Urban Utilities Planning: Water Supply, Sanitation and Drainage
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Module - 07
Sanitation and Drainage Fundamentals
Lecture - 33
Sewage Systems Part I

Welcome back. In lecture 33, we will talk about Sewage Systems and this is the part 1.

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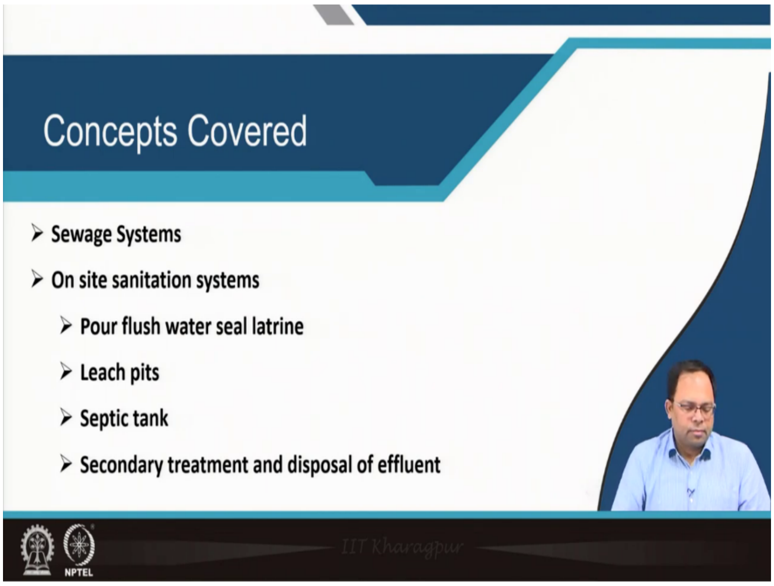

We will discuss about sewage systems, onsite sanitation systems, and within onsite sanitation systems, we will talk about pour flush water seal latrine, leach pits, septic tanks and secondary treatment and disposal of effluents.

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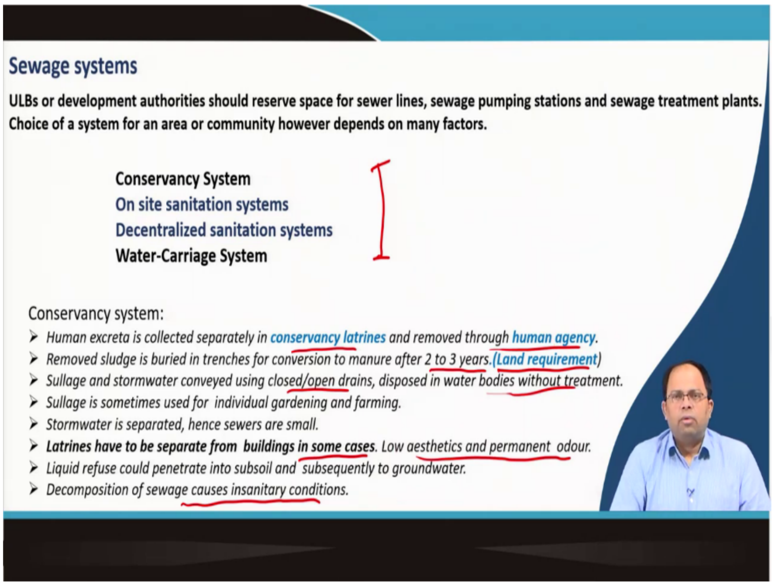

Sewage systems

Designing or choosing a particular kind of sewage system for an urban area depends on many factors. Usually, ULBs or other agencies should reserve space for sewer lines, sewage pumping stations, sewage treatment plants and space for its expansion and development in the future because it would be very difficult to acquire space later on. When there is such a provision, home buyers and developers are confident to acquire land in the areas concerned.

When we talk about sewage systems, there are different kind of systems; primarily there is the conservancy system and the water carriage system. So, we have broadly touched upon that in our earlier lecture, where conservancy system is the old system where manual scavenging is involved. That means, we need to clean the system by human agency and not an automatic system.

Whereas, water carriage system is an automatic system where toilets are directly connected with pipe network and water is used to drain all the sewage into the pipelines, and then eventually it is transported to the treatment units where it is treated and then disposed.

