Urban Utilities Planning: Water Supply, Sanitation and Drainage
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Module - 06
Water quality, testing, treatment
Lecture - 26
Water Quality and Testing Part I

Welcome back. In module 6, the concepts of Water Quality Testing and Treatment will be covered. In lecture 26, Water Quality and Testing, Part 1 will be covered.

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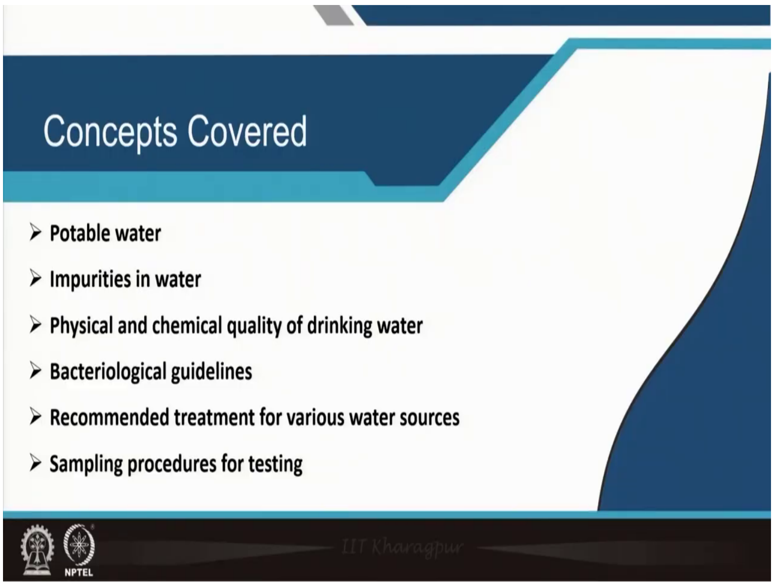

The different concepts that will be covered in this lecture are potable water, impurities in water, physical and chemical quality of drinking water, bacteriological guidelines, recommended treatment for various water sources, and sampling procedures for testing.

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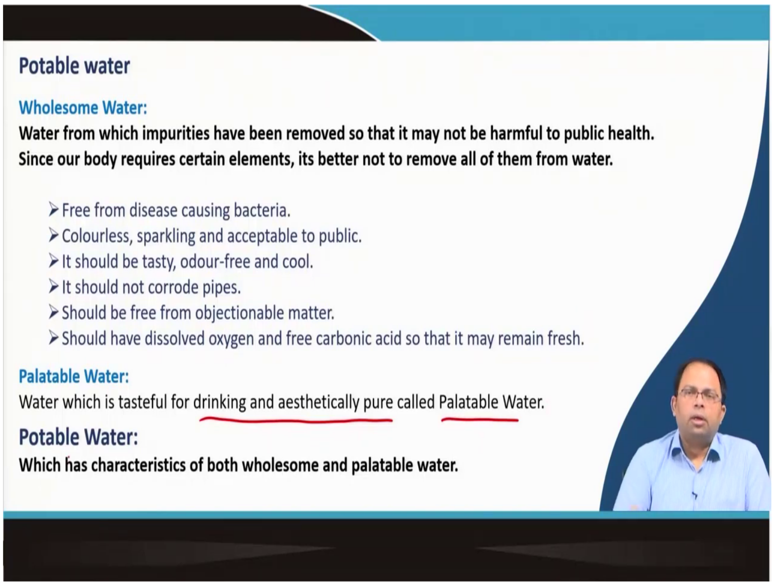

Potable water

Potable water has the characteristics of both wholesome water and palatable water. Palatable water is basically what is tasteful for drinking and aesthetically more pure. But wholesome water is water from which impurities have been removed, thus it is not harmful to public health.

Even though most of the impurities are removed from water, but certain elements are retained since everything is not harmful. Regarding impurities, at least disease-causing bacteria should be removed, and one should make sure that the water that we are consuming should be colourless, sparkling, and acceptable.

In addition, it should be tasty, odour-free, and cool; that means, it should not be very hot as well. It should not corrode pipes. This is important for the different transmission pipelines or the treatment units. It should be free from objectionable matter, and should have dissolved oxygen and free carbonic acid so that it remains fresh.

