratitudes and thanks to ***Prof. Kapil Gupta*** of IIT, Bombay, due to whose help, he was able to include photographs of *aerated grit chambers* and *aerated lagoons* as existing in Mumbai, along with giving details of the disposal of sewage into the Mumbai sea.

Thanks are also due to Prof. S.C. Prasad presently Principal & HOD Civil at MIET Meerut (previously HOD at NIT Allahabad) for suggestions, based on which changes have been affected in the chapter of BOD.

The author also records his thanks to the Publishers for promptly printing this revised edition. The author also wants to record his unforgettable sincere gratitudes towards one of his old teacher, ***Prof. R. Naryanan*** (the then HOD Civil Engg. Deptt, Delhi College of Engg. Delhi), who infact provided the inspiration to the author to start writing books, when he was highly depressed in his life at its prime stage, due to having been rejected on medical grounds for a Class I job through the Engg Services Competition, for having lost his Left Lung in early childhood.

Since the book has continuously been revised edition after edition, some typographical errors might still be existing in the book.

The author will certainly be grateful, if such misprints and ommissions if any, are brought to his notice, for making amends in the future editions of the book.

July 11, 2021

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   Photoview of one of the 4 aerated oxidation lagoons (ponds) at Ghatkopar Sewage Treatment Plant, Mumbai

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   General Layout of Proposed Sewage Treatment Plant (Extended Aeration Type of Activated Plant) for Example 10.1 for Dalhousie town (H.P. State of India)

4. **Chart Fig. 10.2 .... at the end of the book**

   Design Details of Sewage Treatment Plant (Extended Aeration Activated Sludge Plant) for Example 10.1 to be adopted for treating sewage of Dalhousie town (H.P. State of India)

5. Colour Photo Fig. 17.1 (*a*) 644-645

Proposed Air Quality Index (AQI) Chart in India. Categories in index are based on concentrations of Eight Air Pollutants, and Associated Health Impacts of each category

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Global AQI chart. The observed values dated Nov. 18, 2014 shows that air quality in Delhi (India) is extremely poor

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Proposed Dams in Narmada Valley

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Sardar Sarovar Dam

Conversion of f.p.s., c.g.s., and S.I. Units into M.K.S. Units

Conversion of f.p.s. Units into M.K.S.	*Conversion of c.g.s. Units into M.K.S.*	*Conversion of S.I. Units into M.K.S.*
	For Length	
1 ft = 0.3048 m 1 mile = 1.609 km = 1609 m 1 inch = 0.0254 m	1 cm = 0.01 m 1 micron (μ) = 10^{-6} m	S.I. unit is same *i.e.* *m*
	For Area	
1 ft^2 = 0.093 m^2 1 mile^2 = 2.59 km^2 = 259 ha† 1 acre = 0.4347 ha	1 cm^2 = 10^{-4} m^2	S.I. unit is same *i.e.* *m*^{2}.
	For Volume and Discharge	
1 ft^3 = 0.0283 m^3 1 acre ft = 1233.6 m^3 ≈ 0.123 ha. m = $\frac{1}{2}$ cusec. day 1 gallon (*i.e.* imp. gallon) = 4.546 litres 1 U.S. gallon = 3.785 litres	1 cm^3 = 10^{-6} m^3	S.I. unit of volume is also same *i.e.* m^3.
1 ft^3/sec (cusec) = 0.0283 m^3/sec (cumec) 1 cusec = 2.447 MLD (Million litres per day) 1 cusec = 0.538 MGD (Million gallon per day)	1 cm^3/sec = 10^{-6} m^3/sec	S.I. unit of discharge is also same *i.e.* m^3/s (cumecs)
	For Force	
1 lb* = 0.454 kg* 1 poundal = 0.031 lb* = 0.0141 kg*	1 dyne = $\frac{1}{981}$ gm* = 1.02 × 10^{-6} kg*	1 Newton (N) = $\frac{1}{9.81}$ kg* = 0.102 kg* = 10^5 dynes
	For Pressure	
1 lb/in^2 (psi) = 703 kg*/m^2 1 lb/ft^2 = 4.882 kg*/m^2	1 kg*/cm^2 = 10^4 kg*/m^2 = 10 m of water head	1 Pascal (P_a) = 1 N/m^2 = 0.102 kg*/m^2 1 k.Pa = 1000 Pa = 102 kg*/m^2 = 0.102 m of water head 100 k.Pa = 10.2 m of water head

† ha stands for hectares ; 1 ha = 10^4 m^2

*lb here is lb wt., gm here is gm wt., and kg here is kg wt.

