Environmental Engineering

Water Supply, Sanitary Engineering and Pollution

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Tata McGraw-Hill Publishing Company Limited
NEW DELHI

McGraw-Hill Offices

New Delhi New York St Louis San Francisco Auckland Bogotá Guatemala Hamburg Lisbon London Madrid Mexico Milan Montreal Panama Paris San Juan São Paulo Singapore Sydney Tokyo Toronto

Sponsoring Editor: REUBEN ISRAEL
Editorial Supervisor: KAUSHIK GHOSH
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Published by Tata McGraw-Hill Publishing Company Limited,
4/12 Asaf Ali Road, New Delhi 110 002, and printed at
Roopabh Printers, 4 115 Vishwas Nagar, Shahdara, Delhi 110 032

Foreword

Environmental engineering is an emerging area with considerable potential. This subject covers major areas concerning water, air, and land environments. Increasing populations necessitate rapid industrialisation and greater urbanisation. This causes water, air, and land environments to suffer. Every citizen in general, and every engineering student in particular, should be aware of the natural state of the environment, its capacity to adjust and its abuse and the consequential problems. However the civil engineering student should know more about the environment as he is charged with the responsibilities of supplying quality water and collecting, treating and disposing waste waters. Collecting, transporting and disposing solid wastes also form part of the civil engineering profession.

Even though excellent textbooks written by foreign authors are in the market, these books deal with the situations prevailing in the advanced countries, and are very costly. A few books authored by Indians have come out. However, these are not sufficient and more authors are to be encouraged in this area. This book is a welcome addition.

In this book, the course contents are framed to meet specific objectives. The authors' vast experience in various capacities in technical education have probably helped them in this successful attempt. Environmental engineering, like any other engineering subject, has to be taught such that the scientific principles, engineering design and practice parameters are understood by the student. Every textbook writer should aim at it and every teacher should strive for this.

I am sure the teachers and students of polytechnics will find this book very useful.

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Preface

A civil engineering technician is expected to be in charge of the operation and maintenance of water supply and sanitary works, and conduct tests to determine the quality of water and sewage so that the right type of treatment may be given. An attempt has been made in this book to present the basic principles of water supply and sanitary engineering so that the technician would achieve the above objectives after going through the book. In view of the importance of environmental engineering, an elementary treatment of air pollution and industrial waste treatment processes has been included to enable the civil engineering technician to keep abreast of the latest trends and techniques in the field.

The book caters to the requirements of the syllabi prescribed by various Boards in Public Health Engineering (Environmental Engineering). The material has been made, as far as possible, practice-oriented and the Government of India Manual developed by an expert Committee as well as I S Codes have been followed. We thank Sir Naram Krishna Rao, Retired Chief Engineer, Andhra Pradesh, for having reviewed the material and offered suggestions to make it more practical.

The subject matter has been explained in simple and lucid language with plenty of sketches to enable the students of polytechnics to follow the contents with very little help. A number of objective-type, short-answer and structured essay-type questions have been included at the end of each chapter for the benefit of the student in testing his understanding of the subject.

Comments and suggestions are welcome from users of the book.

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Contents

1

Introduction

Objectives: *Upon completion of this unit, the student should be able to know the importance of water-supply.*
State the necessity for public water-supply ○ List the major treatment processes for a water-supply scheme with the help of a flow chart.

1.1 GENERAL IMPORTANCE OF PUBLIC HEALTH ENGINEERING-WORKS

Water is essential for life. Without water, human beings cannot survive. This is the reason why civilisations have always sprung up on river-banks. Water is required for various purposes in community life, viz. cooking, drinking, bathing, washing, watering gardens, etc. In olden days, water was carried in pots for domestic use from wells for the family's needs. But as the community developed and with the concentration of population in cities, the demand for water increased. Also with the rapid industrialisation taking place, a vast amount of water is required to run industries. The community has to be protected from fire-hazards. For all these needs, it is no longer possible to depend on private individual sources of supply. Hence, it is important that water is supplied to the community from a public source and it should be safe for drinking purposes.

The population of India is likely to be around 1000 millions by the end of this century. The urban population would be around 400 millions by that time, which would be almost double the present urban population. Hence, there would be heavy demand for water-supply for domestic as well as other needs such as irrigation, industry, etc. This would call for identification of sources of water and their proper use.

The task of constructing and maintaining water-supply and sanitary works is that of the Civil engineer and hence the Civil engineering student should have a thorough knowledge of Public health engineering and should understand the principles of planning, designing and estimating water and sanitary works.