In between this conservancy system and water carriage system, there is onsite sanitation system and decentralized sanitation system. Onsite sanitation systems are different from a conservancy system, but there are certain overlaps. Some of the toilets used in onsite sanitation systems can be called as a conservancy system like a pit toilet.

Whereas, other advanced kind of septic toilets, septic tanks and then other kind of effluent treatment systems can be designed in onsite sanitation system which may not be a part of the conservancy system. The other one is the decentralized sanitation system.

There may be overlaps between onsite sanitation systems and water carriage systems in this decentralized sanitation system. Some of the systems could be similar to a water carriage system but still different. That is why we can have these four kinds of system discussed separately.

In conservancy system, we have conservancy latrines where the human excreta are removed using human agency. The removed sludge is buried in trenches for conversion to manure after 2 to 3 years which requires land. So, sullage and stormwater in this particular system is conveyed through closed or open drains and disposed in water bodies without treatment and sullage is sometimes used for gardening and farming. Stormwater is separated from sullage and sewers required for that would be a smaller size.

In conservancy system, latrines have to be separate from buildings. In some cases, toilets cannot be within the building itself which may not be aesthetic. There may be odour involved in this kind of systems as well. Liquid refuse can penetrate into subsoil and subsequently into ground water because we are disposing the waste directly into the soil and decomposition of sewage may cause unsanitary conditions.

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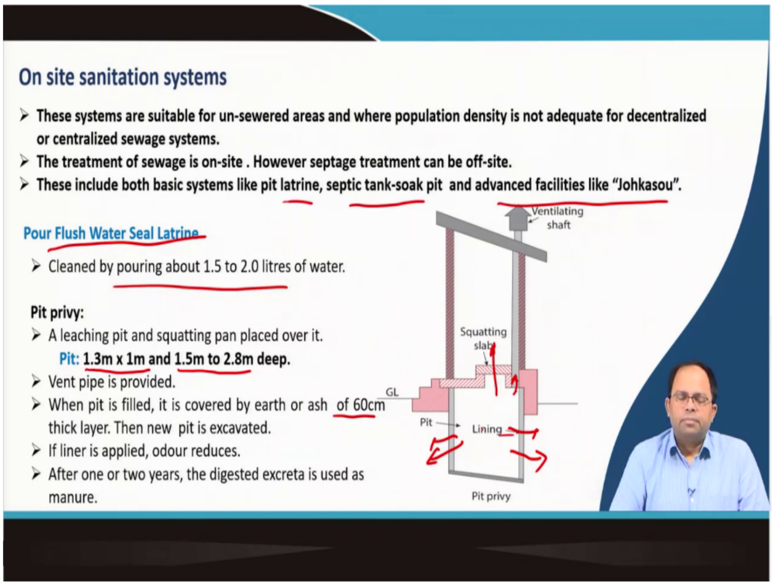

On site sanitation systems

On site sanitation systems are suitable for unsewered areas, where population density is not adequate. We can have a decentralized system in this unsewered low population areas as well and the treatment of sewage is on site i.e., it is treated locally and septage treatment is offsite. This is the difference with the conservancy system.

Sewage treatment is via septic tanks or via twin pits on site, but the septage part has to be properly treated offsite in a treatment plant.

These include, both basic systems like pit latrine, septic tank-soak pit and advanced facilities like the Johkasou. So, these are the different kind of toilets present in on site sanitation systems.

The first kind of toilet or latrine discussed here is called the pour flush water seal latrine. Water is poured to flush this toilet and the squatting pan will have a water seal so that gases or insects cannot come back from the pit into the squatting pan. Usually these kind of toilets are cleaned by pouring about 1.5 to 2 liters of water. It also has a leaching pit which allows water to leach from the sides. A squatting pan is placed over it and the size of the pit is around 1.3 meter to 1 meter, and it could be of depth of 1.5 meter to 2 meter. A vent pipe is connected so that gases can pass. When pit is filled it is covered by earth or ash of

60-centimeter-thick layer and then new pit is excavated. The entire structure has to be taken and placed over another pit and this pit is covered by earth or ash of 60 centimeter or 2 feet thick layer.