Conversion of f.p.s. Units into M.K.S.	*Conversion of c.g.s. Units into M.K.S.*	*Conversion of S.I. Units into M.K.S.*
1 lb/cft = 16.02 kg/m^3	**For Density (ρ)** 1 gm/cm^3 = 1000 kg/m^3	S.I. unit of density is same *i.e.* kg/m^3.
1 lb*/cft = 16.02 kg*/m^3	**For unit wt. or specific wt. (γ or w = $\rho.g$)** 1 gm*/cm^3 = 1000 kg*/m^3	1 N/m^3 = 0.102 kg*/m^3 1 kN/m^3 = 102 kg*/m^3
1 ft lb* = 1.356 kg.m^2/sec^2 = 1.356 Joule (J)	**For Energy** 1 Erg or 1 g-cm^2/sec^2 10^7 Ergs = 1 kg m^2/sec^2 = 1 Joule	S.I. unit is Joule where 1 Joule = 1 N.m = 1 kg-m^2/sec^2
1 Btu or BTU = 0.252 k.cal = 1.055 kJ	**For Heat Energy** 1 cal = 10^{-3} k.cal	1 kJ = 0.239 k.cal
1 ft lb*/sec = 0.138 kg* m/sec 1 H.P. (fps) = 550 ft* lb/sec = 75.9 kg* m/sec = 746 watts	**For Power** 1 gm* cm/sec = 10^{-5} kg* m/sec 1 H.P. (metric) = 75 kg m/sec = 735 watts	S.I. unit is watt, where 1 Watt (*W*) = 1 J/s = 1 Nm/s = 0.102* kg* m/sec = $\frac{1}{735}$ H.P. (metric)
f.p.s unit is lb sec / ft²*, *where* 1 lb* sec/ft^2 = 4.887 kg* sec/m^2 (mks)	**For Dynamic Viscosity (η or μ)** (*c.g.s. unit is dyne. sec / cm²* or **Poise** 1 Poise = 0.0102 kg sec/m^2 1 centi poise (cP) = 10^{-2} P	*S.I. unit is N.s / m²* or Pa.s 1 N.s/m^2 = 1 Pa.s = 10 **Poise** = 0.102 kg* sec/m^2
1 ft^2/sec = 0.093 m^2/sec	**For Kinematic Viscosity** $\left(\nu = \frac{\mu}{\rho} \text{ or } \frac{\eta}{\rho}\right)$ 1 cm^2/sec **(Stoke)** = 10^{-4} m^2/sec 1 centi stock = 10^{-2} Stock	*S.I. unit is same as in M.K.S. : i.e. m²/s* 1 m^2/s = 10^4 **Stoke** (St)

[Note. *w* for water = 1000 kg/m^3 = 9.81 kN/m^3 = 9810 N/m^3.]

*kg here is kg wt., lb here is lb wt., and gm here is gm wt.

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Introduction

1.1. Systems of Sanitation

The waste products of a society including the human excreta had been collected, carried and disposed of manually to a safe point of disposal, by the sweepers, since time immemorial. This primitive method of collecting and disposing of the society's wastes, has now been modernised and replaced by a system, in which these wastes are mixed with sufficient quantity of water and carried through closed conduits under the conditions of gravity flow. This mixture of water and waste products, popularly called **sewage,** thus automatically flows up to a place, from where it is disposed of, after giving it suitable treatments ; thus avoiding the carriage of wastes on heads or carts. The treated sewage effluents may be disposed of either in a running body of water, such as a stream, or may be used for irrigating crops.

This modern **water-carried sewerage* system** has completely replaced the **old conservancy system of sanitation** in the developed countries like U.S.A. However, India being a developing country, still uses the old conservancy system at various places, particularly in her villages and smaller towns. The metropolitan cities and a few bigger towns of our country, no doubt, have generally been equipped with the facilities of this modern water carriage sewerage system ; and attempts are being made to equip the remaining cities and towns with this system, as soon as funds become available.

The *modern water-carried sewerage system* is preferred to the old conservancy system, because of its following *advantages* :

(*i*) The water carriage system is more hygienic, because in this system, the society's wastes have not to be collected and carried in buckets or carts, as is required to be done in the conservancy system.

