Department of Civil Engineering, I.I.T. Delhi

CEL795: Water and Wastewater Treatment Processes

(1st Semester 2011-2012)

Water: Sources and Requirement *(Courtesy: Dr. Arvind K. Nema)*

1.1. Introduction

Water is chemical compound of hydrogen and oxygen which occurs in solid, liquid and gaseous form. These all forms are considered to be most useful for existence of life. It is considered to be most important component for the survival of living being next to air. Water is required for multiple uses such as agricultural, domestic, community or industrial use in our life and for each use quality of water differs. To make water available for various purposes we have to know the requirement then quantity and then the quality. As an engineer, we have to plan the water supply schemes concentrating mainly on:

- Water requirement
- Water source
- Water quality
- Water distribution network

Objectives

After studying this unit, you should be able to:

- Understand basic concepts related with water supply schemes,
- Assess the different type of water requirements,
- Factor affecting the water demand,
- List and discuss the available sources of water,
- Describe the criteria for the selection of source of water for domestic or industrial purposes.

1.2. Planning of Water Supply Schemes

In order that a community gets water as per its requirement, it is essential to plan a good water supply scheme. In planning, it is to be seen that sufficient amount of water of required quality is available to the community. Design of a suitable water supply system consists of collection, transportation, treatment and distribution.

For collection, it is essential to find out source of water, which may be as near as possible to the town or city to which water is to be supplied. If water from one source is not sufficient, then more sources are to be searched out. Amount of water required is ascertained on the basis of population forecast and per capita demand. It is to be seen that quality of collected water is as per requirement for which it is to be used. Quality requirement differs for different purpose. For example, for industry and drinking purpose water requirements may be quite different. For drinking purpose, it is to be seen that it should be palatable and should be as per standard laid of water depends on source from which it is being collected. For example, treatment of underground water and surface water may be quite different for drinking purpose. The treated water should be made available to the consumers with minimum of difficulty. Distribution system should be planned in a flexible way so that there might be provision for future development and there should be possibility of uninterrupted water supply even during repairs and maintenance. A good water supply scheme is that which gives minimum investment. Details of the water supply scheme will be discussed in detail in following chapters.

1.2.1 Financing of Water Supply Schemes

Water supply has to be done on community basis. Whole community of a particular area has to be supplied with water for their requirement. Hence, financing of water supply scheme has to be done by some agency.

When a new work has to be constructed, its capital cost may have to be borrowed. The burden of capital repayment falls on future consumers. Loan capital is repaid in annual installments over a fixed period by the capital plus interest method or by the annuity method. Alternatively a sinking fund may be set up which comprises of annual saving invested on a regular basis so that amount accumulated with interest will be sufficient to redeem the loan in one single payment when the loan period ends. In sufficient profits are made by an undertaking, depreciation of an asset value, achieves the goal of getting a new Plant or part of it after the depreciation be constructed and collecting revenue from water users, the repayment of loan and maintenance of the project from revenue collected can be done for a business project. But water supply is a welfare scheme, hence, revenue collection from users may not be sufficient to pay the loan and maintain the scheme. In such case there are two alternatives:

- To use appropriate technology
- To obtain some subsidiary or grant (mostly at the construction stage or at construction as well as maintenance stage).

1.2.2. Appropriate Technology

Many water undertakings throughout the world have limited financial resources because water supply for mankind comes under welfare schemes. They have to supply water to low income populations as well and consequently have low revenue and the government, sometimes, becomes unable to fund water works deficits and have only limited offshore earnings to pay for important items. While planning for such cases, designer should take into consideration these constraints and should use appropriate technology.

Appropriate technology means to use the Plant which is simple. It should not be so complex and automated that as soon as it develops a fault, no one knows how to repair it locally; it should be such that local people can understand and can repair themselves when it has a breakdown. While designing, the work, he should keep in mind that we should provide something which the local personnel will be able to operate efficiently and to repair them, when it develops fault. The repair of worn out of defective parts can be done locally. It may not have to be imported. For appropriately efficient, the Plant may not be latest in automated design, at the same time it should not be so crude and dependent upon a lot of hard labour in which case, the chance are that it will not run efficiently. The process of water treatment, disinfecting and pumping can be such that it is reliable, easily reparable and at the same time be labour saving to keep labour requirements within the ability of water undertaking. By such means, the engineer can ensure that the scheme will be most appropriate to be resources and needs of the undertaking.

