LECTURENOTES

WATERSUPPLYANDWASTEWATERENGINEERING

5THSEMESTER

DIPLOMA (CIVILENGINEERING)

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Chapter1:IntroductiontoWaterSupply,QuantityandQualityofwater

Topicstobecovered:

i) Necessityoftreatedwatersupply
ii) Per capita demand, variation in demand and factors affecting demand
iii)Methodsofforecastingpopulation,Numericalproblemsusingdifferentmethods
iv)Impurities in water–organic and inorganic ,Harmful effects of impurities
v) Analysisofwater–physical,chemicalandbacteriological
Water quality standards for different uses

Necessityoftreatedwatersupply

- Toprovidethecommunitywithgoodqualitypotablewaterwith sufficient quantity to meet their requirements
- To prevent the population from deadly water borned diseases such as cholera,dysenteryetcbyprovidingthemwithtreated goodqualitywater

Percapitademand,variationindemandandfactorsaffectingdemand

Percapitawaterdemand(liters/capita/day)

$$= \frac{Totalannualaveragewaterconsulptionofcommunity}{population \times 365}$$

Waterdemandofacommunity(IS1172:1993)

- Domesticwaterdemand
- Industrialwaterdemand
- Institutionalorcommercialwaterdemand
- Demandforpublicuse
- Firedemand
- Demandtocompensatelossesandtheft

Domestic/residentialwaterdemand

- Itincludeswaterrequirementsfordrinking,cooking,bathing,washingof clothes, utensils etc.
- Provisionissometimesmadetodomesticanimal.
- IS1172-1171recommendspercapitawaterconsumptionof135L/day?

Average domestic water consumption in an Indian city:

Use	ConsumptioninL/day/person
Drinking	5
Cooking	5
Bathing	55
Washingclothes	20

Washingutensils	10
Washingandcleaningofhouses	10
Flushingtoilet	30
Total	135

Industrialwaterdemand

- Thepresenceofindustries nearthecitieshasagreatimpactonthewater demand.
- Thequantityofwaterdemanddependsupontypeofindustries.
- Foracitywithmoderate factorsaprovisionof40liters/day/capita for each purpose.

Institutionalwaterdemand

- Itincludesthewaterusedinhospitals,schools,hostels,colleges,hotels, railway & bus stations, cinema halls etc.
- According to IS 1172-1171 recommendation a per capita water consumption is 45lit/day is required under this head.

Demandforpublic orciviluse

- Waterrequirementforpublicorcivilusesare:-
- Roadwashing
- Sanitation
- Publicparks
- Firefighting
- Forroadwashinginthe municipalityareaa provisionof5 liters/day/head is made.
- Similarlyforsanitarypurposessuchasflushing,sewersystemetc.A provision of 3-10 liters /day/head is made.
- Waterrequiredformaintainingpublicparksmaybe2-3liters/day/sq.m

Firedemand

- Waterrequiredforfirefightingisknownas firedemand.
- Fire maytakesplaceduetofaultyelectricwiresbyshort-circuiting, fire catching materials, explosions, bad intension of criminal people.
- Firedemandcanbecalculated fromthe followingformula:
  - Kuichling’sformula:$Q=3182\sqrt{P}$
  - Boston'sformula:$Q=5663\sqrt{P}$
  - Freemanformula:$Q=1136(p/10+10)$
  - Nationalboardoffireunderwritersformula:$Q=4640\sqrt{p}(1-0.01\sqrt{p})$

WhereQ=Quantityofwaterinliters/day p=
population of thousand

Theunitoffiredemandwillbein**liters/m in**foralltheabove formulas.

Q.Computethefiredemandforacityhavingpopulationof140,000using various formulas.

Demandtocompensatelossesandtheft

- Leakage&overflowfromservicereservoirs
- Leakageofmainservicepipeconnections
- Leakage&lossesofconsumers'premises.
- Largeleakage&wastagefrompublictaps
- Lossesinthesupplylineare manyduetodefective,pipejoints,crack pipes, loose, valves & fittings.
- InIndiaapercapitawaterconsumptionof55litres/dayisrequired under this head.