If liner is applied, odor reduces. After 1 or 2 years, the digested excreta are used as manure. Since we are using another pit, this becomes manure, and we can use the sludge.

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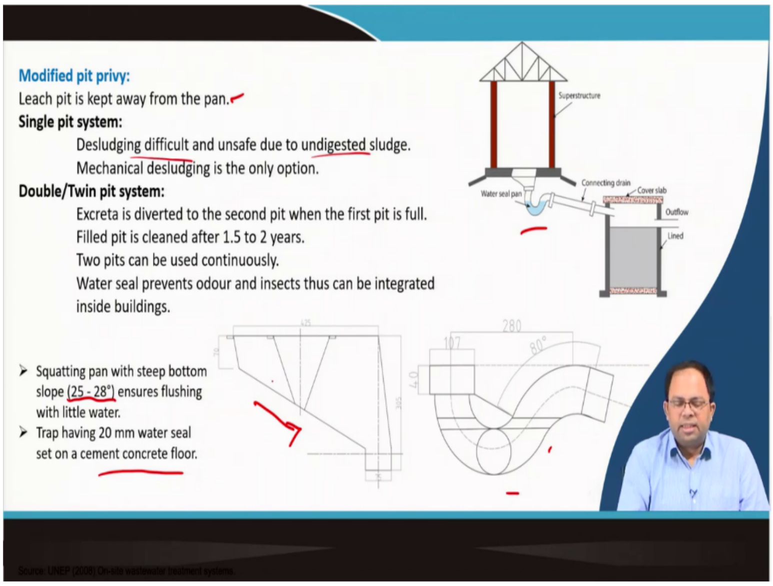

Modified Pit Privy

A modified pit privy is a much better system where the leach pit is kept away from the pan; that means, we have a toilet superstructure along with the squatting pan and the pit is separate. The toilet does not need to be shifted, so it remains where it is and the connection needs to be shifted to another pit.

In case of a single pit system desludging is difficult and unsafe due to undigested sludge. The pit has to be cleaned at certain intervals, without stopping usage. So some part of the sludge will be undigested and it has to be removed which makes it a less preferred option. Mechanical desludging is the only option in this case. The other option is a double or twin pit system, where there are two pits and excreta is diverted to the second pit when the first pit is full and filled pit is cleaned after 1.5 to 2 years when it has turned into manure. So, in this way we can avoid this problem.

Two pits can be used continuously and water seal prevents odor and insects thus can be integrated inside buildings as well. So, it is better not to have pit toilet inside a building, but if required we can also have it because we have the water seal in place. The only difference is because we are using a very little quantity of water, it is a pour flush system, and there is no flushing system. So, we use a different kind of squatting pan design where it is of a greater slope which ensures flushing with little water. The trap is having only a 20 mm water seal set on the cement concrete floor. This is the difference with standard pans, bend and the trap.

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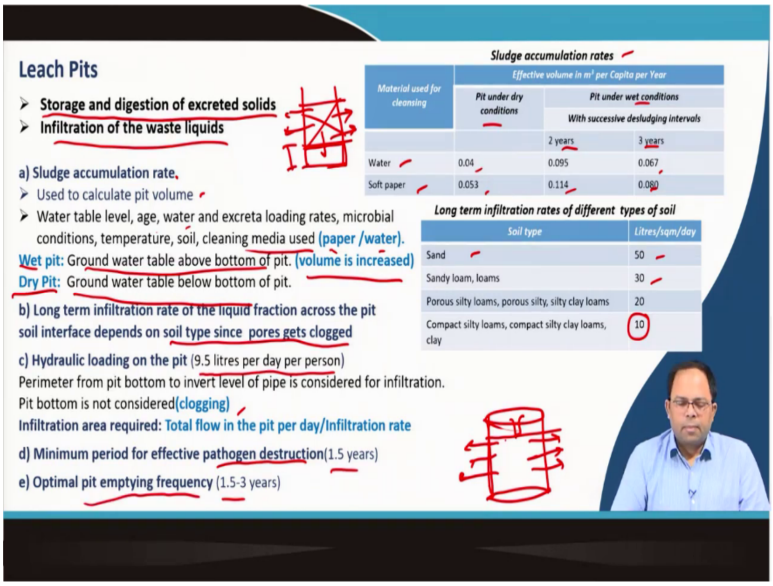