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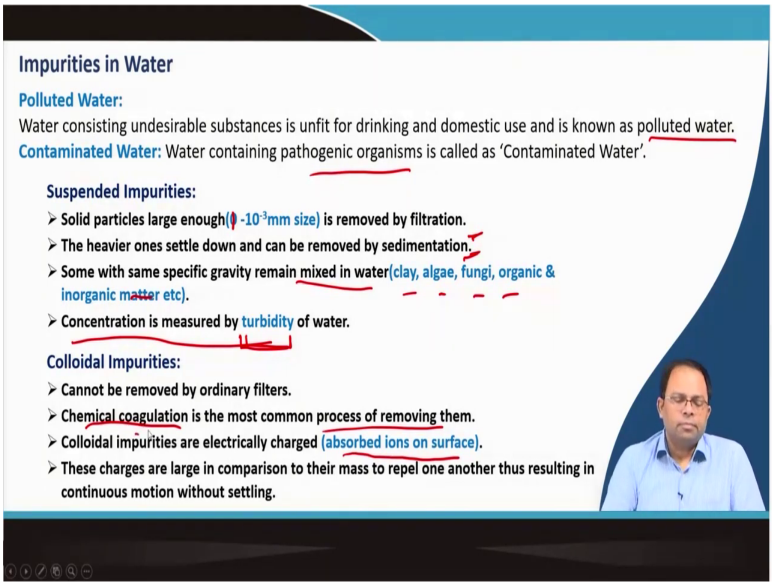

Impurities in water

There is a need to understand about these impurities in water because whenever we are planning an urban area, we need to understand the different sources of water and its quality. For example, if water testing is done in rural areas, there is lot of faecal coliform bacteria in the given water sample But we need to make sure that these levels are not up to the level which can actually harm us. Prior to that, we first need to understand the kind of impurities that could be present in water. While some of them may be harmful, some of them are not. Some of them impart certain characteristics to water, for example, presence of certain impurities will change the colour of water.

The water which we drink should not have any colour in it or should have very little amount. This is the reason why the understanding of kind of impurities in water is important.

The water which contains undesirable impurities is known as polluted water and the water containing pathogens is known as contaminated water. The polluted water and contaminated water are the ones which we should be worried about.

There are different types of impurities in water. Broadly these can be categorized in three groups, i.e., suspended impurities, colloidal impurities and dissolved impurities. Suspended impurities are basically solid particles which are large-sized, i.e., $1 - 10^{-3}$ mm size. These kinds of impurities could be removed through filtration. If the water containing these impurities are passed through any kind of filter, it would be actually able to remove these kind of particles because these are large in size and they get stuck in the pores of the filter. On the other hand, some of these particles could settle down because of their own weight. This is because specific gravity of particles are higher than that of water. If the water containing these type of impurities are kept in a particular space, they will separate and settle down. However, in some cases the specific gravity is not that high for some of these particles and they will remain mixed with water such as clay, algae, fungi, and some amount of organic and inorganic matter. The overall amount of these suspended impurities can be measured by their concentration which is measured by the turbidity of water. Thus, if we can measure the turbidity of water, we can understand the total amount of suspended impurities in that the water.

Thus, total suspended impurities can be removed either through sedimentation or through filtration. In a particular source of water, there could be different kinds of impurities and accordingly, we have to determine what kind of treatment has to be undertaken for a given kind of water sample based on the kind of impurities present in it. For example, if there are heavy particles, sedimentation can be done, or if there are smaller particles, filtration can be done.

Another kind of impurity in the water includes colloidal impurities. Colloidal impurities are even smaller than suspended impurities. Thus, these cannot be removed by ordinary filters, and thus some other ways should be employed. Chemical coagulation is done to remove these impurities. In this method, some chemicals are added into the water and these react with these particular colloidal particles and then they form some other compounds which are larger in size and can be easily removed.

Colloidal impurities are electrically charged which means they have ions on the surface which is either positive or negatively charged. Because of this charge, they repel each other. Moreover, the mass of the particles is also very less, thus they are able to repel each other very easily. This results in continuous motion of these particles inside the liquid that makes it difficult to separate. This is the reason why chemical coagulation is used to separate these kinds of impurities.