1.2.3. Scheme Based on Subsidiary

Water supply is a welfare scheme like hospitals the government has to see that population gets good and sufficient quantity of water to keep them in good health. This is done through water board in big cities and municipalities in towns or notified area committees, where they exist. In some states, water distribution is done by Public Health Engineering Department of State Government. Through Government allocation (may be in the form of soft load or welfare scheme) water supply system is constructed and then through water tax from the consumers, maintenance of equipment and staff is done. Loan of water supply scheme are available from different foreign and national sources. UNESCO, WHO and World Bank are some of the helping agencies for water supply scheme whereas Central Governments and State Governments are the national agencies.

When water is sold to be community, following demand relationship applies

$$\mathbf{Q = k\,P^{e}} \qquad \textbf{(1)}$$

Where, Q is the consumption at price P per unit of consumption, k is a constant and e is a co-efficient which measures the elasticity of the demand. An increase of price will tend to reduce consumption, thus e is negative:

$$\textbf{Q is proportional } \mathbf{1/P^{e}} \textbf{ i.e. } \mathbf{Q \propto 1/P^{e}} \qquad \textbf{(2)}$$

When e- 0 then $P^e = 1.0$ meaning that changes of prices have no effect on consumption. The elasticity of demand is said to be nil. This happens when the price is so low that it has no effect on consumption or need for water is so great that it must be had at any price. When e = -1.0, then Q is proportional to 1/P in which case small change is P cause almost same proportionate change in Q.

1.2.4. Design Period of Water Supply Scheme

Water supply projects are designed to serve over a specified period of time. This time after completion of the project is called "design period". It is expressed in years. During design period, the structures, equipment and components of the water supply scheme are supposed to be adequate to serve the requirements. As per normal procedure water works is designed for a period of 30 years. Following factors are considered before taking in a decision on design period of water supply schemes:

i) Useful life of pipes, equipment and structures.
ii) The anticipated rate of growth. If rate is more, design period will be less.
iii) The rate of inflation during the period of repayment of loans when inflation rate is high, a longer design period is adopted.
iv) Efficiency of component units. The more the efficiency, the longer will be design period.

As per Indian Standard, average design period of different components are given in Table 1.1

Table 1.1: Design Period of Different Components of a Water Supply Scheme

S.No.	Components	Design Period (Years)
1	Storage by Dams	50
2.	Infiltration Work	30
3.	Pumping	
	i) Prime House (Civil Works)	30
	ii) Electric Motors and Pumps	15
4.	Water Treatment Units	15
5.	Pipe Connections to Several treatment units and other small appurtenances	30
6.	Raw water and clear water conveying mains	30
7.	Clear waster reservoirs at head works, balancing tanks and service reservoirs	15
8.	Distribution system	30

Source: Manual on Water Supply and Treatment: III Edition (1999)

1.3. Water Requirements

Water requirement may be divided into following categories:

a) Domestic,
b) Institutional,
c) Industrial
d) Public,
e) Agricultural, and
f) Compensation of losses.

1.3.1. Domestic Water Requirements

Domestic water requirement may be divided as:

i) In-house requirement
ii) Sprinkling requirement

In-house requirement includes drinking, cooking, sanitation, house cleaning, clothes washing etc. Sprinkling requirement includes water requirement for garden watering, lawn sprinkling, car washing etc. Domestic consumption under normal condition in an Indian city as per National Building Code, has been taken as 135 litres per head per day (in short designated as l/h/d) or litres per capita per day (lpcd).

