Basic Environmental Engineering
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Lecture 11
Environmental Quality and Standards 1

Hello everyone. Now, we will discuss on the topic environmental quality and standards. In the previous classes, we have discussed that different types of pollutants enter into atmosphere, water and soil and these pollutants are transmitted from one place to other and enter into the human body or any living organism and generates different types of consequences or health impacts.

Thus it is very clear to us that there should be certain standard or certain values of these pollutants above which we may suffer different diseases. But if it is below certain limit it may be clean to us, it may be safe to us. Thus we should have good idea about the quality parameters of air, water and soil. And also we should have some idea about the standards.

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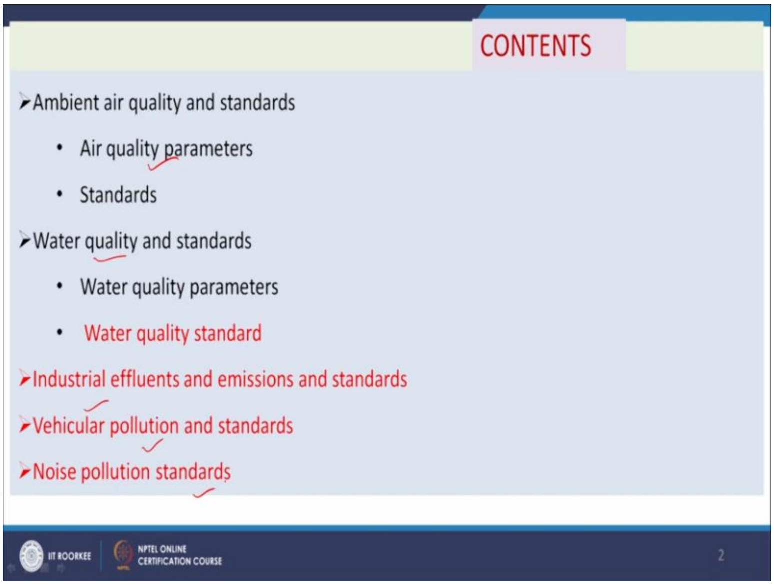

So, now, we will discuss on the ambient air quality and standards air quality parameter and standards then we will discuss water quality and standards, water quality parameters and then what are the standards. Then we will discuss industrial effluence and emission and their standards. And vehicular pollution and their standards. And noise pollution standards. So, these will help us to understand the possibility of risk or the health consequences or any adverse consequences on our health or on the environment.

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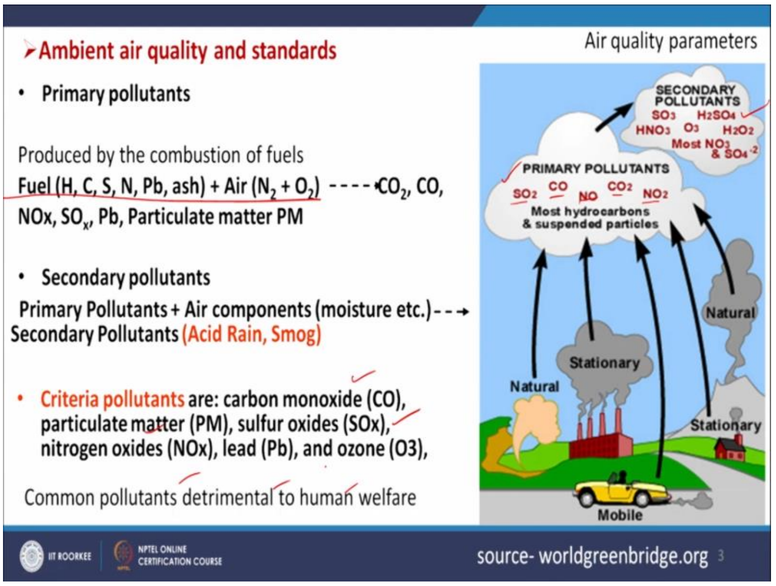

Now, you see air quality parameters, already, we have discussed in the previous classes, some of the classes that there are some criteria pollutants for air, so, to mention the quality, we need to know the values of those parameters like say particulate matter, carbon monoxide, SOx, NOx, lead and ozone.

Here we will see that these pollutants like SOx, NOx, here a particularly sulphur dioxide NO_2, NO, CO, CO_2 are entering into the atmosphere from different primary sources. So, these are primary pollutants and these primary pollutants are converted to other form of these and those are called secondary pollutants.

And secondary pollutants basically, these primary pollutants are converted to those form and these primary pollutants which are generated from different activities mostly from fuel combustion that is as mentioned here and we have discussed in detail in our previous class. So, here we will see that what are the quality parameters that is this criteria pollutants which you have mentioned here and what should be the limit, permissible limit, so, that we will be discussing.

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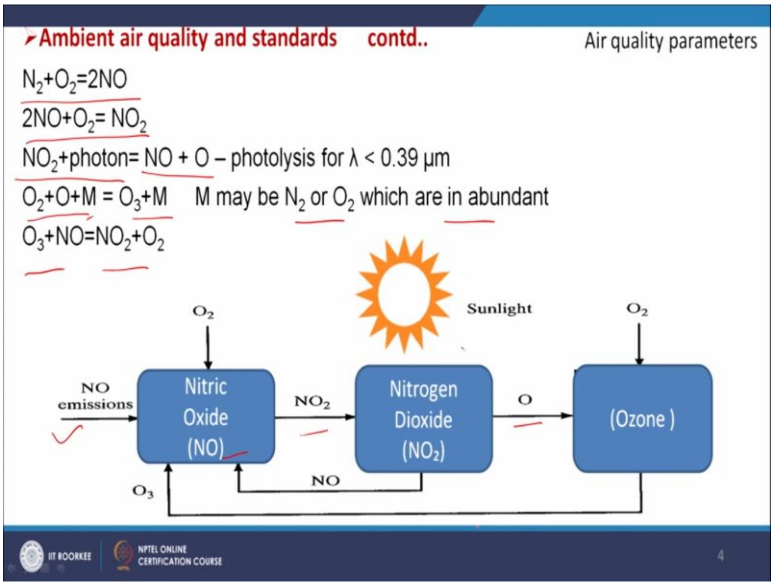

Before that we will be seeing that NOx, different types of nitrogen oxide concentration in the atmosphere can vary in a day. So, there are some reactions and conversions of this different types of NOx like say

$N_2 + O_2 = 2NO$

$2NO + O_2 = NO_2$

NO_2 + photon = NO+ O- photolysis for $\lambda < 0.39$ μm

$O_2+O+M = O_3+M$ M may be N_2 or O_2 which are in abundant

$O_3+NO=NO_2+O_2$

So, different types of reactions are responsible for the conversions of these NOxes or different type of oxides of nitrogen.

So, NO emissions, so, here it is oxygen. So, NO is converted to NO_2, NO_2, again here say sunlight NO_2 will be giving us oxide, oxygen and nascent oxygen and then that will be reacting with oxygen and give us ozone. So, that ozone will be. So, there is some different types of reactions where the oxides of nitrogen transfer from one form to other form.