Percapitawaterdemand

- Forthepurposeofestimationoftotalrequirementofwaterthedemand is calculated on an average basis & is expressed in liters/day /capita
- Itisobtainedbydividingthequantityofwatersupplyduringthe yearby no. of days in the year & the no. of persons served

Percapitawaterdemand(liters/capita/day)

$$= \frac{Totalannualaveragewaterconsulptionof\,community}{population \times 365}$$

Foranaverage,Indiantown,therequirementsofwaterinvarioususesare:

- Domesticuse-135lpcd
- Industrialuse-40lpcd
- Publicuse-25lpcd
- Institutionalandcommercialuse-15lpcd
- Losses&thefts-55lpcd

  Total(percapitawaterdemand)=270lpcd

Q.Whatwillbetheaveragequantityofwaterrequiredbyacity of population 50,000?

Variationinwaterdemand:

- Seasonalvariation
- Dailyorhourly variation

Seasonalvariation:

- Thewaterdemand varies fromseasontoseason.Insummerthedemand will be maximum whereas will be minimum in winter season

- People will tend touse more water inbathing, cooling, watering lawnetc. in summer season than the winter season.

Dailyorhourlyvariation:

- In most of the Indian city the peak demand occurs in the morning & evening. During the night hour the consumption is below the average.
- This variation depends on the general habits of the people, climatic condition, and character of the city such as residential, industrial or commercial.

Thevariationsareasfollows:

Averagedailywaterdemand(Q)=Population×percapitawaterdemand

Maximum daily water demand = $Q_{\max(daily)} = 1.8Q$

Maximumhourlywaterdemand=$Q_{\max(hourly)} = 1.5Q_{\max(daily)} = 2.7Q$

Factorsaffectingwaterdemand:

ThevariationinpercapitawaterdemandinIndiancitiesdependsonfollowing factors:

- Size&typeofcommunity
- Standardofliving
- Climaticcondition
- Qualityofwater
- Costofwater
- Waterpressure
- Methodofsupply

Size&typeofcommunity

- The fluctuationindemanddependsuponthesizeofthecity.
- Inalargecitythe fluctuationmaybelesswithhigherdemand.
- Inasmallcitypercapitaconsumptionisexpectedtobeless,because there are only limited uses of water.
- Thepresenceofindustriesinasmallcityincreasesitsdemand.

Standardofliving

- Thehigherthestandardofliving,thehigherthedemand.
- Such as the per capita water demand of the town increase with the standard of living of the people .The people will start use of air conditioners, room coolers, maintenance of lawns, use of flush latrines, use of automatic dish washer etc. with the rise in their standard of living.

Climaticcondition

- Inthecommunitylocatedina hotclimatethewater usedwillbe increased by bathing, lawn sprinkling etc.
- Similarlyinextremecoldclimatesthewatermaybewastagedueto freezing in pipes resulting increase consumption.
- Henceextremesathot&coldcause variationindemand.

- Qualityofwater-Poorqualityofwaterresultsinareductioninuse
- Pressureinthesupply-Highpressureresultsinincreaseusewhile low pressure results in decrease use
- Methodofsupply-Thewatersupplymaybeintermediate. Generally intermediate supply will reduce the rate of demand.
- Costofwater-Ifcostofwater is morepeoplewillreducetheusageofwater hence demand will be less and vice versa.

Methodsofforecastingpopulation,Numericalproblemsusingdifferent methods

Population:Populationindicates totalno.ofhumanbeingsliving inacertain area at any particular time.
Populationdensity:Itindicatesthe no.ofpersonsperunitarea.
Populationforecasting:Itisthe methodofforecastthepopulationinthecoming decades.

Methodsofpopulationforecasting:

- Arithmeticincreasemethod
- Geometricincreasemethod
- Incrementalincreasemethod
- Decreaserateofgrowthmethod

Arithmeticalincreasemethod

- Itisthesimplestmethodofpopulationforecasting.
- Inthis methodperdecadeincreaseinpopulationisassumedtobe constant.