Amount of domestic requirement may vary depending on size and location of a city or town. Depending upon location of a place living habits and condition vary. In a more civilized country per capita requirement of water is more. Similarly, for a big city per capita water requirement will be more than a small town. Per capita demand for a place may be as low as 75 lpcd to as high as 500 to 600 lcpd. Factors, which affect per capita requirement, are summarized below:-

a) **Climatic Condition :** In dried regions more water is required than colder places because of frequent bathing, more cleaning and more requirement of water for gardening etc. In hot and dry climate more consumption of drinking water is also there.

b) **Status and Habits of Residents:** For affluent class of people, more water is required because of their present habits and more sophisticated living style. For example, a house of rich people may have bathing tubs for their bath where excessive amount of water may be required per capita. In some of the Asian countries, toilets are cleaned after using it by pouring buckets of water. In addition, for their personal cleaning people use water. They do not use toilet papers and in such practice more water is consumed. In some religion people, wash themselves before every prayer and due to such habits also consumption of water varies.

c) **Size and type of the City:** for large city per capita, water requirement is more than a small town. For bigger city where population density is high, special arrangement has to be done for fire fighting also. Although this type of demand may be taken up separately, it enhances per capita water demand. Large city have sewer system for waste water disposal and for this case water requirement may go as high as three times as open drain system. A town may be a smaller one but if it is an industrial town then per capita demand may be composed with a big city because of indirect use of water. Although an average value of 135 lcpd is taken for an Indian town but the total demand may go as high as 240 to 260 lcpd for a big or an industrial city. The values varies from 75 lcpd to 260 lcpd depending upon size and location of a town or city.

d) **Availability of Sewer:** It sewage system has been provided in the locality, consumption of water will be more and per capita demand may go high. Because for flow of sewage in closed conduits sufficient water should be available. Table 1.2 suggests tentative for various water supply schemes.

Table 1.2: Recommended Per Capita Water Supply Levels for Designing Schemes

S. No.	Classification of towns / cities	Recommended Maximum Water Supply Levels (lpcd)
1.	Town provided with piped water supply but without sewerage system	70
2.	Cities provided with piped water supply where sewerage system is existing/ contemplated	135
3.	Metropolitan and mega cities provided with piped water supply where sewerage system is existing / contemplated	150

Source: Manual on Water Supply and Treatment: III Edition (1999)

e) **Mode of Water Supply:** Mode of water supply may be continuous of intermittent. In continuous system water is supplied continuously for 24 hours, whereas in intermittent system, water is supplied at peak demand hours. In morning and evening, sometimes when sufficient storage of water is available at the source, water is also supplied around noon hours. In both the systems, some advantage and disadvantage are there. In continuous supply, wastage of water is there through open and cracked joints. Whereas in intermittent supply, people leave taps open and when water supply is continued, water is wasted through these open taps. Generally, out of fear people store more amount of water than required. And when water supply is started, these collected water in pots and small tanks are thrown and again refilling is done. Of course, after getting confidence in the water supply system, this practice of water storage goes away.

f) **Policy for Water Tax Collection:** Water tax may be collected by knowing amount of water consumed. This information is obtained by providing water meters at the entrance of premises of the consumers. In that case, controlled water is consumed by consumers. But provision of water meters cause head loss and pump capacity has to be enhanced which may cause additional expenditure. Water meters may go defective and in such case accurate measurement of consumption may not be there or frequent replacement of meters, may be required which may cause annoyance to consumers. To overcome this difficult, water tax is levied on consumers as per assessment. Municipal or water supply agency assess the size and quality of house and based on some basic consumption, principle water tax is assessed. In some cases, water tax is levied on flat rate. And in such case more consumption and wastage of water is there.

Table 1.3: Recommended Water Requirement for Various Institutions

S. No.	Institutions	Liters per head per day
1.	Hospital (including laundry)	
	(a) No. of beds exceeding 100	450 (per bed)
	(b) No. of beds not exceeding 100	340 (per bed
2.	Hotels	180 (per bed)
3.	Hostels	135
4.	Nurses homes and medical quarters	135
5.	Boarding schools / colleges	135
6.	Restaurants	70 (per seat)
7.	Air ports and sea ports	10
8.	Junction Stations and intermediate stations where mail or express stoppage (both railways and bus stations) is provided	70
9.	Terminal station	45
10.	Intermediate stations (excluding mail and express stops)	45 (could be reduced to 25 where bathing facilities are not provided)
11.	Day schools/ colleges	45
12.	Offices	45
13.	Factories	45 (could be reduced to 25 where bathing facilities are not provided)
14.	Cinema, concert halls and theatres	15