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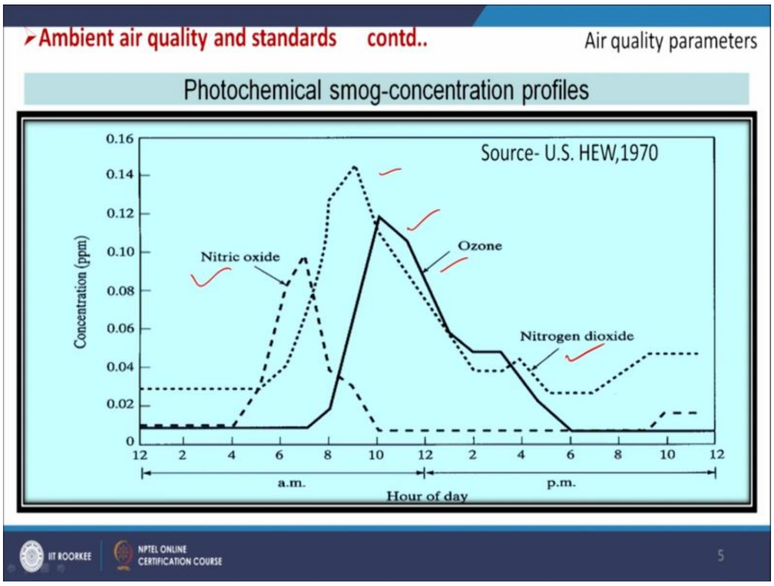

So, here, if we see the relative abundance of this nitric oxide, nitrogen dioxide and ozone in a day. So, you see here, say this is at midnight then 2 am, 4 am, 6 am, 8 am, 10 am, 12 am. So, we are getting maximum ozone here and maximum nitrogen dioxide but these concentrations are reduced with time. So, that way along with the day, at different time, different types of NOx and nitrogen oxides are available in the atmosphere. Now, we will see the standards. So, what will be the ambient air standards, which is available in our surrounding?

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So, in that case, as you have mentioned there are some criteria pollutants, so, we will see here SO_2, NO_2, SPM, RSPM. So, this standard was developed in 1994 that is National Ambient Air Quality Standards.

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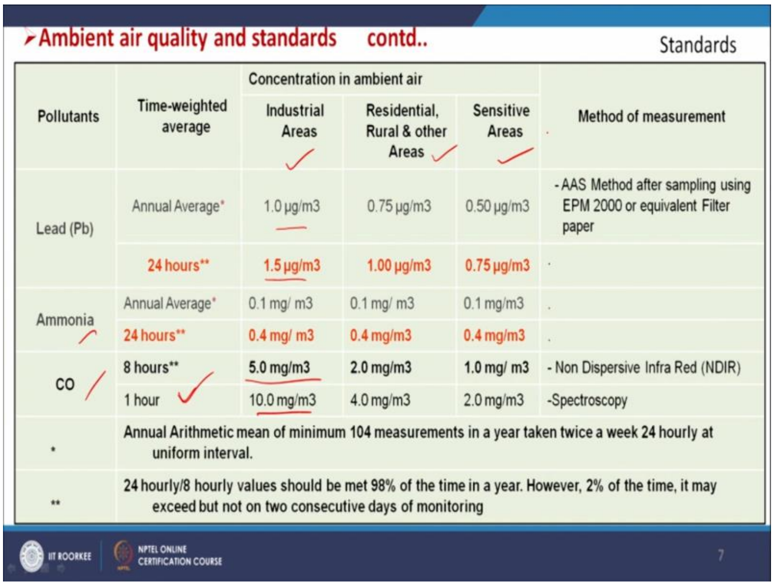
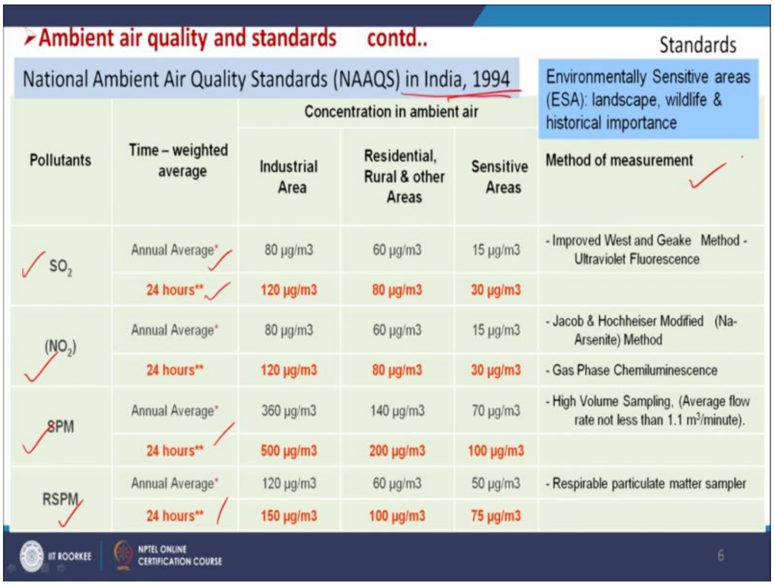


Pollutants	Time-weighted average	Concentration in ambient air: Industrial Areas	Residential, Rural & other Areas	Sensitive Areas	Method of measurement
Lead (Pb)	Annual Average*	1.0 µg/m3	0.75 µg/m3	0.50 µg/m3	- AAS Method after sampling using EPM 2000 or equivalent Filter paper
	24 hours**	1.5 µg/m3	1.00 µg/m3	0.75 µg/m3	
Ammonia	Annual Average*	0.1 mg/ m3	0.1 mg/ m3	0.1 mg/m3	
	24 hours**	0.4 mg/ m3	0.4 mg/m3	0.4 mg/m3	
CO	8 hours**	5.0 mg/m3	2.0 mg/m3	1.0 mg/ m3	- Non Dispersive Infra Red (NDIR)
	1 hour	10.0 mg/m3	4.0 mg/m3	2.0 mg/m3	-Spectroscopy
*	Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval.				
**	24 hourly/8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days of monitoring				



Pollutants	Time – weighted average	Concentration in ambient air: Industrial Area	Residential, Rural & other Areas	Sensitive Areas	Method of measurement
SO_2	Annual Average*	80 µg/m3	60 µg/m3	15 µg/m3	- Improved West and Geake Method - Ultraviolet Fluorescence
	24 hours**	120 µg/m3	80 µg/m3	30 µg/m3	
(NO_2)	Annual Average*	80 µg/m3	60 µg/m3	15 µg/m3	- Jacob & Hochheiser Modified (Na-Arsenite) Method
	24 hours**	120 µg/m3	80 µg/m3	30 µg/m3	- Gas Phase Chemiluminescence
SPM	Annual Average*	360 µg/m3	140 µg/m3	70 µg/m3	- High Volume Sampling, (Average flow rate not less than 1.1 m^3/minute).
	24 hours**	500 µg/m3	200 µg/m3	100 µg/m3	
RSPM	Annual Average*	120 µg/m3	60 µg/m3	50 µg/m3	- Respirable particulate matter sampler
	24 hours**	150 µg/m3	100 µg/m3	75 µg/m3	

And these are the pollutants, which are mentioned and then lead, ammonia, carbon monoxide. So, these are the total pollutants mentioned in this. Here we will see there are annual average, 24-hour basis for SOx, for NOx also for SPM also for RSPM also. But here for carbon monoxide 8 hours and 1-hour average are also there. This annual average means we are living in our environment throughout the year.

So, the pollutant concentration should be very very less, because you are exposed throughout the year. So, in that particular area, the pollutant concentration should be less. But if we are exposed to a restricted area for some duration, at that time, the pollutants concentration may be slightly more than the annual average values.

You see example for this lead and all average 1.0 $\mu g/m^3$ but here for 24-hour basis 1.5 $\mu g/m^3$. That means if we are exposed to an environment for certain period of time then if the pollutants are even in higher in concentration that will not impact on our health.

Similarly, say in case of carbon monoxide 8 hourly basis 5 mg/m^3 but 1 hourly basis 10 mg/m^3. So, if we expose for 1 hour, if the concentration is having $\mu g/m^3$ carbon monoxide then it may not be any negative impact. And if we expose there for 8 hours, we, this concentration cannot be 10 that has to be 5 otherwise we may say, we may face some negative consequences. So, these are the basis and different values are given.