Mathematically,dp/dt=k
Wheredp/dtistherateofchangeofpopulation k is the constant
LetP_0bethelatestknownlastdecadepopulationdata
$\bar{x}$bethearithmeticaverageofperdecadeincreaseinpopulation
Population after 1 decade, $P_1 = P_0 + \bar{x}$
Populationafter2decade,$_2 = P_1 + \bar{x} = P_0 + 2\bar{x}$
Populationafter ndecades,$= P_0 + n\bar{x}$

Problem: The following is the population data of a city available from past census records. Determine the population of the city in 2011 by arithmetic increase method.

Year	**1931**	**1941**	**1951**	**1961**	**1971**	**1981**	**1991**
population	**12000**	**16,500**	**26,800**	**41,l500**	**52,500**	**68,000**	**74,100**

Solution:

Year	Population	Incrementperdecade
1931	12,000	----
1941	16,500	4,500
1951	26,800	10,300
1961	41,500	14,700
1971	52,500	11,000
1981	68,000	15,500
1991	74,100	6,100
Totalincrement		62100
Averageincrementperdecade($\bar{x}$)		62100/6 =10350

Latest known population (P_0) = 74,100

Numberofdecades(n)=(2011-1991)/10=2

Population after n decades, $P_n = P_0 + n\bar{x}$

=74,100+2×10,350=94,800

Geometricincreasemethod

Inthis method itisassumedthatthe%increaseinpopulationfromdecadeto decade is constant.

Let$\bar{r}$(ork)bethegeometricaverageofperdecadepercentage increasein population (assumed to be constant)

Tofindfuturepopulation,$\bar{r}$iscompoundedwiththeexistingpopulation.

Populationafter1decade,$_1 = P_0 + \frac{\bar{r}}{100} P_0 = P_0(1+\frac{\bar{r}}{100})$

Population after 2 decades,

$$P_2 = P_1 + \frac{\bar{r}}{100} P_1 = \left(1+\frac{\bar{r}}{100}\right) P_1 = P_0\left(1+\frac{\bar{r}}{100}\right)^2$$

$$Population\,after\,n\,decades, = P_0\left(1+\frac{\bar{r}}{100}\right)^n$$

r can be found out as $r = (r_1 + r_2 + \cdots + r_n)^{\frac{1}{n}}$

Problem: The following is the population of a city available from past census records. Determine the population of the city in 2011 by Geometric increase method.

Year	**1931**	**1941**	**1951**	**1961**	**1971**	**1981**	**1991**
population	**12000**	**16,500**	**26,800**	**41,l500**	**52,500**	**68,000**	**74,100**

Solution:

Year	**Population**	**Increment/ decade**	**%increase/ decade**
1931	12,000	________	______
1941	16,500	4,500	37.5
1951	26,800	10,300	62.42
1961	41,500	14,700	54.85
1971	52,500	11,000	26.50
1981	68,000	15,500	29.52
1991	74,100	6,100	8.97
Average %age increment per decade ($\bar{r}$)			31.07

Latest known population (P_0) = 74,100

Number of decades (n) = (2011-1991)/10 = 2

$$Population\,after\,n\,decades, = P_0\left(1+\frac{\bar{r}}{100}\right)^n$$

$$= 74100\left(1+\frac{31.07}{100}\right)^2$$

Exercise:

The following is the population of a city available frompast census records. Determine the population of the city in 2010, 2030 and 2050 by arithmetic and Geometric increase method.