The free carriage of night soil in carts or as head load, which is required in the conservancy system, may pose health hazards to sweepers and other residents, because of the possibilities of flies and insects transmitting disease germs from these accessible carts to the resident's foods and eatables ; whereas, in modern sewerage system, no such danger exists, because the polluted sewage is carried in closed conduits, as soon as it is produced.

(*ii*) In the conservancy system, the waste products are generally buried underground, which may sometimes pollute the city's water supplies, if the water supply pipes happen to pass through such areas or the wells happen to draw water through such areas.

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*The term sewerage is applied to the art of collecting, treating and finally disposing of the sewage.

(*iii*) In the conservancy system of sanitation, the entire day's human feces are collected and then disposed of in the morning, once a day. Thus, from this type of latrines, pungent smells may continue to pollute the surroundings for the entire day. But since in the water carried system, the human excreta is washed away as soon as it is produced, no such bad smells are produced. Moreover, in the conservancy system of sanitation, the waste waters from bath rooms, wash basins, kitchen sinks, etc. ; is carried through open road side drains, as this is supposed to be not so foul, since it does not contain human excreta. But these road side drains are generally abused by children or adults for passing their stools, particularly at night hours, thus creating foul and more unhygienic conditions. No such problems exist in the water carriage system.

(*iv*) In water carriage system, the sewage is carried through underground pipes (popularly called **sewers**) which owing to their being underground, do not occupy floor area on road sides or impair the beauty of the surroundings. The road side drains carrying foul liquid in the conservancy system, will no doubt pose such problems.

(*v*) The water-carried system may allow the construction of latrines and bath-rooms together [popularly called water-closets (W.C.)], thus occupying lesser space with their compact designs. This system is also very helpful for multistoreyed buildings, where the toilets, one above the other, can be easily constructed, and connected to a single vertical pipe.

Inspite of these advantages of the modern water-carried system, it has not been possible to completely replace the old conservancy system, mainly because huge capital funds (of the order of ₹ 10,000 to 15,000 per person) are required for the construction of such a system. Besides the huge initial investments, the RMO expenses are also high, which make it difficult to replace the simpler and cheaper conservancy system. Moreover, for the functioning of sewerage system, ample amount of water must be made available to the people, and hence, reliable and assured water supply system must, first, be installed, before installing the sewerage system.

1.2. Types of Sewage, and Types of Sewerage Systems

This modern water carriage sewerage system not only helps in removing the domestic* and industrial** wastewaters, but also helps in removing storm water drainage***. The run off resulting from the storms is also sometimes

*__Domestic sewage__ consists of liquid wastes originating from urinals, latrines, bath-rooms, kitchen sinks, wash basins, etc. of the residential, commercial or institutional buildings. This sewage is generally extremely foul, because of the presence of human excreta in it.

**__Industrial sewage__ consists of liquid wastes originating from the industrial processes of various industries, such as Dyeing, Paper making, Brewing, etc. The quality of the industrial sewage depends largely upon the type of industry and the chemicals used in their process waters. Sometimes, they may be very foul and may require extensive treatment before being disposed of in public sewers.

The sum total of domestic and industrial sewage, may be termed as **sanitary sewage** or simply **sewage**.

***The run-off resulting from the rain storms was used to be called **storm sewage,** but the modern approach is to call it **storm drainage** or simply **drainage,** so as to differentiate it from *sewage*, which is much more foul as compared to the *drainage*, and requires treatment before disposal.

carried through the sewers of the sewerage system, or more generally is carried through separate set of drains (open or closed) directly discharging their drainage waters into a body of water, such as a lake or a river. Since the rain run-off is not so foul as the sewage is, no treatment is generally required to be given to the drainage discharge. When the drainage is taken alongwith sewage, it is called a **combined system** ; and when the drainage and sewage are taken independently of each other through two different sets of conduits, it is called a **separate system.** Sometimes, a part of drainage water, especially that originating from the roofs or paved courtyards of buildings, is allowed to be admitted into the sewers ; and similarly sometimes, the domestic sewage coming out from the residences or institutions, etc., is allowed to be admitted into the drains, the resulting system is called a **partially separate system.**

Strictly speaking, it is generally advantageous and economical to construct a 'separate system' at least in the bigger cities and towns. But in practice, it is generally not possible to attain a 'truly separate system' because some rain water may always find its way into the sewers either through wrong house sewer connections or through open manhole covers. Similarly, wherever the authorities find insufficient sewer capacities, they divert part of the sewage into the storm water drains, thus making most of our existing systems as 'partially separate' only.