Another important aspect here we see that industrial areas, residential, rural and other areas and sensitive areas. So, for three different locations was identified by the CPCB or the regulatory body in the 1994 air quality standards and these are the values. And this column shows different methods which can be used for the analysis purpose and to get the values of these parameters.

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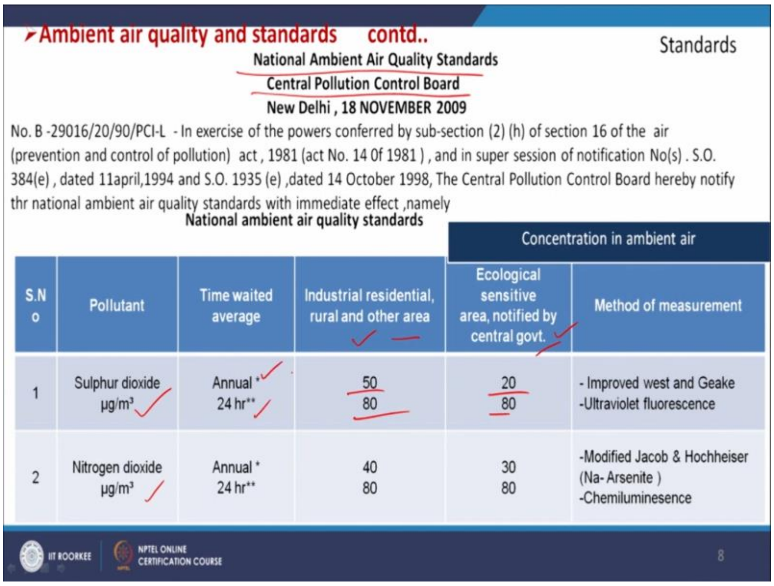
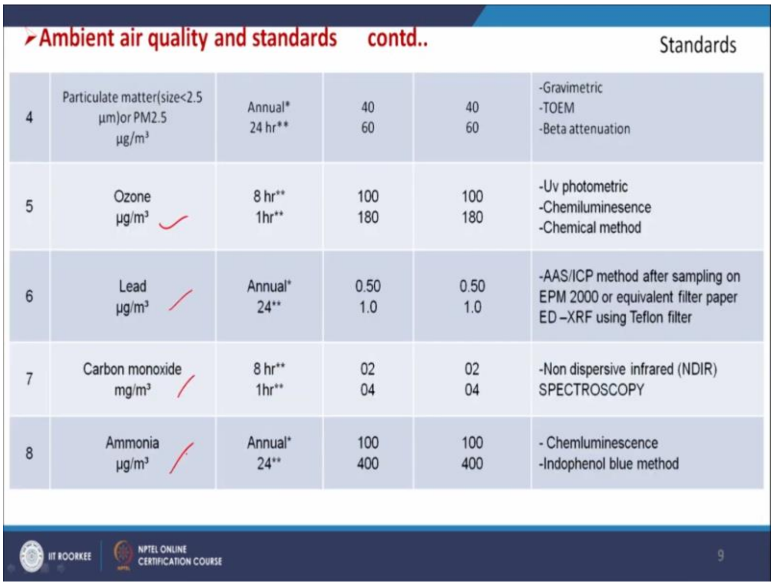
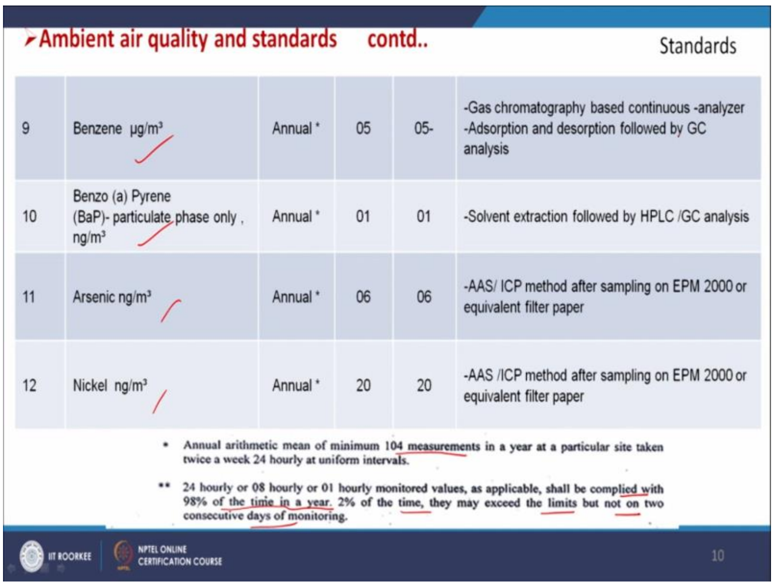


			Concentration in ambient air		
S.No	Pollutant	Time waited average	Industrial residential, rural and other area	Ecological sensitive area, notified by central govt.	Method of measurement
1	Sulphur dioxide µg/m³	Annual * 24 hr**	50 80	20 80	- Improved west and Geake -Ultraviolet fluorescence
2	Nitrogen dioxide µg/m³	Annual * 24 hr**	40 80	30 80	-Modified Jacob & Hochheiser (Na- Arsenite) -Chemiluminesence



4	Particulate matter(size<2.5 µm)or PM2.5 µg/m³	Annual* 24 hr**	40 60	40 60	-Gravimetric -TOEM -Beta attenuation
5	Ozone µg/m³	8 hr** 1hr**	100 180	100 180	-Uv photometric -Chemiluminesence -Chemical method
6	Lead µg/m³	Annual* 24**	0.50 1.0	0.50 1.0	-AAS/ICP method after sampling on EPM 2000 or equivalent filter paper ED –XRF using Teflon filter
7	Carbon monoxide mg/m³	8 hr** 1hr**	02 04	02 04	-Non dispersive infrared (NDIR) SPECTROSCOPY
8	Ammonia µg/m³	Annual* 24**	100 400	100 400	- Chemluminescence -Indophenol blue method



9	Benzene µg/m³	Annual *	05	05-	-Gas chromatography based continuous -analyzer -Adsorption and desorption followed by GC analysis
10	Benzo (a) Pyrene (BaP)- particulate phase only , ng/m³	Annual *	01	01	-Solvent extraction followed by HPLC /GC analysis
11	Arsenic ng/m³	Annual *	06	06	-AAS/ ICP method after sampling on EPM 2000 or equivalent filter paper
12	Nickel ng/m³	Annual *	20	20	-AAS /ICP method after sampling on EPM 2000 or equivalent filter paper

* Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

** 24 hourly or 08 hourly or 01 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

Now, in 2009, Central Pollution Control Board have revised this and as per these National Ambient Air Quality Standards, there are more parameters.

You see here sulphur dioxide, nitrogen dioxide and then Ozone, lead, carbon monoxide, ammonia, then benzene, benzopyrene, arsenic, nickel. So, these are not there in the 1994 standards. So, what does it mean, day by day people are becoming more aware about the negative impacts of different types of pollutants present in the air and new pollutants are also added as the quality parameter.

And here you see, another difference we see with respect to 1994 standards the values are reduced and there are two categories, unlike three categories in 1994 standard. Here we have industrial, residential, rural and other area and ecological sensitive area notified by central government. So, the values are also different.

However, this basis for annual basis and 24-hour basis are remaining same for all the cases, up to carbon monoxide as you have seen and other are added like this that is annual basis. So, this is the new national ambient air quality standard as per CPCB notification 2009. And here it is given, what is annual basis. Annual basis means annual arithmetic mean of minimums 104 measurements. So, there are 52 weeks. So, twice in a week. So, 104 number of minimum samples has to be considered and their average has to be considered as the annual basis.