1.2 DEVELOPMENT OF WATER-SUPPLY

The first modern water-supply and sanitary schemes were started in 1800. With the advent of the theory of water-borne diseases by germs, there was rapid development in water-supply and sanitary schemes and almost all the important towns in the UK and the US were provided with protected water-supply.

In India, the first public water-supply system was provided for Calcutta in 1870 and was followed by other cities. The progress, however in this field has been very slow. Although during the First and Second Five Year Plans, several crores of rupees were alloted for water-supply and sanitary schemes, shortage of materials like cost-iron pipes and technical manpower hampered progress.

The National Water Supply and Sanitation Committee of 1960 reported that only 6.5% of the population was supplied with potable drinking water and that too mostly catering to the urban population. Even this is grossly inadequate. There are very few cities which provide continuous water-supply to the community. India has thus a long way to go in the matter of providing safe drinking water to urban and rural areas. Therefore, the Government has now formulated proposals, in accordance with the International Decade for Water-Supply and Sanitation Programme, to be executed at a cost of Rs. 15,000 crore for the entire country. This envisages protected water-supply to all people residing in towns and villages.

1.3 NEED FOR PROTECTED WATER-SUPPLY

Water supplied to the community should be treated to make it fit for drinking purposes for the following reasons:

- The water in the rivers is often polluted by the people inhabiting the watershed. This water carries bacteria, some of which are pathogenic, and can cause water-borne diseases such as typhoid, dysentery (amoebic and bacillary), cholera, etc. When such water is consumed by human beings, there may be epidemic outbreak of the diseases mentioned.
- Wases from some of the industries are let off into rivers and pollute the water rendering it unsafe for human consumption.
- Surface run-off due to rainfall partly percolate into the ground dissolving the salts and minerals present in the soil. As a result, sometimes the ground water cause diseases such as fluorosis due to the presence of fluorides in the water. For example, in some districts of Andhra Pradesh many people suffer from the effects of fluorosis contracted from water consumed. First there may be the mottling of teeth and later deformation of the bones.

1.4 GENERAL LAYOUT OF A WATER-SUPPLY SCHEME

The source of water-supply may be surface water such as a river, or a lake ground water source such as deep well or spring. The water is collected by intakes. Raw water contains suspended and dissolved impurities as well as harmful bacteria. The water from intakes is therefore first taken to the treatment plants. Following are the main processes involved in a typical water-supply treatment plant:

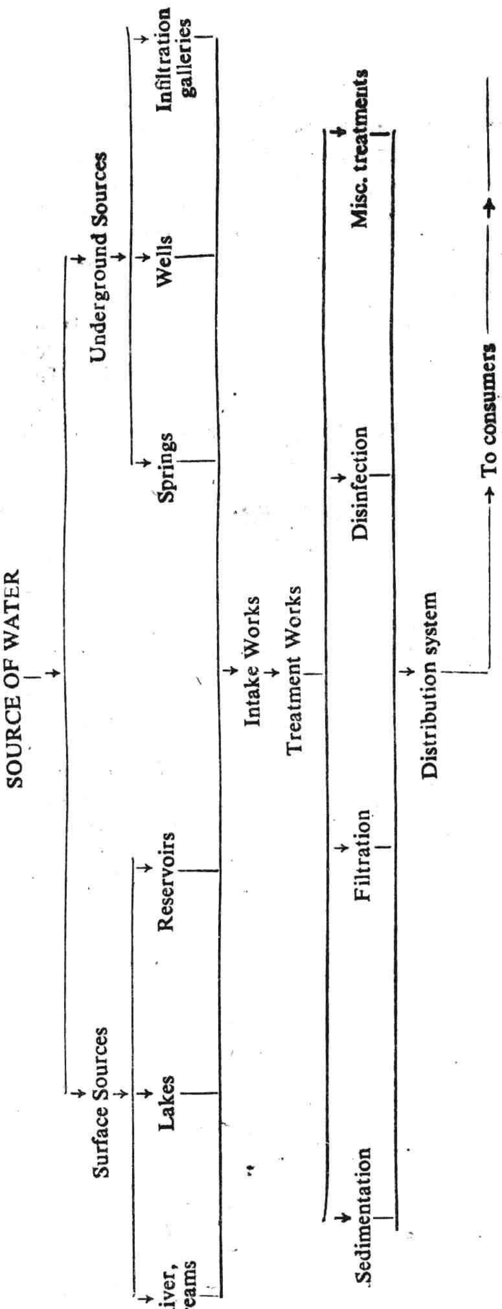

FIG. 1.1 Flow Diagram of a Water-Supply Scheme

- Sedimentation
- Filtration
- Disinfection

In the process of sedimentation, the suspended solids are removed by allowing them to settle down in sedimentation or settling tanks. Sometimes chemicals called coagulants are added to expedite the settling process.