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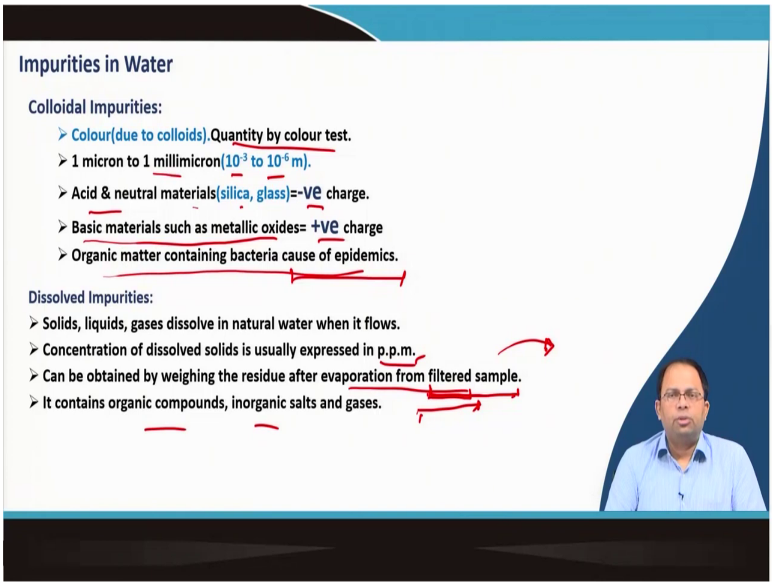

In the water containing these impurities, some amount of colour is imported because of these colloids and this can be determined by the colour test. The sizes of these particles are 10^{-3} – 10^{-6} m. The particles can be acidic, neutral and basic. Acid and neutral materials like silica and glass provides a negative charge to the particles, while basic materials such as metallic oxide provides it a positive charge. Organic matter containing bacteria could be also present as colloids which can cause epidemics. This is the reason why one needs to be very careful about colloids as well.

The third type of impurity includes dissolved impurities. Dissolved impurities could be solids, liquids, gases but these are usually present when water flows in natural environment and gases gets dissolved in the water. The concentration of dissolved solid could be expressed in part per million. This can be obtained by weighing the residue after evaporation from a filtered sample.

On boiling the water, the water will evaporate and a residue would be left that will contain both organic and inorganic materials. Gases will be evaporated. Thus, all the dissolved impurities could be got rid in this way. The evaporated water could be again converted into liquid.

After doing chemical coagulation, sedimentation and filtration only the dissolved impurities will be left which can be removed via evaporation. All the other impurities have already been removed earlier. Another way can also be employed where one can just do the evaporation and can get rid of the entire quantity of water. In this way, all different kinds of impurities could be removed.

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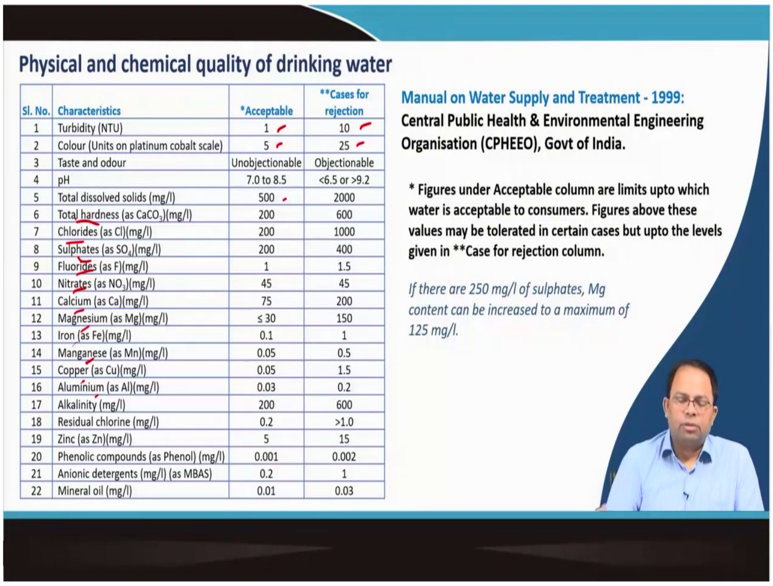