So, what is the concentration of the pollutants which is fuelling throughout the year? And 24 hourly or 8 hourly or 1 hourly mentioned values, as applicable, shall be complied with 98 % of the time in a year and 2% of the time they may exceed the limits, but not on two consecutive days of monitoring. So, here also different methods which can be used for the determinations of the concentration of these parameters in the air.

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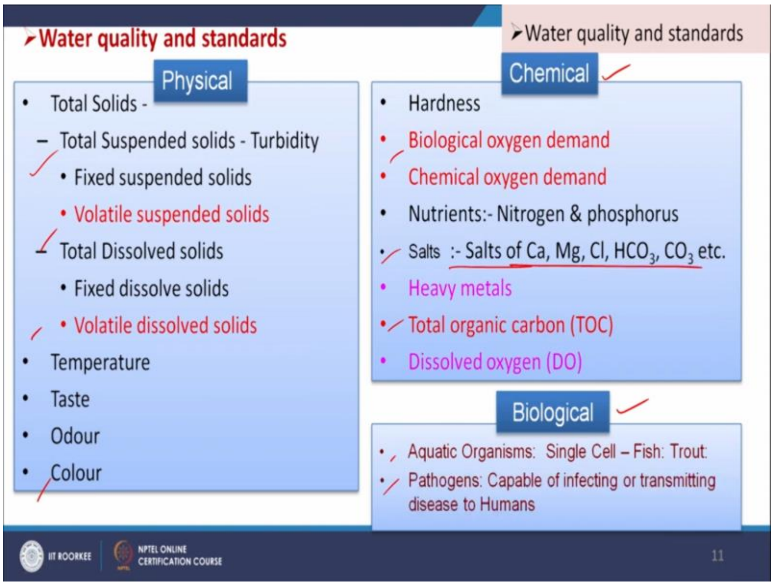

So, this is ambient air quality standards. Now, we will discuss the water quality and their standards. So, water quality, we have seen in the previous class as well that water has some physical properties or physical qualities, some chemical qualities and some biological qualities.

So, quality parameters will be of physical, chemical and biological type. And these are the different types as mentioned in this slide. Our objective will be to know how the quality will vary. We will also in a subsequent chapters discuss how to analyze these quality parameters and how to get the values of those. But here we will be discussing something more about the water quality in terms of salts present in the water.

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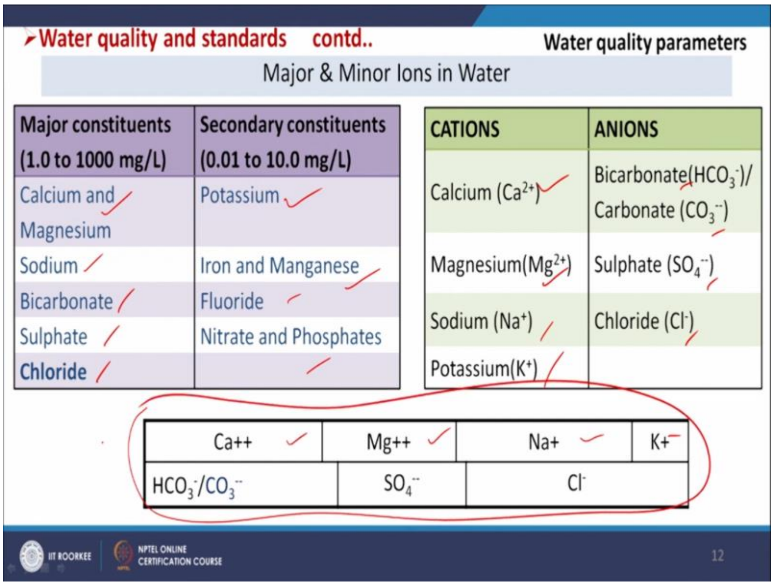

So, you see, if we see different types of salts and ions present in the water then we see that there will be calcium, magnesium, sodium, bicarbonate, sulphate and chloride in larger concentration that is 1 to 1000 mg/L and these other will be in lesser concentration, there is potassium, iron, manganese, fluoride, nitrate and phosphorus, that is 0.01 to 10 mg/L.

And we can classify these into two categories, the cations and anions that is calcium, magnesium, sodium, potassium ion, whereas bicarbonate, carbonate, sulfate and chloride ion. So, we can present this data in a bar graph or in a table. So, like this say, this is calcium, magnesium, sodium. So, this is your cations and these are the anions, concentration both are same. So, that is ion balance, there will be some balance of the ions.

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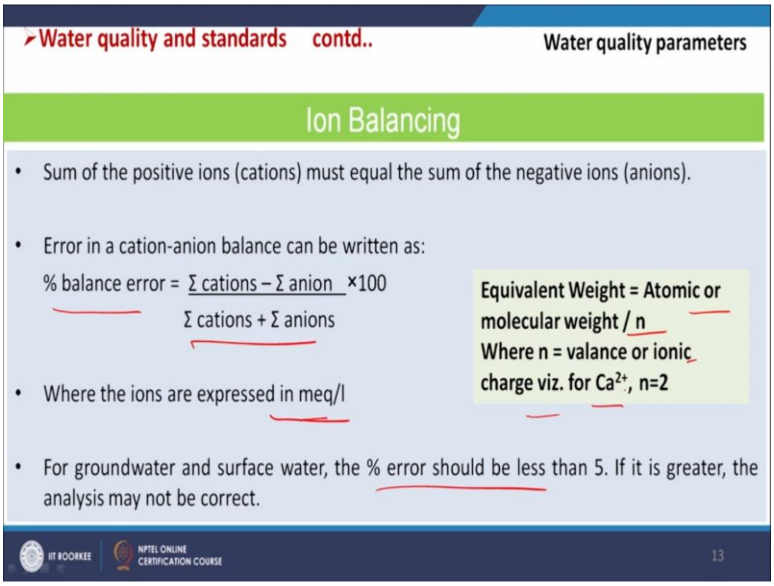

So, sum of positive ions must equal to the sum of negative ions. In any water theoretically it should be there. But many times due to error in the analysis, we may not get the exact ion balance without any error. Normally, there exist some error. And up to 5% error is acceptable and if it is more than that then we need to again reevaluate the values and to get the quality parameter.

And when we are interested to get the percentage balance error in the ion balance error

$$\% \text{ balance error} = \frac{\Sigma \text{ cations} - \Sigma \text{ anion}}{\Sigma \text{ cations} + \Sigma \text{ anion}} \times 100$$

This cation and anion concentrations are taken in mili equivalent per liter. So, this is the definition, this is the way we can calculate the error in the ion balance. So, that is equivalent weight equal to atomic or molecular weight/n. So, here n is valence or ionic charge that is for Ca^{2+}, n = 2, for Al^{3+}, it is n =3.

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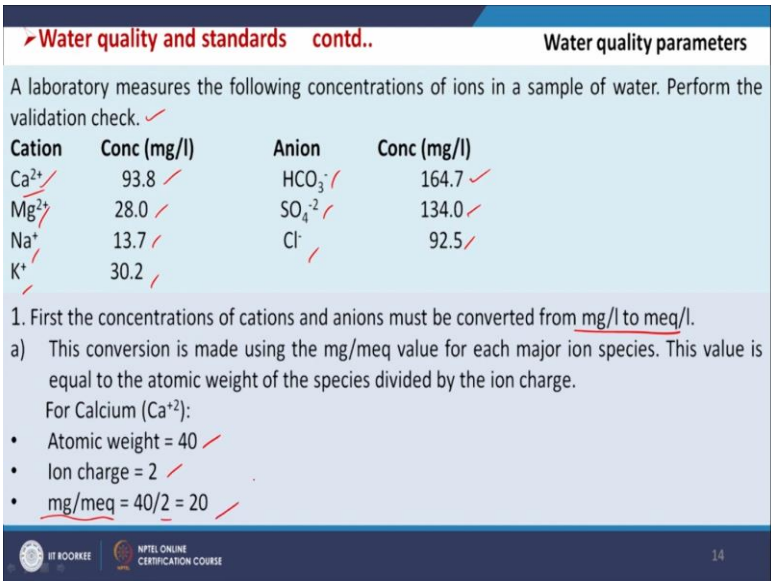

Now, you see a laboratory measures the following concentrations of ions in a sample of water, perform the validation check, whether this analysis is correct or not. That means we have to do the iron balance error calculation. Then if it is within limit, less than 5% then we will say that these data are correct.