Leach Pits

Leach pit allows leaching of water from the surface of that particular pit and it is meant for both storage and digestion of excreted solids and infiltration of the waste liquids into the surrounding soil. It thus requires space for storage of the digested solid as well as water before its eventual infiltration through the surrounding wall of that particular pit. So, when we design a leach pit, we have to understand the sludge accumulation rate because this will give the space required for the sludge that would be accumulated per person per year. So, this is used to calculate the pit volume or the size of the pit along with water table level, age, water, and excreta loading rates, microbial condition, temperature, soil, and cleaning media. Cleaning media can be either water or paper used for cleaning. These are the two things that we need to consider when we design a particular pit.

There are two kinds of pits; wet pit and dry pit. Wet pit is when the groundwater table is above the bottom of the pit and dry pit is when groundwater table is below the bottom of the pit. Sludge accumulation rates vary according to the kind of pit and the cleaning media used. For example, if it is under wet condition using water as the cleaning media and the period between desludging is 2 to 3 years, the sludge accumulation rate is 0.04 meter cube per capita per year. Under dry conditions and when paper is used for cleaning, then the rate is higher at 0.053 meter cube per capita per year because of the use of paper.

Basically based on the number of users, and the per capita rate of sludge accumulation, we can determine the size or the volume that we have to reserve for sludge storage or digested excreta.

Once the accumulation volume is understood, the other part is infiltration. We have to understand how much of water will enter the pit and how much can infiltrate from the surrounding walls. Infiltration cannot happen from below due to the presence of sludge and will only happen through the side walls. So, long term infiltration rate of the liquid fraction across the pit soil interface depends on soil type since pores gets clogged. There are different kinds of soil and each has got different sizes of pores and that determines what would be the infiltration rate for that particular soil type.

So, for example, when we look into sand, the infiltration rate is 50 liters per square meter per day. Then, sandy loam, it is 30 square liters per square meter per day and for porous silty loams, porous silty, silty clay loams, it is 20 liters per square meter per day. When it is compact silty loam, and clay type of soil, it is very little which is 10 liters per square meter per day. When it is 10 liters, it is not feasible to have a leaching pit.

So, the next thing that we measure is what is the hydraulic loading on the pit; that means, how much water gets inside the pit. We assume that it is about 9.5 liters per day per person. Based on the number of persons who is using the pit, we can estimate how many liters of water goes into that pit. Based on that volume of water divided by the infiltration rate, we can calculate how much surface area is required for the water to infiltrate into the surrounding soil.

The minimum period of effective pathogen destruction is 1.5 years. So, that is after that time period we will be cleaning or shifting to a new pit. And once we shift to a new pit, we will leave it for 1.5 years. So, that the sludge gets digested and all the pathogens are destroyed. Therefore, the optimum pit emptying frequency is around 1.5 to 3 years.