Sl. No.	Characteristics	*Acceptable	**Cases for rejection
1	Turbidity (NTU)	1	10
2	Colour (Units on platinum cobalt scale)	5	25
3	Taste and odour	Unobjectionable	Objectionable
4	pH	7.0 to 8.5	<6.5 or >9.2
5	Total dissolved solids (mg/l)	500	2000
6	Total hardness (as $CaCO_3$)(mg/l)	200	600
7	Chlorides (as Cl)(mg/l)	200	1000
8	Sulphates (as SO_4)(mg/l)	200	400
9	Fluorides (as F)(mg/l)	1	1.5
10	Nitrates (as NO_3)(mg/l)	45	45
11	Calcium (as Ca)(mg/l)	75	200
12	Magnesium (as Mg)(mg/l)	≤ 30	150
13	Iron (as Fe)(mg/l)	0.1	1
14	Manganese (as Mn)(mg/l)	0.05	0.5
15	Copper (as Cu)(mg/l)	0.05	1.5
16	Aluminium (as Al)(mg/l)	0.03	0.2
17	Alkalinity (mg/l)	200	600
18	Residual chlorine (mg/l)	0.2	>1.0
19	Zinc (as Zn)(mg/l)	5	15
20	Phenolic compounds (as Phenol) (mg/l)	0.001	0.002
21	Anionic detergents (mg/l) (as MBAS)	0.2	1
22	Mineral oil (mg/l)	0.01	0.03

Physical and chemical quality of drinking water

The Central Public Health and Environmental Engineering Organisation in India (CPHEEO)have given the standards for acceptable limits of different impurities in water for drinking purpose. It means that for drinking water, there has to be certain properties which should be within certain standards or certain limits.

In some cases, higher values are tolerated as seen in the fourth column that shows the cases for rejection. The values shown in the third column are limits up to which water is acceptable to consumers. The values above these may be tolerated in certain cases but up to the levels given in the fourth column.

Turbidity is measured using NTU. In this case, 1 unit is acceptable whereas 10 unit is the maximum limit in certain cases. Colour of the water is measured on a platinum cobalt scale. In this case, 5 units are acceptable whereas 25 units is the maximum limit when we can reject it. Regarding taste and odour, there has to be no objection. pH value from 7 to 8.5 is acceptable, whereas lesser than 6.5 or higher than 9.2 is not acceptable. For total dissolved solids, a maximum of 500 milligrams per litre is acceptable and 2000 milligrams per litre is the maximum limit in any other case. Similarly, there are other attributes as well including total hardness, chloride(sodium product or salt present in water), sulphates, fluorides, nitrates, calcium, magnesium, iron, manganese, copper, aluminium, etc.

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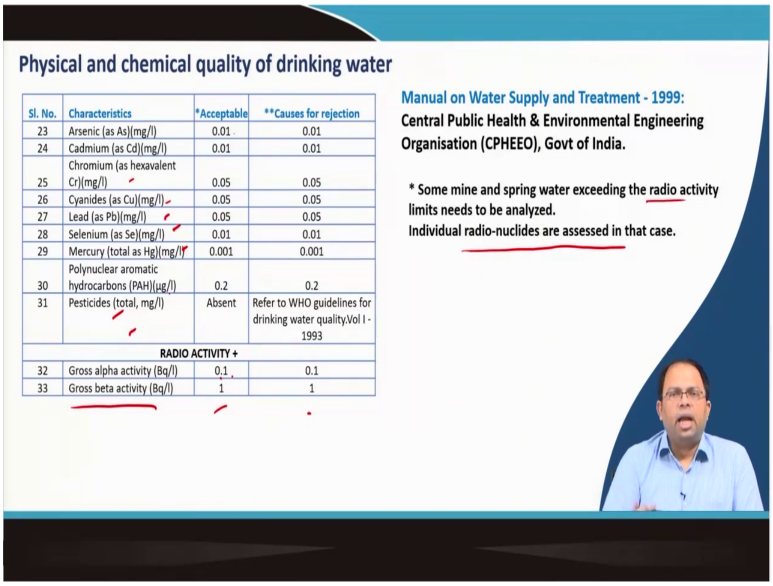

There are some other elements that are harmful and those are the ones for which acceptable limits are very limited values. These are the elements including arsenic, cadmium, chromium, cyanides, lead, selenium, and mercury. Also, some pesticides, and polynuclear aromatic hydrocarbon are also the ones which should be very careful about.

The acceptable limit is 0.01 milligrams per litre for arsenic, 0.01 milligrams per litre for cadmium, and 0.05 milligrams per litre for chromium as hexavalent chromium. These elements are the ones which create cancers and different kind of diseases. Thus, one must be very careful about these kind of constituents of drinking water.