Source: Manual on Water Supply and Treatment: III Edition (1999)

1.3.2. Institutional Water Requirements

In addition to domestic demand water requirement for different institutions, is also assessed for a town or city. A well developed city or town has hospitals, schools, restaurants, hotels, railway stations, bus terminus and offices of different departments. To cater to need for water of these establishments, consideration has to be given for water requirements of these units while planning for water supply system of a town or city. Bigger the town or city larger requirements will be there. On an average additional per capita demand for these units may be taken as 25 litres/head/day to 60 litres/head/day depending on the town or city. Approximate water requirements for these units may be taken as given in table 1.3 for proper assessment of water needs while planning for a water supply scheme.

1.3.3. Industrial Water Requirements

Factors governing industrial water requirement depends on several factors. Such, as type of industry size of industry and number of industries for a particular water supply scheme. A water supply scheme may be planned for a residential town and amount of water requirement, may be taken care of for existing industry in the town or city likely to come up. Sometimes, a water supply scheme is planned for an industrial area where different types of industry of different sizes are located or likely to come. A case may be there, in which size of the industry is of such a giant one, that water supply scheme has to be planned for that particular industry in addition to housing and other amenities associated with the industry. Water requirement for a few industries located in a town may be taken around 60 litres/head/day but the demand may go as high as 500 litres/head/day depending on type of industry. Table 1.4 gives an idea of water consumption for different kinds of manufacturing industrial units.

Table 1.4 : Industrial Needs of Water

Industry	Unit of Production	Water Requirement in Kilolitres per unit
Automobile	Vehicle	40
Distillery	(Kilolitre Alcohol)	122-170
Fertilizer	Tonne	80-200
Leather	100 Kg(tanned)	4
Paper	Tonne	200-400
Special quality Paper	Tonne	400-1000
Straw Board	Tonne	75-100
Petroleum Refinery	Tonne(crude)	1-2
Steel	Tonne	200-500
Sugar	Tonne(Cane crushed)	1-2
Textile	100 Kg (goods)	8-14

Source: Manual on Water Supply and Treatment: III Edition (1999)

1.3.4. Requirement for Public Use

This includes requirement for Traffic Terminals, Fire, and Public Gardens etc.

<u>Requirement of Traffic Terminals and Stations</u>

The water requirements for traffic terminals, such as railway stations, but stations, harbours, airport etc. include provisions for waiting rooms and waiting halls. For retiring rooms, additional provisions are to be done. As per National Building Code, requirement for water supply for traffic terminals and stations may be taken as given in Table 1.5

Table 1.5 : Water Supply Requirements for Traffic Terminal and Stations

Nature of Station/Terminal	With Bathing Facilities	Without Bathing Facilities
	Litres/Capita/Day	
Intermediate Stations (excluding mail and express stops)	45	23
Junction Stations and intermediate Stations where mail or express stoppage is provided	70	45
Terminal stations	45	45
International and Domestic airports	70	70

Estimation of number of persons is done by the average number of passengers handled by the station daily. Consideration should also be given for staff and vendors likely to use the facilities.

Requirement for Fire Fighting

With increase in density of population and at a place, where hazardous activities are there, chances of fire are more. For hazardous industries such as explosive factories etc., special arrangements are made for fire fighting. For towns and cities in general, arrangement of additional water supply is done for fire fighting when fire breaks out in the locality. Municipalities and corporations make provisions for fire hydrants and for private buildings in a thickly populated city having multi-stories, some mandatory provisions are to be done for fire fighting. Fire hydrants are generally provided with the water mains at a distance of around 150 meter apart. Fire fighting pumps are connected into them as soon as fire breaks out in the locality. Since pumps throw water on the fire at a very high pressure, the minimum water pressure available at fire hydrants, should be around 1.5 kg/sq.cm. and this pressure should be available around 4 to 5 hours for constant use of the fire hydrant. As per the existing provisions one third of the fire fighting water requirement should be from storage reservoirs. The balance may be distributed in several static tanks at strategic point, which may be filled by nearest source of water such as streams, ponds or water tankers, etc.