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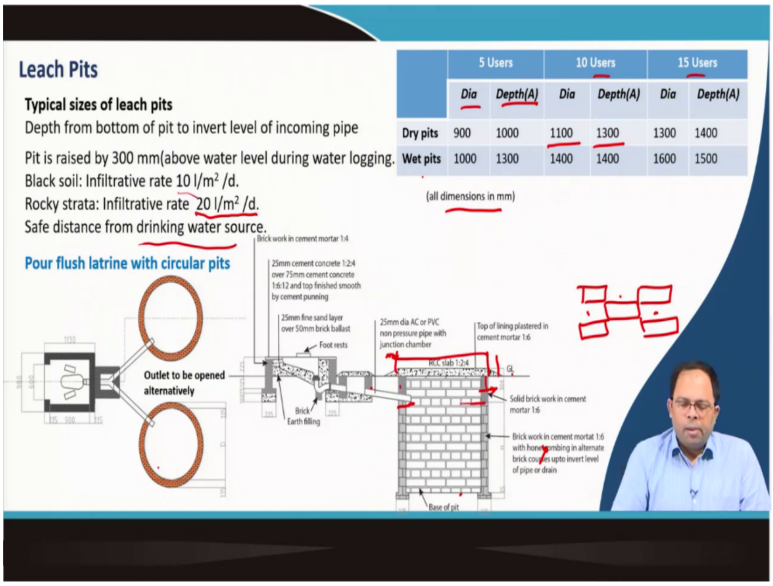
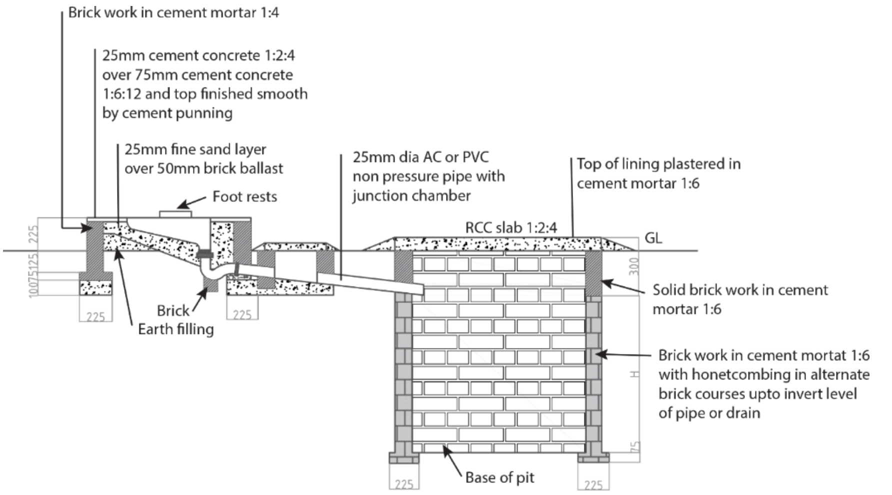


The typical sizes of the leach pits are as follows:

	5 Users		10 Users		15 Users	
	Dia	***Depth(A)***	***Dia***	***Depth(A)***	***Dia***	***Depth(A)***
Dry pits	900	1000	1100	1300	1300	1400
Wet pits	1000	1300	1400	1400	1600	1500



Pit should be raised by 300 mm (above water level during water logging)

Black soil: Infiltrative rate 10 l/m^2 /d.

Rocky strata: Infiltrative rate 20 l/m^2 /d.

It should be at a safe distance from drinking water source.

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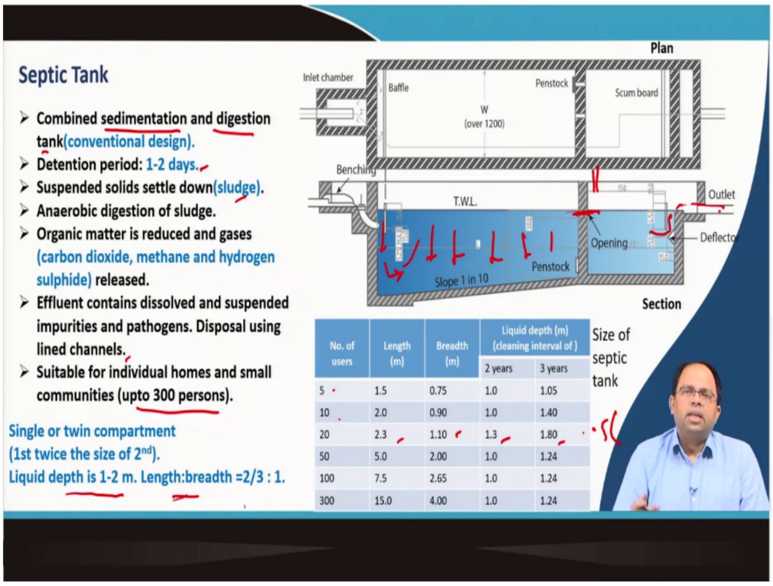

Septic Tank

Septic tank combines both the processes of sedimentation as well as digestion of that particular excreta. It has a first chamber and the second chamber. In the first chamber, there is a baffle wall where the sedimentation happens. After that the effluent goes from the top and then goes to the next chamber, some amount of sedimentation occurs. Then, it travels to the outlet. So, this is the standard design of a septic tank. This is a two chambered septic tank. There could be even more chambers.