Now, here you see cation like say calcium, magnesium, sodium, potassium concentration is given this, this, this and anion bicarbonate, sulfate and chloride, the concentrations are also given. Then we have to validate it. That means we have to calculate the ion balance calculation.

So, now, let us do. So, first the concentrations of cations and ions must be converted into mg/L or meq/L. So, for this what we will do? Say, let us take one example for calcium. So, for calcium (Ca^{+2}):

Atomic weight =40.

Ion charge = 2.

mg/meq = 40/2 = 20.

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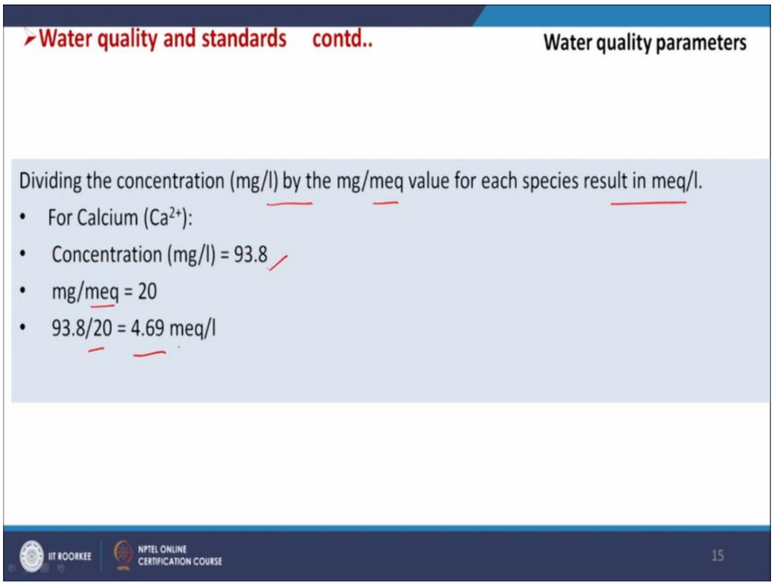

Then dividing the concentration mg/L by the mg/meq value for each species result in the meq/L. So, for this calcium, concentration in this case is 93.8 mg/L.

mg/meq = 20

93.8/20 = 4.69 meq/L for calcium.

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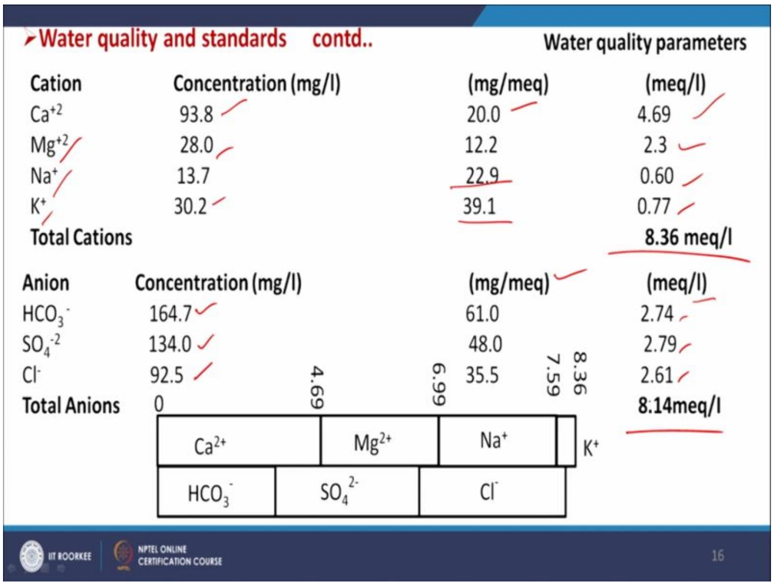

So, similar way, we can calculate for magnesium, for sodium, for potassium, we have concentration mg/L and we have mg/meq. So, that is your atomic weight of this and then mg/meq of these and then these are meq/L. So, the calculations I have shown with respect to calcium, similar way for others also we can do and we will get these values basically.

And this value we have got that is atomic weight/n, like say calcium 40/2 but the sodium has 1, so, n equal to 1, valency 1. So, 22.9. There is atomic weight/1. So, 22.9 we are getting here. Similarly, for potassium. Now, for anions we have these three anions, their concentrations are also given here.

So, we have to calculate the mg/meq. So, that is 61, 48 and 35.5 for all these three, respectively. And then if we get the value of meq/L by the similar way for calcium ion we have calculated in the previous slide. So, these values are becoming like this. So, here we are getting 8.36 meq/L total cation and here we are getting 8.14 meq/L total anion. So, the difference will be this minus this and if we calculate the percentage is less than 5 %.

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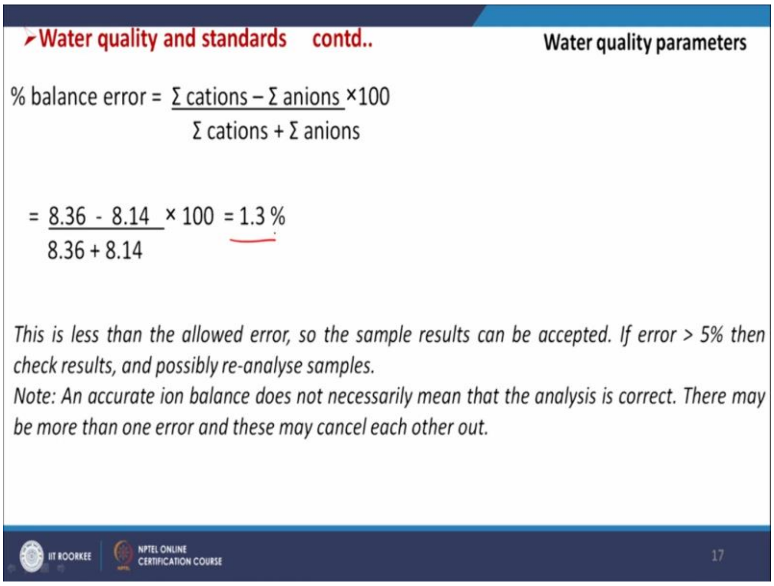

The percentage here we are getting that is equal to

$$\%\ \text{balance error} = \frac{\Sigma\ \text{cations} - \Sigma\ \text{anion}}{\Sigma\ \text{cations} + \Sigma\ \text{anion}} \times 100$$

$$= \frac{8.36 - 8.14}{8.36 + 8.14} \times 100 = 1.3\%$$

So, our error is less than 5 percent. So, this analysis report is validated.