Year	Population
1970	40000
1980	46000
1990	53000
2000	58000

Impuritiesinwater–organicandinorganic,Harmfuleffectsofimpurities

Rawwater→Treatment→Wholesomewater

Qualityofwater(testingofwater)

- Toknowtheextentofimpuritiespresent inthewater,basedonwhich degree of treatment is decided.
- Toensurethequalityofwaterbeforesupply

Impuritiesinwater

<u>Basedonsizeof impurities:</u>

- Suspendedimpurities(macro)[10^{-1}mmto10^{-3}mm]
- Colloidalimpurities(micro)[10^{-3}mmto10^{-6}mm]
- Dissolvedimpurities(micro)[10^{-6}mmto10^{-8}mm]

Suspendedimpurities

- Thesuspendedparticleswhichhavethe samespecific gravityasthatof water are mixed in the water.
- E.g.clay,organicandinorganicmattersetc.
- Theseimpuritiesaremacroscopicandthesizeoftheseimpuritiesranges from 10^{-1} mm to 10^{-3} mm.

Colloidalimpurities

- It is very finely divided dispersion of particles in water. All the colloidal impurities are electrically charged (due to presence of ions)and remain in continuous motion.
- E.g. acid materials like silica, glass, acquire negative charge where as basic materials such as metallic oxide, aluminumoxide, ferrous oxide are positively charged.

- Due to the electric charge action all the colloidal particles remain in motion and don't settle which makes its removal very difficult.
- Most of the time colloidal impurities impact color to the water. The size of colloidal particles ranges between 10^{-3} mm to 10^{-6} mm.

Dissolvedimpurities

- Some impurities are dissolved in water when it moves over the rocks soil etc. These dissolve impurities may containorganic compounds, inorganic salts and gases etc.
- Thesizeofthedissolvedparticlesvariesfrom10^{-6}mmto10^{-8}mm.

<u>Basedonnatureofimpurities:</u>

- Organic impurities: Presence of organic impurities promotes growth of micro-organisms in the water which is objectionable.
- Inorganic impurities: Inorganic impurities of natural origin are harmless but human generated are hazardous in nature. E.g. cadmium, chromium, nickel, lead, zinc, mercury, etc. are toxic in nature.

<u>Basedonstateofmatter:</u>

- Physicalimpurities
- Chemicalimpurities
- Biologicalimpurities

Harmfuleffectsofimpurities

- Bacteria-causedisease
- Protozoa-causeodour
- Clay,silt-causeturbidity
- Carbonate-causehardness
- Sulphate-causehardness
- Bicarbonate-causealkalinityandhardness
- Fluorides-causemottledenamelofteeth
- Chloride-tasteandsalinity
- Manganese-causeblackorbrowncolor
- Ironoxide-causetastecorrosiveness,hardnessandcolor
- Metallead-causeleadpoisoning

Analysisofwater–physical,chemicalandbacteriological

The analysis of water is done to identify the impurities present in the water based on which treatment procedures should be adopted in the treatment plants before supplying the water to the public.

Thequalityoftreatedwaterisalsochecked beforesupplytoconfirmit fulfills the requirement of the standards laid down by the public health department.

Thefollowingtestswhicharedoneduringwateranalysis
- Physicaltests
- Chemicaltests
- Bacteriologicaltests

Physicalwaterquality
Itaccessestheextentofphysicalimpurities present inthewater.Physicalwater quality parameters are those which respond to human senses.
1) Temperature
2) Color
3) Turbidity
4) Tasteandodour

Temperature
- The temperature of water is measured by means of ordinary thermometers.
- Warmtemperature isidealformicrobialgrowth
- Solubilityofgasesdependsontemperature.Higherthetemperaturelower will be solubility.
- Chemicalreactionsaretemperaturecontrolled.
- Density,viscosity,vaporpressureandsurfacetensionofwaterdepends on temperature.
- Thedesirablerangeoftemperature is10to20°C

Color
- Apparentcolor→Suspendedsolids
- Truecolor→Dissolvedsolids
  Beforetestingthecolorofthewater,thesuspended matershouldbe removed.
- Colorinwateris measuredonBurgessScale(platinumscale)and expressed in terms of True Colour Unit (TCU).
- Thedeviceusedtomeasurethecolourisknownastintometer.
- 1TCU=1mg of platinumas a chloro platinateion mixed in1litre of distilledwater,thenthecolourproducedis takenas1standardTCU
- Thepermissiblelimitfordomesticwateris5to20TCU

Turbidity
- The opaqueness in water is known as turbidity. It is the resistance to passage of lights through the water by the suspended and colloidal particles.