In the modern days, a 'separate system' is generally preferred to a 'combined system', although each individual case should be decided separately on merits, keeping the following points into consideration :

(*i*) A separate system will require laying two sets of conduits, whereas, a combined system requires laying only one set of bigger sized conduits, thus making the former system costlier. Moreover, the separate conduits cannot be laid in congested streets and localities, making it physically unfeasible.

(*ii*) The sewer pipes in the combined system are liable to frequent silting during the non-monsoon season (when the flows in them are quite less*) unless they are laid at sufficiently steeper slopes, which, in turn, will make them deeper, requiring more excavation and pumping, thereby making them costlier.

(*iii*) In a combined system, the less-foul drainage water gets mixed with the highly foul sewage water, thus necessitating the treatment of the entire flow, needing more capacity for the treatment plant, thereby making it costlier. Whereas, in the separate system, only the sewage discharge is treated and the drainage discharge is disposed of without any treatment.

(*iv*) In case, flooding and backing up of sewers or drains occur due to excessive rains, more foul and insanitary conditions will prevail in the case of combined sewage than in the case of storm drainage alone.

(*v*) Since the sewer lines are generally laid deep and at steeper slopes, as compared to the storm water surface drains, pumping of sewage and often no

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*Since heavy rain storms concentrated for a period of 3 months or so do occur, and there are poor water supplies here in India, the ratio of the 'drainage' to 'sewage' works out to be as high as 20 to 30. Thus, during non-monsoon periods, only 1/20th to 1/30th of the designed discharge will be passing through the sewers, if the combined system has been adopted.

pumping of drainage is required in a separate system. Whereas, the entire discharge will have to be pumped, if the sewage and drainage discharges are mixed together ; thereby making the combined system more costly.

(*vi*) The economy of the two systems must be worked out for each individual project, and the economical system be adopted, if physically feasible.

1.3. Components of a Sewerage System

A sewerage system consists of a network of sewer pipes laid in order to carry the sewage from individual homes to the sewage treatment plant. This network of sewers may consist of *house sewers* (or individual house connections) ; *lateral sewers* ; *branch sewers* (or submains) ; *main sewers* (generally called *trunk sewers*) ; *outfall sewer* (*i.e.* the sewer which transports sewage to the point of treatment) ; etc. *Manholes* are provided in every sewer pipe at suitable intervals, so as to facilitate their cleaning and inspection. In the sewers, which carry the drainage discharge either solely or in combination with sewage, *inlets* called *catch basins* are provided to permit entrance of storm water from street gutters.

In order to avoid the large scale pollution of the water sources and to keep them usable for the downstream people, the original contaminated sewage is not allowed to be discharged directly into the water sources. A complete treatment including *screening, sedimentation, biological filtration* (or *activated sludge treatment*), *sludge digestion,* etc. is therefore, given to this extremely foul sewage, so as to bring down its BOD and concentrations of other constituents to safer values, before discharging it into a national river resource. However, a recent use of sewage is being made for irrigating crops. For this use also, the sewage has to be treated, so as to bring down its constituents to permissible values, as per the requirements of I.S. 3307—1965.

All these aspects are explained in details in subsequent chapters.

1.4. Design and Planning of a Sewerage System

The sewerage system must be properly and skilfully planned and designed, so as to remove the entire sewage effectively and efficiently from the houses, and up to the point of disposal. The sewers must be of adequate size, so as to avoid their overflow and subsequent damages to properties, and health hazards. In order to provide economically adequate sized sewers, it is necessary that the likely sewage discharge be estimated as correctly as possible. The sewer pipes should then be designed to be laid on a slope that will permit reasonable velocity of flow. The flow velocity should neither be so large, as to require heavy excavation and high lift pumping ; nor should it be so small, as to cause the deposition of solids in the sewer, bottoms.

The sewers are generally designed to carry the water from the basements, and should therefore, be atleast 2 to 3 m deep. As far as possible, they should be designed to flow under gravity with $\frac{1}{2}$ or $\frac{3}{4}$ th full. Owing to the requirements of seeking gravity flow, the sewage treatment plant should generally be located in a low lying area. The design of the treatment units also requires good engineering skill. In order to provide adequate and economical treatment, it is necessary to thoroughly study the constituents of the sewage produced in the particular project, and also the quality and other characteristics of the body of water that will receive the sewage. The permissible standards for effluents, and the possible uses of water downstream, should also be studied. The legal bindings, if any, will also have to be taken into consideration, while deciding upon the quantum of treatment required to be given. No fixed standards can be laid for fixing this required treatment, as everything depends upon the exigencies of a particular project.