The detention period of water in the septic tank is 1 to 2 days, but in other cases we have seen even less than 1 day of detention. The design of the tank is such that it would be holding the accumulated sludge plus there is a zone for sedimentation plus the space required for water to be stored or detained for 1 to 2 days.

Suspended solids settle down and they form the sludge. Anaerobic digestion of sludge takes place because there is no oxygen. Organic matter is reduced and gases are released such as carbon dioxide, methane and hydrogen sulfide.

In some cases, a vent pipe is provided in the septic tank. The effluent contains both dissolved and suspended impurities and pathogens and hence we cannot dispose it directly into open drains or the sewer network. So, it has to be disposed through lined channels or it should be treated further. These are suitable for individual homes and small communities up to 300 persons.

A septic tank could be a single or twin compartment. In some cases, we can create further compartments by placing baffle walls. Usually, the first chamber is twice the size of the second, and the liquid depth is 1 to 2 meters, and length is to breadth is either 2:1 or 3:1.

Some of the typical sizes of septic tanks are given in the table below:

No. of users	Length (m)	Breadth (m)	Liquid depth (m) (cleaning interval of)	
			2 years	3 years
5	1.5	0.75	1.0	1.05
10	2.0	0.90	1.0	1.40
20	2.3	1.10	1.3	1.80
50	5.0	2.00	1.0	1.24
100	7.5	2.65	1.0	1.24
300	15.0	4.00	1.0	1.24

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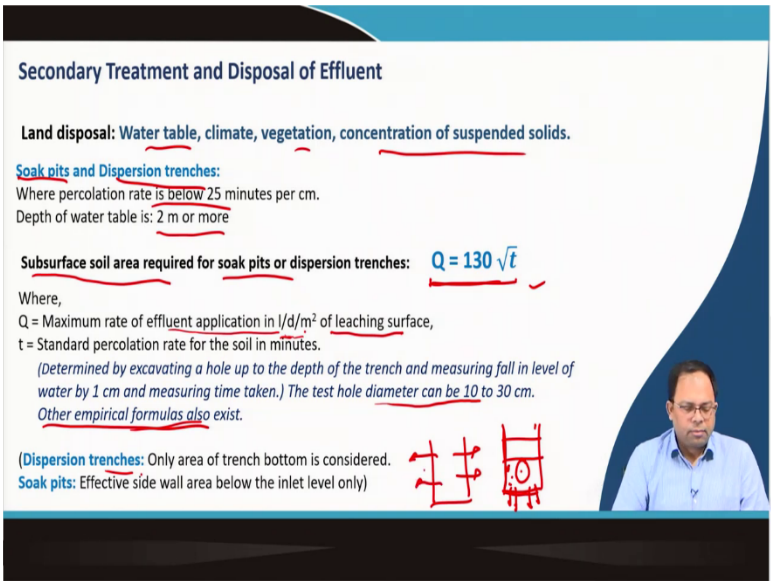

Secondary treatment and Disposal of Effluent

Whenever we are designing septic tank, we need to think about how to dispose of this particular effluent. Usually, we dispose this effluent through land disposal. We can also treat it, but when we dispose it in the land, we need to consider about the water table, the climate and vegetation of the area and concentration of suspended solids in the effluent.

We dispose the effluent through soil in a normal pit toilet and we allow the water to infiltrate. Similarly, we allow the effluent to infiltrate into the ground and for that we will have to design soak pits or dispersion trenches. We cannot just let it on the surface of the ground and we need to put it inside a soak pit or a dispersion trenches.

Soak pits are more or less similar to the pit toilets. Since, the solid or excreta part is already being digested in the septic tank after sedimentation, only the clearer effluent comes in. It has got impurities and pathogens, but in lower quantity.

Soak pits are designed where percolation rate is below 25 minutes per centimeter. Percolation rate is determined by excavating a hole to a depth of the trench and measuring fall in level of water by 1 centimeter and then measuring the time taken. If it is more than that, we do not design it.

The test hole diameter can be 10 to 30 centimeters. We allow water to infiltrate and we see that when the level of water comes down by 1 centimeter, we can determine what is the time taken which is the standard percolation rate for soil in minutes. The depth of water table has to be 2 meter or more and only then can we go for soak pits and dispersion trenches, otherwise if the water table is high then the effluent will actually mix with the ground water.