- Turbidityis measuredinsilica scaleandexpressedintermsofturbidity units (TU).
- 1TU=1mgoffinelydividedsilica mixed in1litreofdistilledwater,then the turbidity produced is taken as 1 standard turbidity unit.
- Turbidityis measuredbyturbidimeters(Jacksonturbidityunit:JTU)and nepthlometers(nepthlometric turbidity unit: NTU).

TasteandOdour

- Tasteandodoursinwater maybeduetothepresenceofdeadoralive micro organism, dissolved gases, mineral substances etc.
- Thewater havingbadsmellorodourisobjectionableandshouldnot supply to the public.
- Odour in water is measured by a device called Osmoscope(200ml capacity)andisexpressedintermsofThresholdOdourNumber(TON)
- TONis adilutionratioatwhichodourisjustdetectable.
- Drinkingwaterstandard forodour=<3TON
- There is no test for taste. Generally a sample having bad colour is expected to taste bad. Taste is expressed as Flavored Threshold Number (FTN).

Chemicalwaterquality

- The followingarethedifferentchemicalwaterqualityparameters

1. **Solids**

Theresidueleftonevaporationiscalledsolids.

- Totalsolids(TS)
- Suspendedsolids
- Totaldissolvedsolids(TDS)

Thepresence ofsolid inwater is measured bygravimetrymethod(weight measurement)andexpressedintermsofmg/Lorppm(partsper million).

Total solids: Measured as the ratio ofweight ofresidue after ovendrying ofraw water to the total volume of water taken

Suspended solids: Suspended solids are measured by filtration method. Filter paper of pore size smaller than the smallest suspended particles is used for filtration. The weight ofsolidretainedon filterpaperis measuredandexpressed in mg/L.

Total dissolved solids (TDS): It includes both colloidal and dissolved particles. TDSofawatersample is measured as theweightretainedafterovendryingofa filtered sample per the volume of filtered sample.

Drinkingwaterstandards forTDS=<500mg/L

2. **pH**

pHisthe measureofpotentialofhydrogenionconcentrationinwater.
Watertreatment ispHsensitiveasextremepHcausesdamage inpropertysuch as pipes etc. and hence increases the cost of treatment.
MeasurementofpH:

- pHpaper:approximatemethod
- Titrometry:notbeingusednowadays
- pHmeter:(potentiometer)Itisadigitalelectronicdevice measurespH very accurately

Drinkingwaterstandard forpH:6.5to8

3. **Acidity**

- Themeasureofabilityofwatertoneutralizebase
- Acidityinwater isgenerallycausedbyexcessmineralsorpresenceof CO_2
- Acidityinwatercausescorrosionproblemandtuberculation(micro-projection)
- Itis measuredbytitrometryandexpressedinterms ofmg/Las$CaCO_3$
  Titrant: NaOH
  Indicator:Methylorange/phenolphthalein

4. **Alkalinity**

- Themeasureofabilityofwatertoneutralizeacids
- Itiscausedbyhydroxylions(OH)carbonatesandbicarbonates
- Alkalinity causes scaling (growth of thin layer inside pipes), incurstanation, and bitter taste to the water.
- Itismeasuredbytitromtry
  method. Titrant: H2SO4
  Indicator:Methylorange/phenolphthalein

5. **Hardness**

- It is the property of water which prevents the lathering of the soap. It is caused due to the presence of carbonate & sulphate of calcium and magnesium in the water.
- Hardness in water causes: corrosion, scaling, bitter taste, increased soap consumption
- Hardness is measured by versenate method (EDTA method) which is a titrometry method.
  Titrant:EDTA
  Indicator: Erichrome black T
  Changeincolor:wineredtoblue

Hardnessinmg/Las CaCo3	Typeofwater
<75	soft
75-150	Moderatelyhard
150-300	Hard
>300	Veryhard

6. Chlorides

- Sodium chloride is the main substance in chloride water. The natural water near the mines and sea has dissolve sodium chloride.
- Excess of chlorides is dangerous and unfit for use. The chloride can be reduced by diluting water. Chloride above 250ppm is not permissible for drinking water.
- The chloride can be determined by titrating the water with silver nitrate andpotassiumchromate. Inthis titrationprocessyellow color willchange into brick red color in the presence of chlorides.