For cities having population more 50,000 water required in m^3 is computed by the equation-

$$Q = 100\sqrt{P} \qquad \textbf{(3)}$$

Where Q is water required in m^3 and P is population in thousands.

Rate of fire demands is calculated by Kuichling's formula which gives amount of water required in litres/minute

$$Q = 3182\sqrt{P} \qquad \textbf{(4)}$$

where, Q= Amount of water requirement in litres/min.
P= Population in thousands.

General Usage of Water

General usage of water for public is not measured separately from trade and industrial consumption in some countries. General or public use may comprise water for fountains, parks, governmental buildings and their grounds etc, of course, supplied free of charge. This may vary from nil to around 100 litres / head / day depending upon class and climate of the city. But the public demand for fire fighting, routine fire hydrant testing, temporary building supplies and sewer flushing is normally so small when expressed as an average daily per capita during the year that it seldom need separately to be estimated.

1.3.5. Agricultural Requirements

Public water supply is not used in our country for agricultural purpose. Only in some farm houses, water may be used for kitchen gardens or minor agricultural purpose. In foreign countries also, private water resources are frequently used for farming, especially for irrigation of crops. Public supply is commonly used for diaries, cattle troughs, farm house purposes, horticulture and green house cultivation. An average consumption of these purposes is given in Table 1.6.

Table: 1.6: Agricultural Requirement

Usage	Estimated Consumption
Intensive dairy farming	80 litres/day per hectare of grazing fully utilized or 1350 litre/day per cow
Average agricultural demand for mixed farming	57 litre/day per hectare of farm land
Glass houses	12400 litre/day per hectare in winter and three times of this value in summer.

1.3.7. Per capita water demand

It is defined as the annual average daily requirement of water of one person it includes domestic requirement, institutional needs, water meant for public use (such as street washing, flushing of sewers etc.), industrial and commercial use and fire fighting, etc. The average daily per capita demand (lpcd) can be written as

$$\frac{\textit{Quantity required in } 12 \textit{ month } (\textit{in litres})}{356 \times \textit{population}} \qquad \textbf{(5)}$$

<u>Factors affecting per capita demand</u>

a) Habit of inhabitants
b) Public services
c) Climate
d) System of supply
e) Metering of water supply
f) System of drainage
g) Availability of alternative sources
h) Distribution pressure
i) Industrialization
j) Cost of water

Wet processing industries require more quantity of water for cooling operations. However, requirement varies on type and size of the industries. Planned cities and towns require considerable amount of water for parks, gardens, hospitals and other government institutions. Although continuous supply is seldom used, in continuous supply more water is wasted. However, in intermittent supply taps may be left open. The best way to solve this problem is to have overhead tanks for buildings through which water may be used by inhabitants wherever required. If water pressure is more, amount of wastage through leakage and joints will be more.

When water charge is taken based on consumed quantity, the consumption comes under control and people try to minimize wastage.

Fluctuations in demand

Although this average daily demand is supplied at uniform rate throughout day and night. It will not be sufficient because the demand or requirement varies hourly, daily, weekly and monthly. The variations are knows as fluctuations in demand.

Monthly Variations: The rate of consumption reaches a maximum in the summer. This high rate usually extends over two to four months depending upon location of the place. In cold countries, a secondary maximum often occurs in the winter owing to the waste of water to prevent freezing.

Daily Variations: The maximum daily rate may be estimated at about 150 percent of the average. For the larger cities, the ratio of 150 percent is seldom exceeded but for the smaller cities the ratio is frequently above 200 percent. The larger average consumption, the greater the variation. The maximum daily rate usually occurs in the month of maximum consumption. Thus, where the maximum daily consumption is 150% of the average, the maximum weekly consumption is likely to be about 130% of the average but for longer period of time, the rate will approach the monthly maximum.