The water from sedimentation tank is taken to filter beds which consist of large layers of sand through which the water passes. The colloidal matter (fine suspended solids) and part of the bacteria are removed.

The remaining bacteria in the water are destroyed by the addition of disinfectants such as chlorine.

The water thus purified is stored in Storage reservoirs from where it is distributed to the town through pipes. The distribution system consists of arterial mains, distribution mains and minor distributaries. The water flows under gravity but sometimes pumping is resorted to.

A typical flow diagram showing the process is given in Fig. 1.1.

EXERCISES

Structured Essay-Type Questions

1. State the need for supplying potable water to community.
2. List the major treatment processes in a water-supply scheme with a flow-chart.

2

Quantity of Water

Objectives: *Upon completion of this unit, the student should be able to know the procedure for estimating water requirements for a water-supply scheme.*
List the factors affecting per capita demand ○ State the requirements of water for domestic purposes, commercial and institutional needs, industrial use, public use, and fire-fighting ○ Explain the variation in demand for water-supply scheme for a town ○ Work out simple problems of forecasting population by different methods ○ State the method of determining total quantity of water required for a water-supply scheme.

2.1 INTRODUCTION

In the design of any waterworks project, the quantity of water required should be first estimated. The quantity of water required depends on the following three factors:

- Rate of demand
- Design period
- Population to be served

The rate of demand is the rate of water to be supplied per person per day. This depends on several factors such as requirements for domestic consumption, normal industrial needs, fire demand, etc. The total demand for all the needs including common requirements such as fire demand, etc., are worked out on per capita basis by dividing the total demand by the number of persons served. The rate of demand is expressed as so many litres/capita/day. Thus if P is the population served, and Q is the quantity of water required per year in litres, then the per capita demand is given by:

$$\frac{Q}{P \times 365} \text{ litres}$$

The design period is the useful of the water-supply scheme. A water-supply scheme is generally designed to meet the requirements over a period of 30 years after its completion.

The population to be served at the end of the design period is estimated by a suitable method. The population to be served multiplied by the rate of demand gives the total quantity of water required.

2.2 FACTORS AFFECTING THE RATE OF DEMAND

It is necessary to know the rate of water to be supplied, as pipes, water-works, etc., have to be designed suitably. The demand for water varies from town to town. The factors affecting the rate of demand are:

- Climatic conditions
- Cost of water
- Habits of people
- Efficiency of the water system
- Metering of services
- Presence or absence of industries
- Quality of water
- Presence or absence of sewerage system
- Sytem of supply.

These factors are explained as follows:

1. **Climatic Conditions** The consumption of water depends on the climatic conditions of the place. For example, in warm countries, water required in summer will be much more than in winter as more watering of gardens, more bathing, more airconditioning, more watering of parks and fountains, etc., would be done. However, in cold countries in winter, taps are kept open to prevent freezing of pipes. This may, therefore, increase consumption in winter.

2. **Cost of Water** The cost of water has an effect on the consumption. If the cost is high, the consumption will be low while it will be high if the cost is less.

3. **Habits of People** The consumption of water depends on the economic status of the consumers and will differ widely in different localities in the same city. In posh localities, the consumption per capita will be high while in slum areas, a common tap may serve several families and thus the consumption per capita would be low.

4. **Efficiency of the Water-Supply System** Efficieny of the waterworks will affect consumption. Leaks in mains, unauthorised connections, etc., increase losses and hence the consumption. These can be reduced by frequent inspection and check.

5. **Metering the Services** Metering consists in provindig a meter in the pipeline from the water main to the building served. Metering generally reduces the consumption of water and forces consumers to use water carefully.

6. **Industries** If industries are present, the water consumption will be more. If, however, the industry has its own source of supply supplementing the city water supply, the consumption will not be affected. Zoning of the city earmaking certain areas for industry would be helpful in estimating the water requirement more accurately.

7. **Quality of Water** The consumption of water varies directly with the quality of water. If the quality is good, then the consumption will be high, while the consumption will be low if the water has an unpleasant odour or taste.

8. Sewerage System If sewerage system exists in the town, the consumption of water will be more. In a sewered home more water will be used for flushing urinals and water closets.

9. System of Supply The water-supply to a town may be continuous or intermittent. In the continuous supply system, the supply will be maintained throughout the day while in the intermittent supply system, the supply will be given only for a few hours in the day.