Similarly, there is a test for radio activity. In some cases, for example, in some mines and spring water, sometimes radioactive elements are found and there is a need to analyze the limits for radioactivity and individual radio-nuclides has to be assessed. The unit for gross alpha activities is Bq. The maximum acceptable limit is 0.1. For gross beta activity, the maximum acceptable limit is 1.These are the two factors that are measured for radioactivity.

In general, these are the standards which have been specified by the government of India for the acceptable limit. It means that whenever water treatment is done, testing should also be also done. The water should conform to these particular limits. In case, the ground water is used directly, one should check that these are the limits that has been adhered to.

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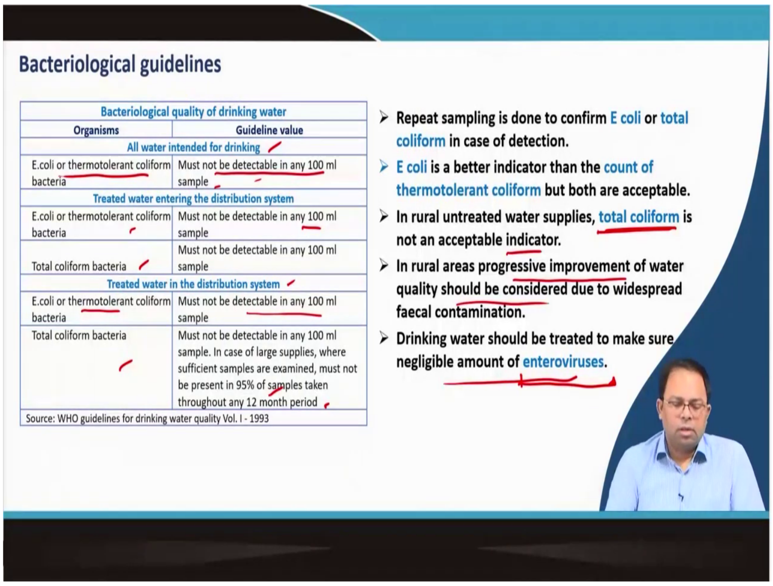

Bacteriological guidelines

In addition to all this chemical constituents, there are guidelines in regards to bacteria. According to these guidelines, most types of listed bacteria are not required or should not be detectable in water. For example E coli or thermotolerant coliform bacteria must not be detectable in any 100 millilitre sample. These are coliform bacteria usually is present in faecal matter. Whenever this kind of bacteria is tested in the water, it indicates that there is faecal contamination of water.

It also means that there can be other pathogenic bacteria in water which would be actually harmful for a human body. Even though coliform itself is not harmful, but their presence indicates presence of other harmful bacteria. That is why it needs to be made sure that that these are not detected in the water sample.

In this context, the three kinds of standards have been mentioned, i.e., water intended for drinking, treated water entering the distribution system, and the treated water in the distribution system. For water intended for drinking, we may need to make sure that thermotolerant coliform or E coli is not being detected in 100 millilitre samples.

Treated water in the distribution system is the water that is getting in the system after treatment. This is water at different points in the distribution system. As there can be contamination in the pipeline i.e., in certain cases there may be leakages from where sewage may be getting mixed with the pipeline. This is why we also have to test the water quality at different points in the distribution network. At these points, there should not be any E coli or thermotolerant coliform bacteria detected. However for total coliform bacteria, even though it should not be detectable in 100 millilitre samples, in case of large supplies where sufficient samples are examined it must not be present in 95 percent of the samples taken throughout any 12 month period. This is the standard specified by CPHEEO.

Usually when E coli is detected, repeat sampling is performed as E coli is a better indicator than the count of thermo tolerant coliform, but both are acceptable. However, in rural untreated water supplies, presence of total coliform is not an acceptable indicator. In rural water supply, there is lot of faecal contamination, thus total coliform bacteria can be present. Thus, if it is taken as an indicator, then none of the water supplies can be of any use. In rural water areas, we cannot expect a clean water supply suddenly. There will be progressive improvement of water quality in rural areas. That is why the standards are kept lower. For drinking water; total coliform can be present to some extent, however E coli should not be present. Drinking water should be treated to make sure negligible amount of enteroviruses are there in rural areas.