The size of the soak pits and dispersion trenches are estimated using the formula:

$$\mathbf{Q = 130}\sqrt{t}$$

Where,

Q = Maximum rate of effluent application in $l/d/m^2$ of leaching surface,

t = Standard percolation rate for the soil in minutes.

So, if we can determine the maximum rate of effluent application, then we can determine the total area required for this pit ot trench, and t is the standard percolation rate for soil in minutes.

For dispersion trenches, we only consider the area of the trench bottom whereas in case of soak pits the effective side wall area below the inlet level is only considered, similar to a standard pit toilet.

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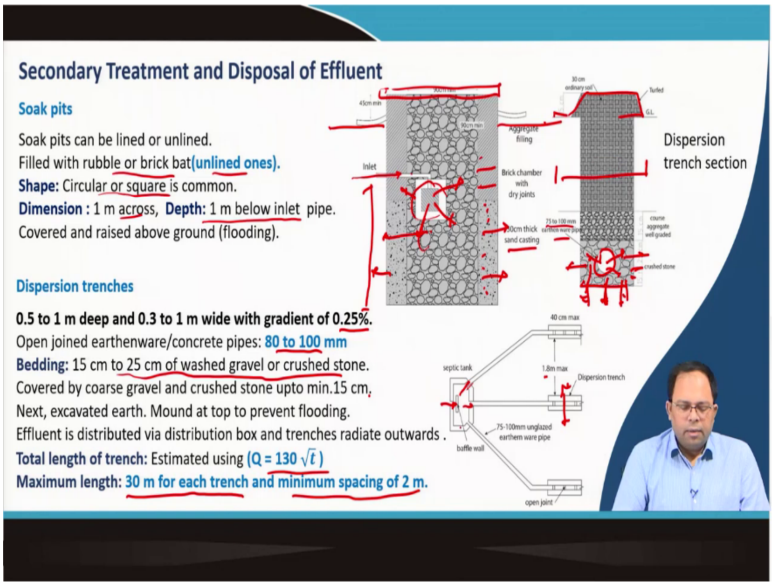

Soak pits can be either lined or unlined. In case of unlined soak pits, it is filled with rubble or brick bats. The most common shape is either circular or square. The dimension is 1 meter across and depth is 1 meter below the inlet pipe. It is covered and raised above the ground so that it does not get flooded in case there is inundation in this particular area. The influent comes in, it comes to this box that is created. Again, it is created with brick, just to create a chamber. From there, it goes into the surroundings and it goes via the media inside. The media actually can treat this water further because of anaerobic digestion. The surface of this media holds some amouns of bacteria which actually helps in this digestion. And then, the cleaner effluent passes through the side walls into the surrounding soil. So, this is how a soak pit operates.

Dispersion trenches are 0.5 to 1 meter deep, and 0.3 to 1 meter wide with gradient of around 0.25 percent. It contains open jointed earthenware or concrete pipes 80 to 100 millimeter in size or 75 to 100 millimeter in size. A bedding of 15 to 25 centimeter of washed gravel or crushed stone is provided, and the pipes are covered by coarse gravel and crushed stone up to 15 centimeter minimum. A earth mound is provided at top to prevent flooding.

Effluent is distributed via a distribution box, and trenches radiate outwards. The inspection box has a baffle wall. The effluent is put into the box first, and from there it is sent in 3 directions. There could be only one dispersion trench as well. Each dispersion trench can be of 30 meter in length maximum and minimum spacing in between them should be 2 meters. Beyond 30 meters, it becomes ineffective. Same formula as that of soak pits is used to determine area.