In the intermittent supply system, the consumption is less. However, there is some dispute about this. It is observed that the intermittent supply consumes more as taps are kept open during non-supply period and when supply is started, water is wasted through these taps. Also people have a tendency to throw away water and collect fresh water when supply is started.

2.3 WATER REQUIREMENTS

The consumption of water for public water-supply scheme is divided into the following classes:

- Domestic needs
- Commercial and institutional needs
- Industrial needs
- Public use
- Fire demand
- Loss and wastage

1. Domestic Needs Supply of water for domestic needs includes water for drinking, washing, cooking, bathing, flushing of toilets, gardening and other purposes such as air-conditioning. The quantity of water required depends on the habits of the peoples served. According to IS: 1172-1983, the minimum requirements of water for domestic consumption is 200 litres per capita where there is flushing system out of which 45 litres/head/day may be taken as flushing requirements and the remaining quantity for other domestic purposes.

2. Commercial and Institutional Needs Commercial needs include the needs of shopping centres, hotels, cinema houses, etc. Institutional demand includes the needs of schools, offices, hostels, etc. According to IS: 1172-1983, the water-supply needs for public buildings other than residences, are shown in Table 2.1.

3. Industrial Needs For small industries within the town, the water required is included in the per capita rate itself. Large industries may use their own source of water. However, if water is required from the public water-supply, then the water required depends on the type and size of industry. The requirement also depends on factors such as the cost of water, availability of water, method of waste disposal and the type of processes involved. Hence the demand for each industry has to be examined individually. The water requirement for a few industries is given in Table 2.2.

TABLE 2.1 **Water Requirements for Buildings other than Residences**

S. No.	Type of building	Consumption per day in litres
1.	(a) Factories where bathrooms are provided	45 per head
	(b) Factories where no bathrooms are provided	30 per head
2.	Hospitals (including laundry)	
	(a) No. of beds not exceeding 100	340 per bed
	(b) No. of beds exceeding 100	455 per bed
3.	Nurses' homes and medical quarters	135 per head
4.	Hostels	135 per head
5.	Offices	45 per head
6.	Restaurants	70 per seat
7.	Hotels	180 per bed
8.	Cinemas, concert halls and theatres	15 per seat
9.	Schools	
	(a) Day schools	45 per head
	(b) Boarding schools	135 per head

TABLE 2.2 **Water Requirements of Industry**

Industry	Unit of production	Water requirement in kilolitres/unit
Automobile	one vehicle	40
Fertiliser	tonne	80—200
Leather	100 kg	4
Paper	tonne	200—400
Sugar	tonne	1—2
Textile	100 kg	8—14

4. **Public Use** Water has to be supplied for public purposes such as washing of street, flushing of sewers, parks, etc. This may be taken as 25 litres per day per capita.

5. **Fire Demand** The Manual on Water Supply and Treatment published by the Government of India recommends the provision of a quantity of water for fire demand obtained in kilolitres/day by the use of the formula $100\sqrt{P}$, where P = population in thousands. This formula is to be adopted for communities with population larger than 50,000. Thus, for a town of 100,000 population, the per capita demand would be

$$= 100\sqrt{100} \text{ klpd}$$

$$= 100 \times 10 \times 1000 \text{ litres/day}$$

$$= \frac{1000 \times 1000}{100{,}000} \text{ litres/capita/day}$$

$$= 10 \text{ litres/capita/day}$$

About 1/3rd of the quantity required for fire-fighting needs is to be kept in service reservoirs, i.e., the reservoir from where the water is distributed to the town. Water for the remaining requirement is stored in several tanks provided at important places. These tanks are filled up by tankers fetching water from nearby ponds, canals or streams.

6. Loss and Wastage Loss of water in a waterworks system is due to:

- Unauthorised water connections
- Leaks in mains due to faulty joints
- Motor and pump slippage.

The loss due to unauthorised connections may be reduced by surveying the areas and detecting them. Even in a 100% metered system, the loss of water sometimes is of the order of 20-30%. Wastage can also be caused by the householder who throws away the stored water and collects fresh water when it is released.

2.4 TOTAL QUANTITY OF WATER FOR A TOWN

The total quantity of water required for a town is the sum of all the requirements explained before. But the requirements vary from town to town depending upon the number and type of industries in the town, the number and type of commercial places, etc.

For an average Indian town, the total demand of water in li[illegible] head per day is as follows:

Domestic use	135
Industrial use	40
Public use	25
Fire demand	15
Losses, wastage	55
	270 litres per head per day

T[illegible]is per capita rate multiplied by the population will give the total qu[illegible]ntity of water required per day for the town.