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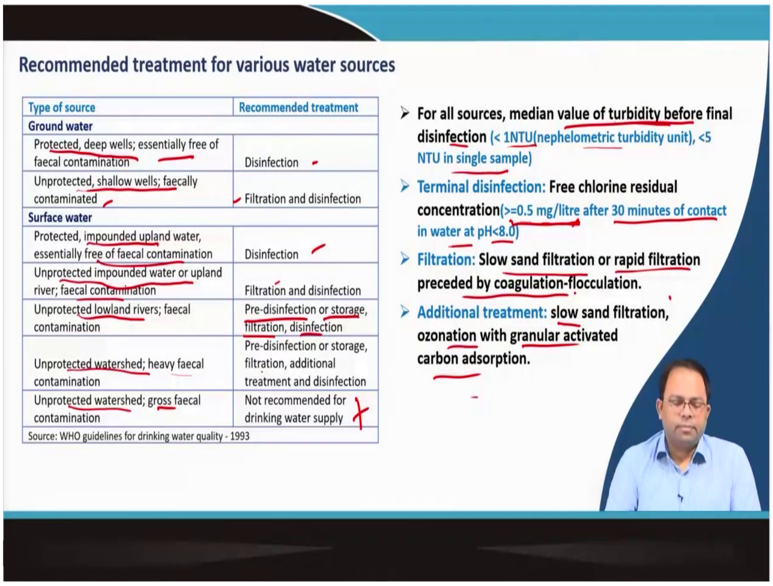

Recommended treatment for various water sources

There are standards for drinking water supply both for urban and rural areas, but when certain area is being planned, there is a need to understand the kind of source and recommend kind of treatment. Sometimes the area may be cut off from the other habitation, i.e., it can be an independent area. In that case, one should understand the recommended treatment for water based on the sources. If it is a ground water like protected deep wells, essentially free from faecal contamination, in this case, we can suggest that this water could be directly taken up just with disinfection or mixing with chlorine. For unprotected, shallow wells with some amount of faecal contamination, filtration and then disinfection should be performed. Only disinfection will not work in this case. Similarly, for surface water sources, if it is a protected impounded upland water (water channel at levels which are above the sea level or at higher levels of the stream) and there is no chance of faecal contamination (because it serves as a dam), the water can be used after disinfection only. However, if the water source is downstream or if it is unprotected impounded water or upland river and faecal contamination is happening, filtration and disinfection should be performed. But if it is unprotected, lowland reserve with faecal contamination, there should be further treatment also, i.e., pre-disinfection, storage, filtration, and disinfection. For unprotected, watershed with heavy faecal contamination, one should perform filtration, pre-disinfection or storage, and additional treatments and disinfection. For unprotected watershed with gross faecal contamination, water sources are not recommended to be used for drinking water supply but sometimes, if there are no other sources, treatment has to be performed.

For all sources, regarding the bacteriological perspective, the median value for turbidity before final disinfection should be less than 1 NTU which is nephelometric turbidity unit and less than 5 NTU in a single sample. It means that if one sample is taken, then it should be less than 5 NTU, but if multiple samples are taken, it should be less than 1 NTU. In terminal disinfection, some amount of chlorine has to be given for disinfection and some amount of it has to be left which is called the residual concentration of chlorine or free chlorine.

The value of free chlorine should be greater than 0.5 milligram per litre after 30 minutes of contact in water at pH of lesser than 8. If there is chance of contamination, then this residual chlorine will disinfect the water.

Filtration refers to slow sand filtration or rapid filtration preceded by coagulation and flocculation. It means that there is a need to perform chemical coagulation before doing filtration. For additional treatment, slow sand filtration, ozonation using granular activated carbon absorption can be performed.

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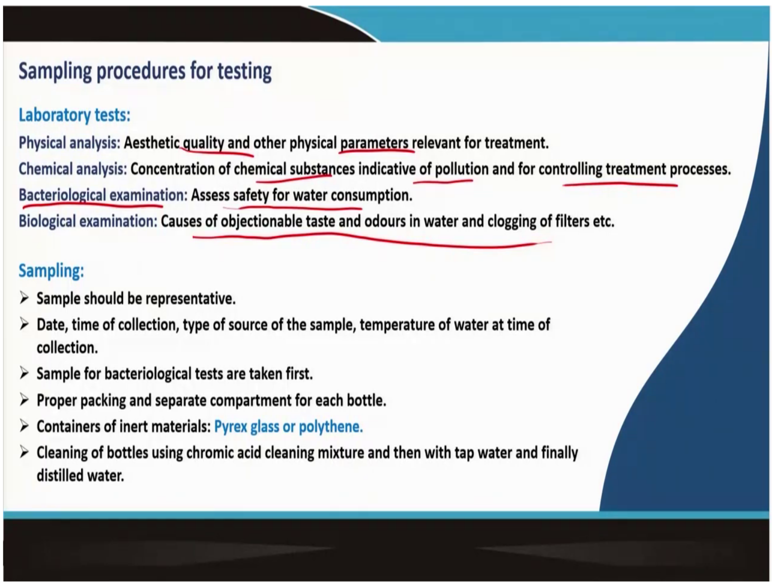