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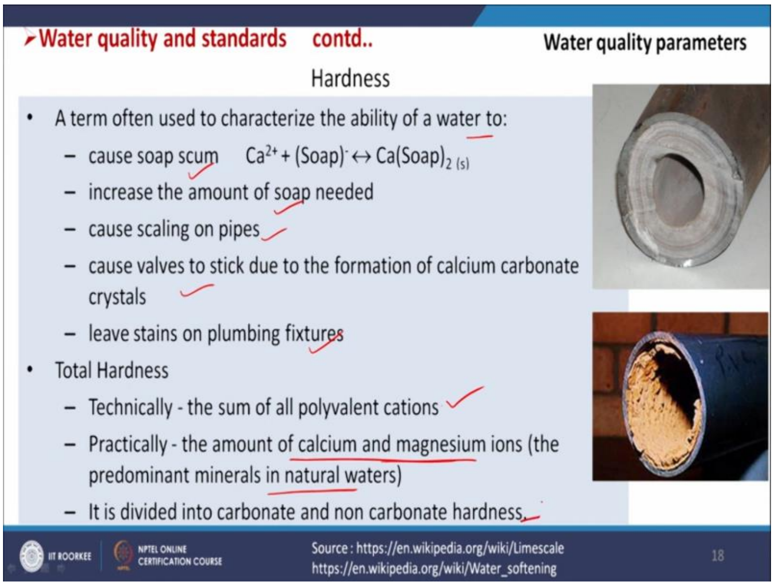

Now, we will discuss another water quality parameter that is hardness that is related to water quality. So, hardness you know a term often used to characterize the ability of a water to cause soap scum and increase the amount of soap needed and cause scaling on pipes like this you see here and cause valves to stick due to formation of calcium carbonate crystals and leaves strains on plumbing fixtures. So, these are characteristics which indicates that yes the water hardness is higher.

And you know we have two types of that is your total hardness that the sum of all polyvalent cations, theoretically, technically, the sum of all polyvalent cations. The amount of calcium and magnesium ions. The predominant minerals in the natural waters. And it is divided into carbonate and non-carbonate hardness. So, this hardness is maybe carbonate hardness and may be non-carbonate hardness.

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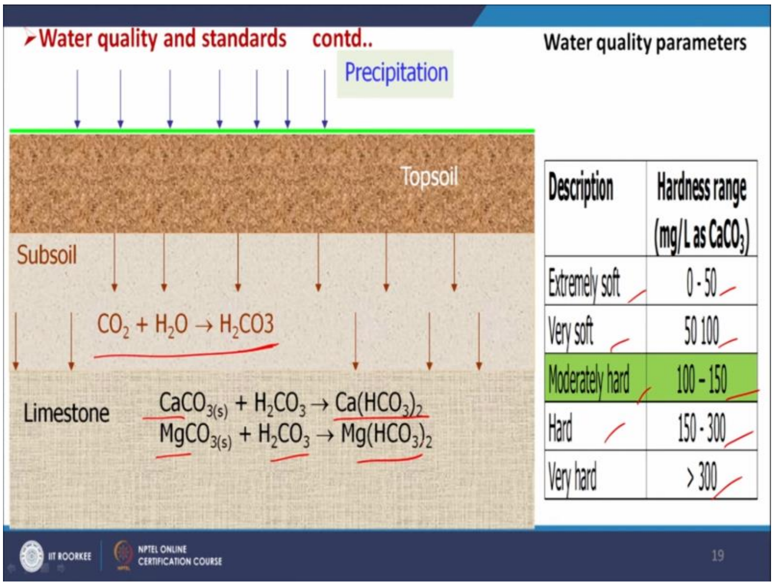

So, you see, if the hardness range is 0 to 50 then it is extremely soft and 50 to 100 very soft, 100 to 150 moderately hard, 150 to 300 hard and if it is greater than 300 then it is very hard. So, this is the hardness range of water and this value we should know.

And you know, when the acid drain takes place or any rain takes place, its pH is basically acidic and then when it percolates to the sub soil then this type of reactions can take place. So, $CO_2 + H_2O \rightarrow H_2CO_3$.

$CaCO_{3(s)} + H_2CO_3 \rightarrow Ca(HCO_3)_2$

$MgCO_{3(s)} + H_2CO_3 \rightarrow Mg(HCO_3)_2$

So, what is the origin of bicarbonate? That is this described in this slide.

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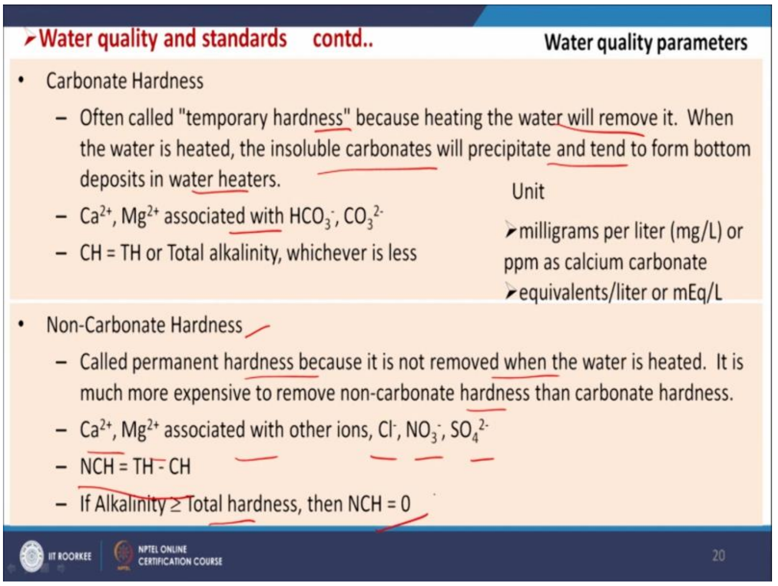

Now, carbonate hardness that is often called temporary hardness because heating the water will remove it. When the water is heated, the insoluble carbonates will precipitate and tend to form bottom deposits in water heaters. And calcium and magnesium associated with bicarbonate and carbonate, they gives a carbonate hardness.

And non-carbonate hardness that called permanent hardness because it is not removed when the water is heated. It is much more expensive to remove non-carbonate hardness than carbonate hardness. And calcium and magnesium associated with other ions like say chloride, nitrate, sulphate, etc. So, calcium and magnesium which is present in the water may be associated with bicarbonate and carbonate or may be associated with other anions.

So, when it is associated with carbonate and bicarbonate we term it as permanent and carbonate hardness. And in other case, we term it as permanent hardness and non-carbonate hardness, temporary hardness. So, non-carbonate hardness is equal to total hardness minus carbonate hardness. Another term we will see, that is alkalinity. If alkalinity is greater than total hardness then non-carbonate hardness is equal to 0.

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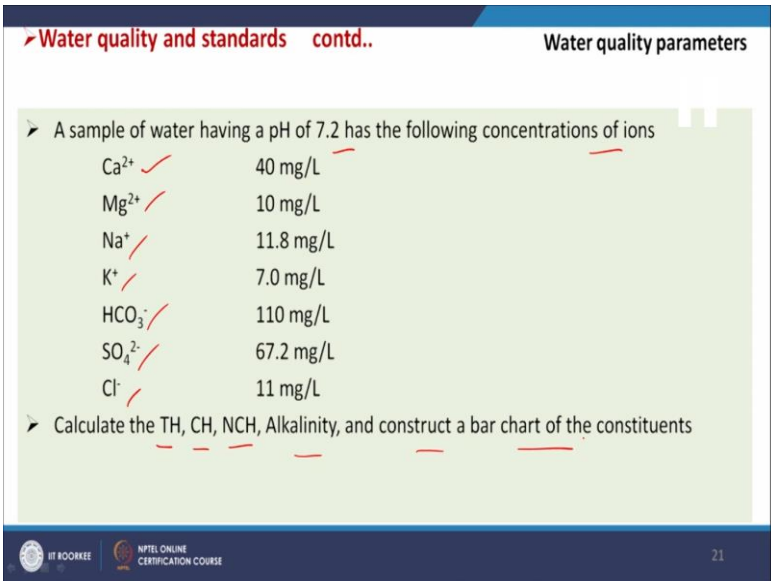

You see, a sample of water having pH of 7.2 has the following concentrations of ions like say calcium, magnesium, sodium, potassium, bicarbonate, sulphate, chloride. So, these values are given. So, now, we have to calculate the total hardness, carbonate hardness and non-carbonate hardness, alkalinity and construct a bar chart of the constituents. We have to make a bar chart from this data. So, now, let us try.