7. Chlorinetest

- Dissolvedfreechlorineisneverfoundinnaturalwaters.
- Residue chlorine is determined by the stratch-lodide test. In this test, potassiumiodide and starchsolutionare added to the sample ofwater due towhichbluecolor isformed. Thisbluecoloristhenremovedbytitrating with N/100 sodium thiosulphate solution and the quantity of chlorine is calculated.
- Theresiduechlorineshouldremainbetween0.5p.p.minthewatersothat it remains safe against bacteria.

8. Ironand manganese

- These are generally found in ground water. If it present in water then the water is not suitable for domestic, bleaching, dyeing and laundering purposes.
- The presence of iron & manganese in water makes brownish red color in it, leads to the growth of micro- organism & corrodes the water pipes.
- The quantity of iron & manganese is determined by colorimetricmethods. In this method some coloring agents are added in the water and colors so formed are compared with standard color solution.
- Itis generallyin0.3p.p.m

9. Dissolvedgasestest

Oxygen: Surfacewaterscontainlargeamountofdissolvedoxygen,because they absorb it from the atmosphere. The presence of oxygen in water is necessary to keep it fresh & sparkling, but more quantity of oxygen causes corrosion to the pipe materials.

Carbondioxide:

- The water absorbs carbon dioxide from the atmosphere. It causes hardness in water.
- Thepresenceofcarbondioxidecanbeeasilydeterminedby mixingofthe lime solution in the water. If it gives milky white color then carbon- di- oxide is present in the water.

Nitrogen:

- The presence of nitrogen in the water indicates the presence of organic matters in the water.
- The presence of nitrates is not so harmful, but in no case its quantity should increase 45 ppm , because excess presence of nitrate will cause disease to the children.
- It is determined by color matching methods. In this method the color is obtained if phenol-di-sulphonic acid & potassium hydroxide are added. The colors so developed are compared with standard colors.

Biologicalwaterquality

Inbiological/bacteriologicalanalysisofwaterthefollowingtwotestsaredone.

- Totalcountofbacteria
- E-colitest

Totalcountofbacteria

- In this method total number of bacteria present in a milliliter of water is counted. The sample of water is diluted; 1 ml of sample water is dilutedin 99 ml of sterilized water. Then 1 ml of diluted water is mixed with 10 milliliter of agar of gelatin.
- This mixture is thenkept in incubatorat 37 degree centigrade for24hours or at 20 ^{o}C for 48 hours. After the sample will be taken out from the incubator& colonies ofbacteria are counted by means of microscope.

Escherichiacoli(E-coli)test

- Now a day a new technique of finding out the E-coli is developed which is called “membrane filter technique”.
- In this method the sample of water is filtered through a sterilized membrane of special design due to which all the bacteria are retained on the membrane.
- The member is then put in contact of culture medium – M – Endos medium in the incubator for 24 hours at 37 ^{o}C. The membrane after incubating is taken out and the colonies of bacteria are counted by means of microscope.
- For drinking water it is necessary that it must be free from pathogenic bacteria.

Waterqualitystandardsfordifferentuses

Waterqualityparameters	**Acceptablelimits**
Temperature	10-15.6°C
Odour	0-4
Colour	10-20ppm
Turbidity	5-10ppm
Taste	Noobjectionabletaste
Totalsolids	<500ppm
Hardness	75-115ppm
Chlorides	<250ppm
Ironandmanganese	<0.3ppm
PHvalue	6.5to8
Lead	<0.1ppm
Arsenic	<0.05ppm
Sulphate	<250ppm
Carbonatealkalinity	<120ppm
Dissolveoxygen	5-6ppm
MPN	<=1nosper100ml
E-coliindex	nil