Sampling procedures for testing

Though we can always perform testing in a laboratory environment, but whenever we go to field/site for conducting surveys, for particular urban areas, we conduct different kind of surveys such as household surveys and traffic surveys. Similarly, we also collect samples of water from different kind of sources to understand water quality, contamination of certain water bodies, for example; contamination via sewage in certain lakes. Thus water samples from the given lake are tested to understand if sewage is getting mixed or not. To accomplish this task, different test are conducted. In certain areas if there is no water treatment unit, we need to recommend a sort of treatment for a particular water body which people can use for drinking and other purposes. That is why quality of water needs to be tested. The quality of water from the distribution network also needs to be tested to understand the quality of the distribution network, if there is some contamination in the water or, if there are leakages within the network. This is the reason why some amount of testing has to be done at the field level, while some amount of testing has to be done immediately as the sample is collected.

These kind of tests confirms the physical, chemical, and the bacteriological properties of the water. The physical analysis helps to understand the aesthetic quality and other physical parameters that is relevant for treatment. The chemical analysis provides an idea about what kind of chemical substances are present in the water and determines concentration of chemical substances that indicate different kinds of pollution. Accordingly, different kind of treatment processes can be suggested. The bacteriological examination is primarily performed to assess safety of the water for consumption purposes. Biological examination is performed to ascertain causes of objection over taste and odors in water and reasons of clogging of filters. Biological contaminants need to be checked, for example, some matter might be getting decomposed in that particular water body. Thus, organic matter, and decomposing organic matter has to be also tested for. In addition, bacteria that can cause various different health issues must also be tested.

Water sampling has to be done carefully following certain procedures. Otherwise, testing results would be not based on the actual water sample, but based on the content already present in the bottle or based on the material of that bottle that is being used.

Whenever a surveying team goes to a field/site for a survey, they need to follow the given steps and they need to carry a given kind of containers along with them.

Firstly, the sample has to be representative; that means, it should represent the water that is been tested. Date, time of collection, type of source of the sample, and temperature of water at time of collection has to be recorded.

Samples for bacteriological test are taken first. Proper packing and separate compartment should be ensured for each bottle. Containers of inert materials of Pyrex glass or polythene should be used as these materials does not react with the water. Cleaning of sample bottles should be performed using chromic acid cleaning mixture, then with tap water and finally, with distilled water.

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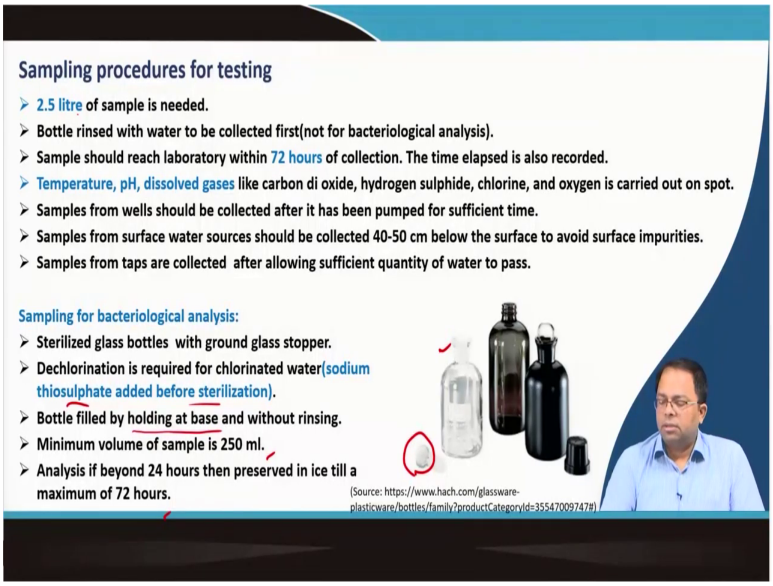

The amount of sample collected is 2.5 litre from each area. The sample bottle has to be first rinsed with water whenever the sample is collected except for the bacteriological analysis.