Hourly Variations: Hourly variations are very important as they have a very wide range. During active household working hours in the morning around 6 a.m. to 10 a.m., and 4 p.m. to 8 p.m. in the evening, the bulk of water is consumed, especially, in the morning hours. During late hours in night demand is almost negligible. If a fire brakes out, a huge quantity of water is required to be delivered during a short duration and this may necessitate maximum rate of hourly supply. To accommodate all these fluctuation, the supply pipes, service reservoirs and distributing pipes must be properly proportioned.

Assessment of Variations

After assessing the total water requirement of different uses of a water supply scheme peak discharge has to be assessed so that the components of the scheme such as source of supply, pipe mains, pumps, filters and allied units, service reservoirs and distribution system may be of sufficient capacity to meet the requirements. The smaller the town, the more variable will be the demand. **The maximum monthly daily or hourly demands are expressed as ratio of their means.**

For an average Indian town:

a) The maximum daily consumption is taken as 180 percent of the average.

=> Maximum daily demand = 1.8 × Annual average daily demand (6)

b) The maximum hourly consumption (or peak demand) is taken as 150 percent of the average hourly consumption of the maximum day:

=> Max. hourly consumption = 2.7 × Annual average hourly demand (7)

However, Peak factor is normally taken on the basis of size of population of any town or city. Table 1.7 gives the recommended Peak Factor.

Table 1.7 : Peak Factors for Cities and Towns

Population	Peak Factor
Up to 50,000	3.0
50,001 to 2,00,000	2.5
Above 2 lakh	2.0
For Rural water supply schemes where supply is effected through stand post for around 6 hours	3.0

Source: Manual on Sewerage and Sewage Treatment: II Edition (1993)

1.4. Water Sources

The sources of water supply may be divided into following classes according to the general source and the method of collection:

Surface Water

1) Natural quiescent water in lakes and ponds
2) Flowing Water as in rivers and streams etc.
3) Artificial quiescent water as in impounding reservoirs.
4) See Water

Ground Water

Water from springs; Water from shallow wells; Water from deep and artesian wells; Water from horizontal galleries.

1.5. Selection of source of water

In selecting a particular source of water for a town or city following important points are generally considered:

- **The Quantity Available:** The quantity of water available from the source must be sufficient to meet the various demands during the entire design period of the scheme.
- **The Quality Available:** The water available from the source must not be toxic, poisonous or in any other way injurious to health. The impurities present should be such as to be removed easily and economically by normal and standard treatment methods.
- **Distance of the Source:** The source of water should be situated as near the city or town as possible. When the distance between source and city is less, lesser length of pipe conduits are required which are quite costly.
- **General Topography of the Intervening Area:** The area or land between the source and the city should not be quite uneven. It should not contain deep valleys and high mountains. In case of such uneven topography, the cost of trestles of carrying water pipes in valleys and that of constructing tunnels through mountains will be enormous.
- **Elevation of the Source of Supply:** The source of water must be on a high contour, lying sufficiently higher than the city so as to make the gravity flow possible. When water is available at lower elevation than the average city level, pumping has to be resorted which involve huge installation and operational cost.

++++++++++++++++Questions to Think:++++++++++++++

QA1.Which parameters do we need to monitor for these water types and why?

Water type	Parameter	Reason(s)
River water		
Tube well water		
Tannery wastewater effluent		
Finished drinking water		

QA2. For the AA community, following information about hourly demand is available for 12-hour duration:

Duration (hours)	Water flow rate (m^3/hr)
0-2	24.5
2-4	19.5
4-6	18.5
6-8	23
8-10	33.5
10-12	47.5

What is the total water demand in the overall 12-hour duration? (Hint: Note that, for example, for first two hours of the day, the required water flow rate is 24.5 m^3/hr, so total water demand for the first two hours would be = $2 \times 24.5 = 49$ m^3/hr). What is the average water demand rate using the 12-hour water demand data?

Answer: Total water demand in the overall 12-hour duration = (total sum of water flow required during 12-hour duration)/12 hours