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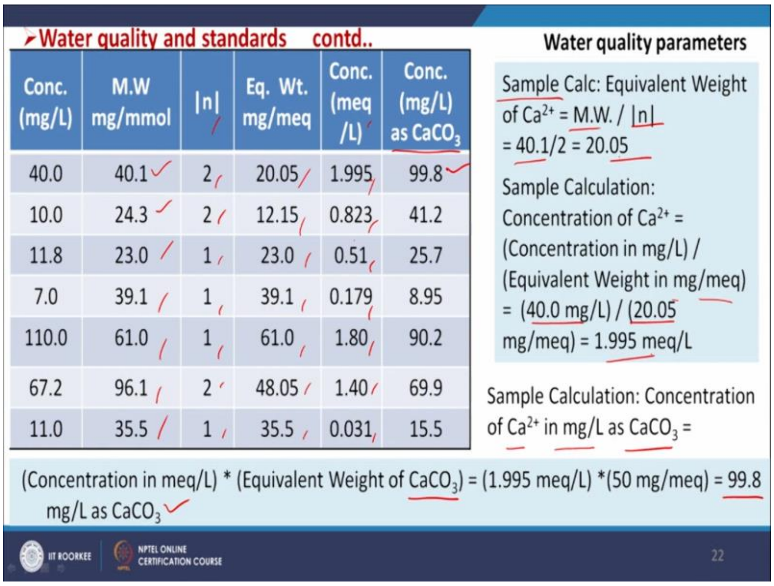

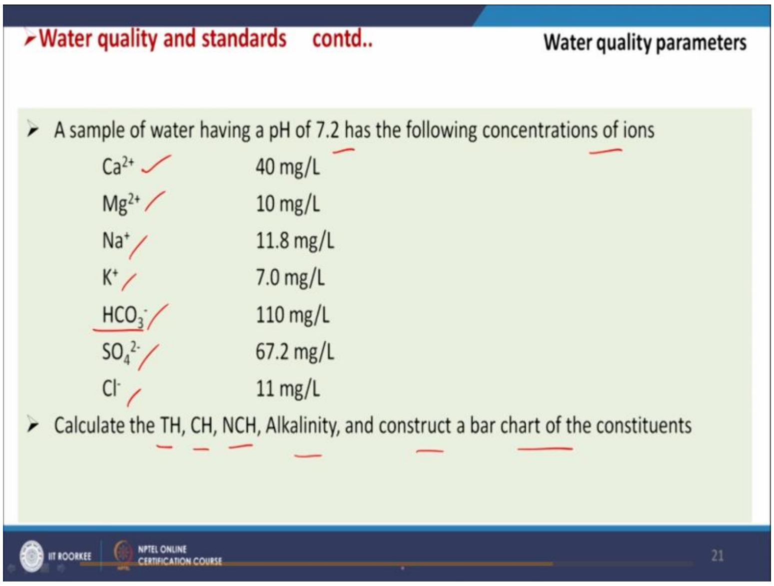

So, what we will do? We have this composition, the concentration for different cations and anions. Now, we have the molecular weight of these cations and anions, we have the charge of it. So, these, then we have equivalent weight mg/meq for different one and then concentration meq/L, as just to have shown for calcium, the similar way others will can also be calculated.

Then we can convert this in terms of concentration mg/L as calcium carbonate. So, this is very important. For example, we will see. For say sample calculation it is given,

Equivalent weight of calcium (Ca^{2+}) = molecular weight/n = 41.1/2.= 20.05.

So, then concentration of calcium(Ca^{2+}) = concentration in mg/L/equivalent weight mg/meq.

= 40 (mg/L)/20.05 (mg/meq) = 1.995 meq/L. So, up to this it is fine.

Then we want to convert it into, in terms of, concentration in terms of calcium carbonate ($CaCO_3$). So, that is concentration of Ca^{2+} in mg/L as calcium carbonate($CaCO_3$).

= (concentration meq/L)*(Equivalent weight of $CaCO_3$).

= (1.995 meq/L)*(50 mg/meq)= 99.8 mg/L as calcium carbonate $CaCO_3$. So, similarly, for other cases also we will put this value and multiply it by 50. So, will be getting this the corresponding values.

Now, what we will see? We have to calculate the alkalinity. So, alkalinity is nothing but the sum of these ions.

Alkalinity = (HCO_3^-) + (CO_3^{2-}) + (OH^-) - (H^+)

So, in our case, we have no H^+, H^- and CO_3^-, if you see the table. So, this is a table, only bicarbonate is there, no carbonate and no hydrogen plus.

Since pH = 7.2

Alkalinity ≅ (HCO_3^-) = (1.80 x 10^{-3}) eq/L

Alkalinity = (1.80 x 10^{-3} eq/L)(50 g/eq)(1000 mg/g)

= 90.1 mg/L as $CaCO_3$

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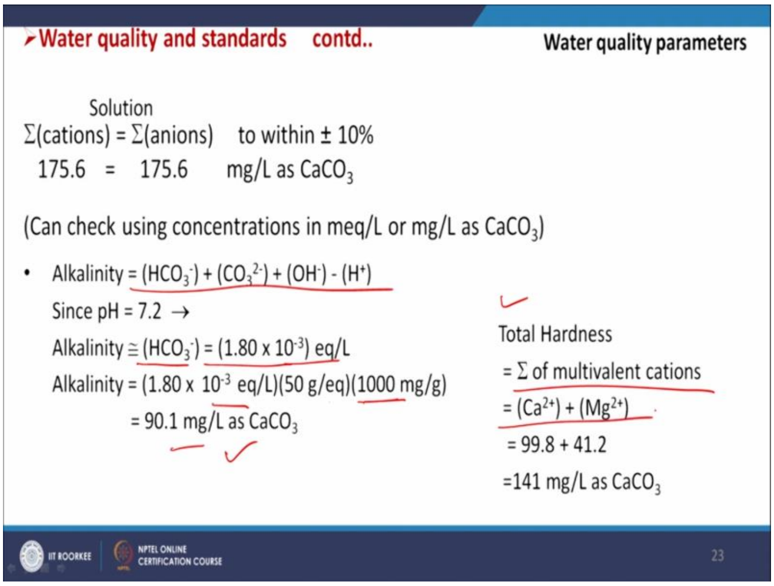

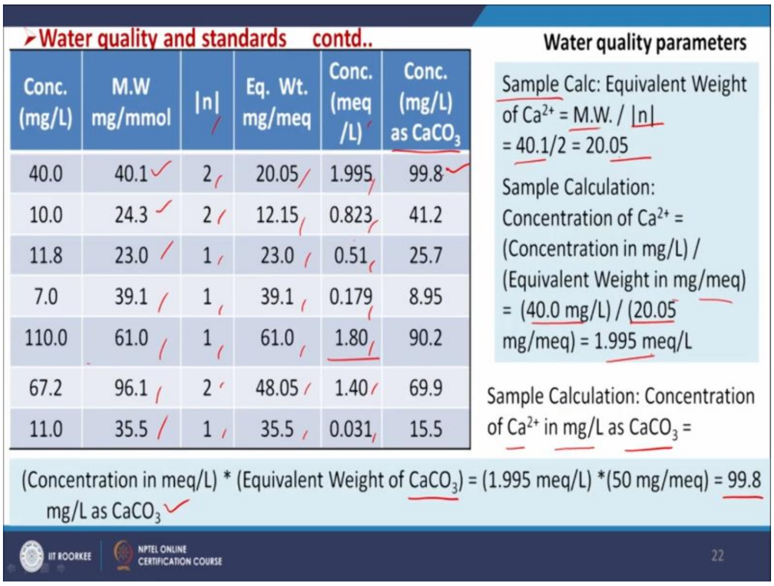

And then we have to calculate the total hardness.