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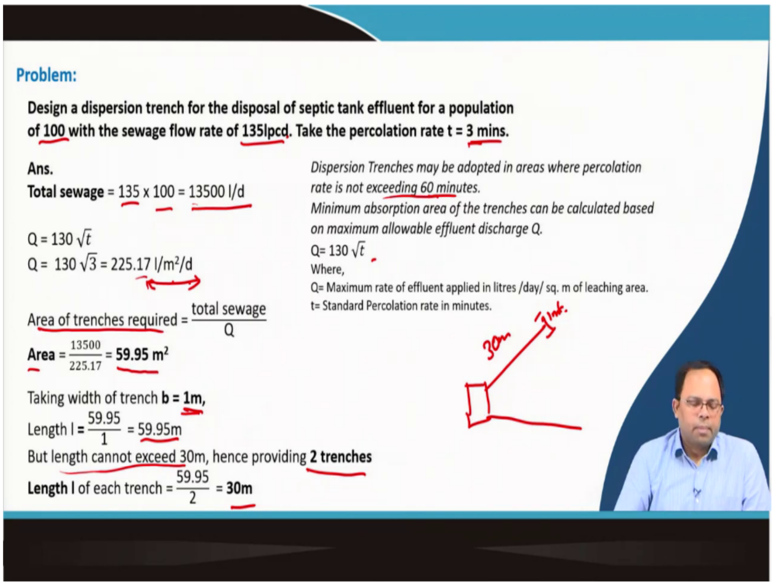

Now, let us look at a small problem to design the size of a dispersion trench.

Question: Design a dispersion trench for disposal of septic tank effluent for a population of 100 with sewage flow rate of 135 lpcd. And take the percolation rate t equal to 3 minutes. So, we have got sewage flow rate of 135 lpcd and a population size of 100.

Now, dispersion trench may be adopted in areas where percolation rate is not exceeding 60 minutes. So, that means, compared to the soak pits, this allows a little bit more flexibility. If it is beyond 60 minutes, we cannot actually use it. And minimum absorption area of trenches can be calculated based on $\mathbf{Q = 130}\sqrt{t}$ as we have discussed earlier.

Answer:

Total sewage = 135 x 100 = 13500 l/d

$Q = 130\sqrt{t}$

$Q = 130\sqrt{3} = 225.17$ l/m^2/d

Area of trenches required = $\frac{total\ sewage}{Q}$

Area = $\frac{13500}{225.17}$ = 59.95 m^2

Taking width of trench b = 1m,

Length l = $\frac{59.95}{1}$ = 59.95m

But length cannot exceed 30m, hence providing 2 trenches

Length l of each trench = $\frac{59.95}{2}$ = 30m

So, we take the maximum width of the trench is 1 meter. So, length of this particular trench will be 59.95 m or 60 m. Since, length cannot exceed 30 meter, 2 trenches of 30 meters each will be designed. In this particular design, we will have an inspection box. From there we can have 2 trenches of 30 meter and then each trench is of 1 meter wide.

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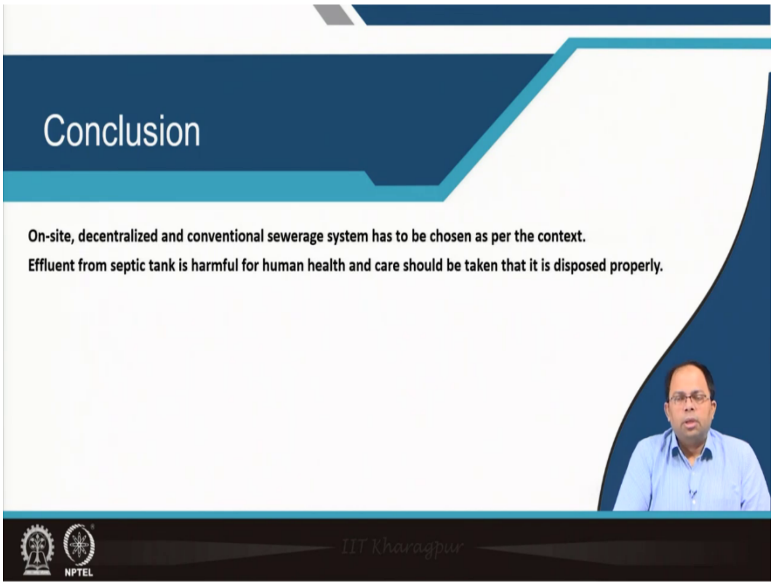

Conclusion

So, to conclude, onsite decentralized and conventional sewerage system has to be chosen as per the context. Effluent from septic tank is harmful for human health and care should be taken that it is disposed properly.

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These are the references.

Thank you.