For all other purposes, the bottle needs to be cleaned with the water from which the sample is being collected. Sample should reach laboratory within 72 hours. It is very important because certain characteristics will change with time such as temperature, pH, dissolved gases like carbon dioxide, oxygen, hydrogen sulphide, etc. Therefore, it is better to perform on the spot testing as soon as possible. To do the testing on the spot, different meters are available that can be directly put in the water to get the results. Samples from wells should be collected after it is pumped for sufficient time. That means, one should be getting the groundwater that is flowing inside the well.

Samples from surface water sources should be collected from 40 to 50 centimetre below the surface to avoid impurities. That means, when the water sample is collected from a river, one should first put the bottle below the water 40 to 50 centimetre, then only release the mouth of the bottle to get the sample. Samples from taps are collected after allowing sufficient quantity of water to pass. These are the standard procedures that you should be followed whenever water samples are being collected for testing.

For bacterial analysis, one needs to be more careful. Sterilized glass bottles with ground glass stopper should be used. When chlorinated water or treated water is tested, we need to dechlorinate first using sodium thiosulphate before the sterilization process. Then, bottle is filled up by holding at base and without rinsing. Minimum volume size is 250 ml which is unlike the 2.5 litre that needs to be collected for other test.

Analysis if needs to be done beyond 24 hours, the sample needs to be preserved in ice till a maximum of 72 hours. After 72 hours, the sample should be discarded.

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The frequency of sampling depends on the type of water that is tested, the treatment process and the local context. The sampling has to be done for both raw water and treated water to see the differences and to understand the base line as well.

Bacteriological sampling has to be conducted at different parts of the water supply system to understand that if the leakage is happening. Testing the water at different points will help to understand where leakage is happening and what kind of contamination it is resulting in.

This table shows the minimum sampling frequency as per Indian standards for distribution system. For larger population of 100000 people, sample has to be collected every day. For a population of 10000, one sample has to be collected per month. For population of 50000 to 1 lakh, sample has to be collected every 4 days. One sample per 5000 population samples need to be collected per month.

For doing water tests, water treatment plants usually have a laboratory but in addition, the utility provider should also test the water quality in the distribution network. Sometimes as a planner, we need to do these tests to understand the situation in that particular network because some information may not be provided by the utility providers. This is where an urban planner should also be ready to test these kinds of samples.

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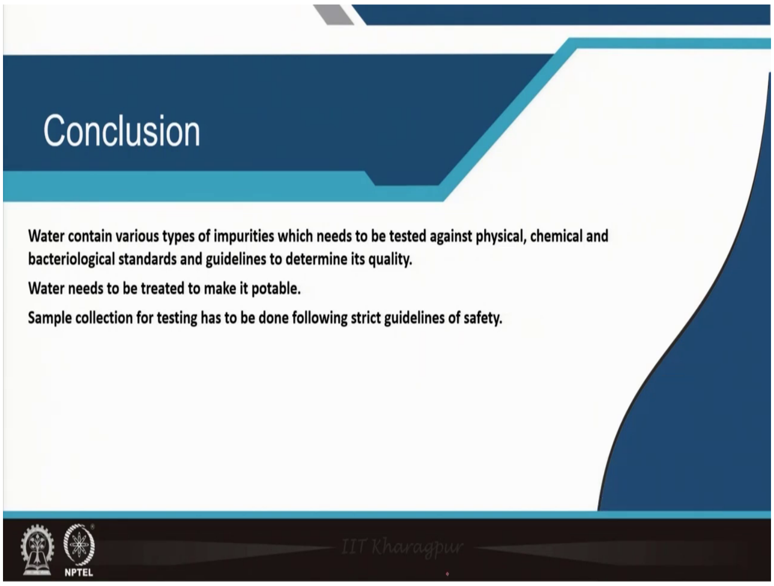

Conclusion

To conclude, water contain various types of impurities which needs to be tested against physical, chemical and bacteriological standards and guidelines to determine its quality. Water needs to be treated to make it potable. Sample collection for testing has to be done following strict guidelines of safety.

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References

These are the references.