Total Hardness = Σ of multivalent cations

= (Ca^{2+}) + (Mg^{2+})

= 99.8 + 41.2

=141 mg/L as $CaCO_3$

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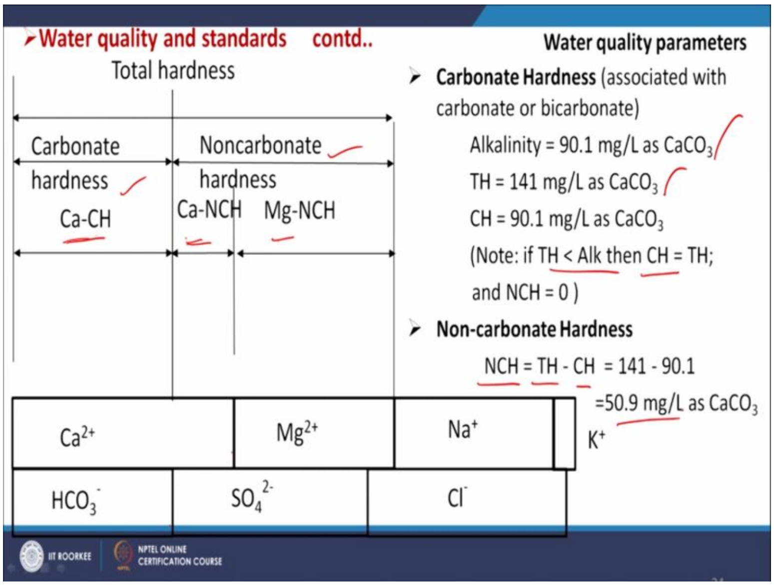

So, now, we have to prepare a bar chart. So, here we are getting carbonate hardness and non-carbonate hardness. And this non-carbonate may be because of calcium and magnesium and calcium concentration is more, so, bicarbonate is here. So, bicarbonate will be attached with calcium, this is assumed. And then sulphate will be with calcium and magnesium both, chloride will be with both.

So, noncarbonate hardness for calcium and magnesium both but carbonate hardness is for calcium, because these concentrations are like this. Then what we will see? Alkalinity you have calculated then total hardness we have calculated. Now, condition is that TH is greater than alkalinity. But we know that if TH is less than alkalinity then carbonate hardness is equal to total hardness but this is not the case. So, we have to calculate NCH

NCH = TH – CH =141 - 90.1 = 50.9 mg/L as $CaCO_3$

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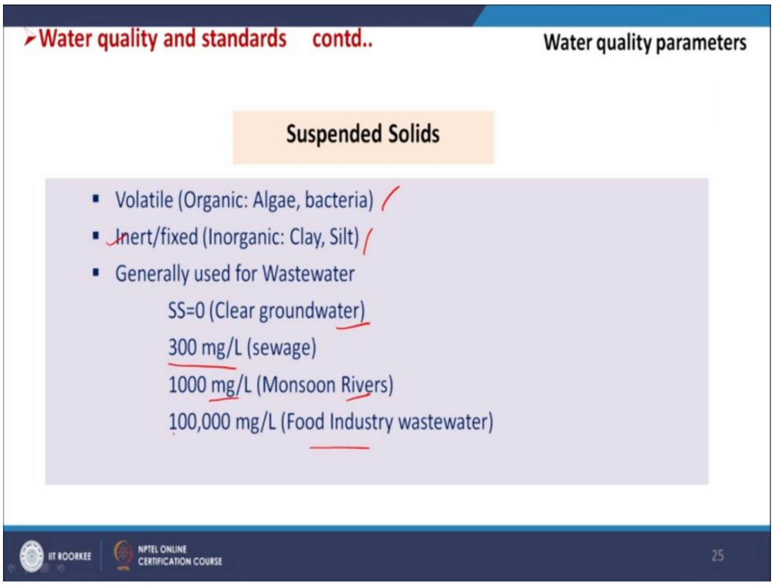

Now, there will be another quality parameter that is suspended solids. So, suspended solids that is maybe volatile in nature, may be inert in nature. So, volatile may be organic, algae, bacteria, etcetera and inert or fixed may be clay and silt. And generally, used for waste water and then for clear ground water, suspended solid is not present in most of the cases, that is SS is equal to 0. And for sewage it is 300 mg/L, for Monsoon River 1000 mg/L and food industry wastewater is equal to here 1 lakhs mg/L.

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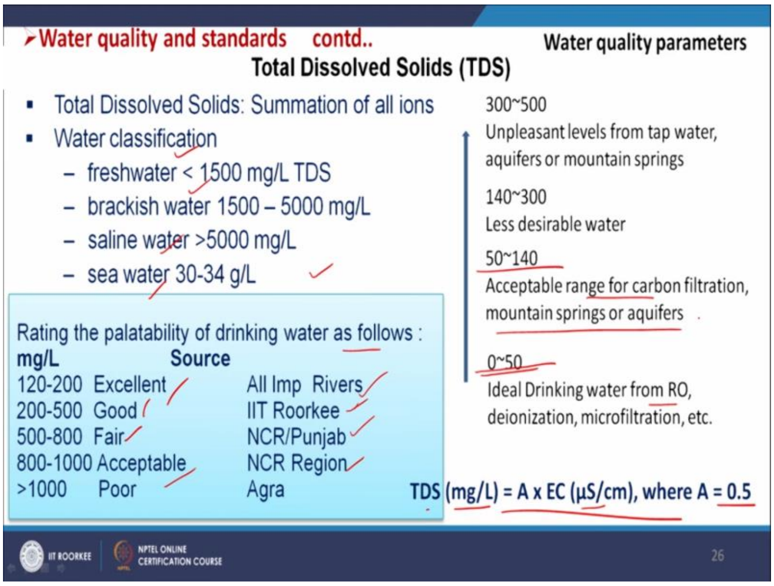

Another parameter is your total dissolved solid. So, total dissolved solids that is the summation of all ions. If we take some water sample and if we heat it then it will be vaporized but some material will be at the bottom of the container and that material will be considered as the TDS that was dissolved in the water and during evaporation the water molecules has gone up and then the solids are present in the container.

So, that is called your total dissolved solid. And total dissolved solid the permissible limit there as per CPCB that is 500 ppm. And normally rating the palatability of drinking water as follows you see 100 to 200 that is considered as excellent and then if TDS is 200 to 500, it is considered good and 500 to 800 fair and 800 to 1000 it is acceptable and after that it is not that good.

But these type of situations are available in different parts, as mentioned here say, this is all-important rivers like 120 to 200 like this. IIT Roorkee campus, NCR and Punjab region. So, these are some normally available concentration of TDS in the groundwater. And for fresh water, for brackish waters, for saline water, seawater normally available TDS is provided here.

And this TDS can be measured by measuring the electrical conductivity in micro siemens per centimeter unit. So,

$$TDS\ (mg/L) = A \times EC\ (\mu S/cm), \text{ where } A = 0.5$$

Regarding TDS, the RO manufacturers, they control the TDS, they even make the TDS concentration below 50 ppm. But you know, these TDS are essential to some extent. Because, this provides the trace metals or different metals in very less concentration which is required for the growth also.

But RO system can remove the TDS even below 50 or it can be reaching to 0 to 50. So, in that case, they are claiming that ideal drinking water from RO but this may not be a suitable option. So, that as per the norms up to 500 ppm, it is OK, but you see 50 to 140, this acceptable range for carbon filtrations, mountain springs or aquifers. So, this type of quality parameter may be very good for health. So, up to this, in this class, thank you very much for your patience.