Since the treatment plant will have to be located at low level ; the flood protection devices both during construction and thereafter, should also have to be taken care of, by the design engineers.

All these design requirements shall be thoroughly discussed in this volume.

1.5. Financing the Sewerage Projects

The full fledged development and functioning of a sewerage system requires enormous capital investments and large amounts of recurring RMO expenses.

The initial money has, of course, to be provided by the Government, but the interest on the capital investments and the depreciation charges as well as the RMO (*i.e.* Running, Maintenance and Operation) expenses must be recovered from the users of these facilities by properly taxing them. However, there cannot be a very rational system of taxing the users of sewerage facilities, because it is not feasible to estimate the quantity of sewage removed from an individual house, and hence cannot be as rationally taxed as can be done for water supplies, which can be measured and taxed according to the volume of water consumed. Consequently, the sewerage services may be financed by adding a certain surcharge, usually a percentage to the water bill. This is somewhat rational in the sense that sewage produced by the house will be directly proportional to the water consumed. Sometimes, charges for sewerage facilities are added, as certain percentage of the annual valuation of the house property, to the property/house tax bills. Nevertheless, the planning engineer must also develop the suitable and logical financing programme, indicating the sources of income and balancing them against depreciation, interest and RMO charges.

1.6. Liability for Damages Caused by Insufficient or Inefficient Sewerage Works

In case of certain damages, the process of claiming compensations through law courts is largely adopted in developed countries like U.S.A. However, Indian people, striving hard for their bread and butter, find it very difficult and almost impossible to go to the long process of redressal through law courts. Moreover, generally, when certain authorities or officials are sued in the court for damages, normally a certain percentage of the claimed amount has to be deposited, making it almost impossible for an ordinary Indian to go to the courts for claiming damages. Nevertheless, we will state here, a few possible chances, when compensations can be successfully claimed, in case certain damages have been caused by insufficient or inefficient sewerage works:

No city governments or public municipalities can be held responsible for not providing sewerage facilities ; but however, when once such facilities have been provided, the officials and municipal bodies will become responsible to certain extent for any damages caused to the health or properties of the citizens, due to its insufficient or inefficient provisions or operations.

If the sewerage system has been constructed, as designed by a competent engineer, normally nothing can be claimed by the sufferers due to inadequate size of sewers. Still, however, damages can always be claimed, if there is some established negligence on the part of the authorities in the maintenance or operation of sewerage works. For example, if the blockage of a sewer is reported to the authorities, who do not take prompt action, then the consequent damages caused by the backing up and overflowing of the sewers, can always be claimed. Similarly, if the leaking sewers happen to pollute water supplies, damages can be claimed for affecting public health, but only if it can be established that the sewerage authorities had a preknowledge of the situation, and they failed to remedy the same. Similarly, if certain manhole cover is left open due to poor maintenance, and if a child happens to fall in it, damages can always be claimed. But again negligence, will have to be established. Even without any negligence, the damages can always be claimed by the property owners for depreciation of their properties, if sewage treatment plant has been established near their properties, which gives off obnoxious smells. Similarly, throwing away of untreated or partially treated sewage in a river resource, may pollute the river water, and pose health hazards to the people utilising such waters, downstream. In such a case also, the affected people can claim compensations.

PROBLEMS

1. Describe conservancy and water-carriage systems. What are the relative advantages and disadvantages of the two system ?

2. Discuss briefly the necessity of replacing the conservancy system by the water carriage system of sanitation.

3. Discuss the relative merits of the separate and the combined systems of sewage, and give the conditions favourable for the adoption of each one of them.

4. Differentiate between :

(*i*) Domestic sewage, industrial sewage and sanitary sewage ;

(*ii*) Combined and separate systems of sewage ; and

(*iii*) Sewage and drainage.

5. Write short notes on :

(*i*) Financing the sewage projects ;

(*ii*) Liability for damages for insufficient or inefficient sewerage facilities ;

(*iii*) Types of sewages ; and

(*iv*) Systems of sewerage.