2.5 VARIATIONS IN RATE OF DEMAND

It is observed that the consumption per capita varies from season to season, month to month, day to day as well as hour to hour. The peak demand, i.e., the maximum consumption in an hour or in a day depends on the habits of the people, climatic conditions, the presence of industry, type of industry, and the mode or hours of supply of water by the authorities.

The peak seasonal consumption occurs in summer when more water will be used for bathing, watering lawns, etc. The peak monthly consumption occurs in summer months. The maximum daily consumption may occur on Sunday when more water for washing and bathing is u[illegible]ed. A typical peak hourly demand graph is shown in Fig. 2.1. It may be noted that the peak demand is during 7 to 9 am on week days and steadily falls and the minimum is reached between 11.00 am to 1.00 pm and again reaches the peak between 7 to 9 pm. The minimum demand on the water system is from 9.00 pm to 5.00 am.

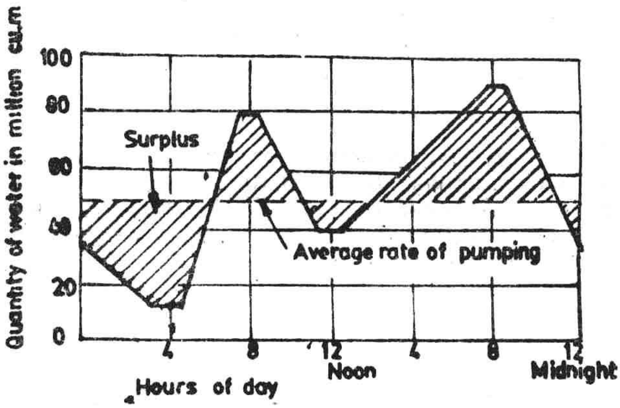

FIG. 2.1 Rate of demand

The rate of demand of the peak hour of the peak day of the maximum demand season is called the absolute maximum hourly demand. The average daily consumption is found by dividing the total annual consumption by the number of days in a year. It has been observed that the peak demand with respect to the average demand is approximately as shown below:

Hourly peak demand	150% of average demand	
Daily peak demand	180%	-do-
Weekly peak demand	150%	-do-
Monthly peak demand	130%	-do-

For example, if the daily average demand for a town is 100 million litres/day, then the maximum daily consumption will be 100 × 1.8 = 180 million litres. The maximum hourly demand is as high as

$$\frac{100 \times 1.8 \times 1.5}{24} = 11.3$$

million litres. The average hourly demand, however would be only 100/24 = 4.2 million litres. The maximum hourly demand is thus nearly three times the average demand.

These values of maximum consumption during a day or an hour are essential for designing the distribution as well as the pumping systems. In case pumps have to directly pump water into the distribution mains, they should be capable of catering to the maximum hourly demand. Generally, a reservoir is provided to balance the demand. In Fig. 2.1, the average rate of pumping is shown, the area above the line indicates the shortage and that below the line indicates surplus. Water is pumped during slack hours and is drawn according to requirements. The storage capacity of the reservoir is generally designed so as to hold four to six hours supply.

The distribution mains, pumps and storage arrangements are designed for maximum hourly demand, i.e., three times the average hourly consumption. The service pipes and feeders are designed for twice the average demand.

2.6 FORECASTING POPULATION

Having decided the design period, the population to be served at the end of the period should be forecast to calculate the water requirements. The population at a future date is determined from the present population and the population of the previous years. The population of any town or city can be obtained from census records.

The following are some methods by which future population is forecasted:

- Arithmetical increase method
- Geometrical increase method
- Incremental increase method.

1. Arithmetical Increase Method In this method, the increase in population is assumed to be constant. The increase in the population is taken as the average increase in the last two or three decades (1 decade = 10 years). Thus if the present population is P, the average increase d, then the population P_n after n decades is given by:

$$P_n = P + nd.$$

Example 2.1 The population figures of a town from census records are given in Table 2.3. Find the population after three decades, i.e., at the end of the year 2011 by the arithmetical increase method.

TABLE 2.3

Year	*Population*	*Increase in population*
1951	100 000	–
1961	109 000	9 000
1971	116 600	7 600
1981	128 200	11 600

Solution Increase in population from 1951 to 1981, i.e., in three decades

$$= 128\,200 - 100\,000$$
$$= 28\,200$$

Increase per decade $= \dfrac{28\,200}{3} = 9400$

Population after three decades, i.e., in 2011

$$= 128\,200 + (9400 \times 3)$$
$$= 156\,400.$$