Air Pollution and Control
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Lecture 41
Introduction to Air Pollution Control

Hello, friends. You may recall that we have studied many aspects of air pollution like monitoring, assessment, modeling, then we have also discussed in detail about several issues of global and regional nature. Now, we want to know how to control air pollution. So, that is very important aspect of air pollution management strategies. So, today we will have an introduction about different principles and control mechanism of air pollution.

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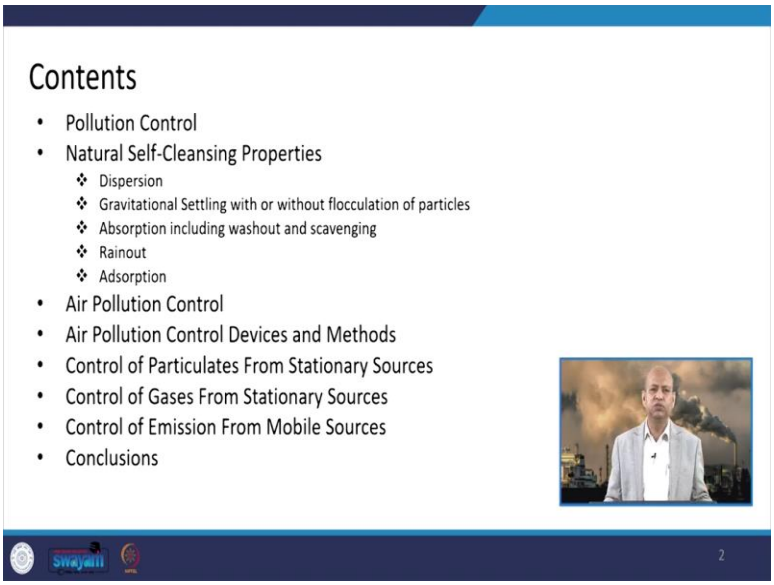

So, the contents of today's lecture is like we will first of all discuss on pollution control, what does it mean by the controlling of the pollution, and then we will also briefly overview natural self cleansing properties of the atmosphere. Basically, like in river streams we have that capacity, similarly, atmosphere also has, and these are like dispersion, gravitational settling, then absorption or adsorption, washout, rain out, wet deposition, dry depletion those kinds of things. And we will also discuss like air pollution control devices and methods with respect to whether it is a stationary source, mobile source or area sources. And then we will see specific control mechanism or equipments which are used for stationary sources of emissions or mobile sources of emissions and then we will conclude.

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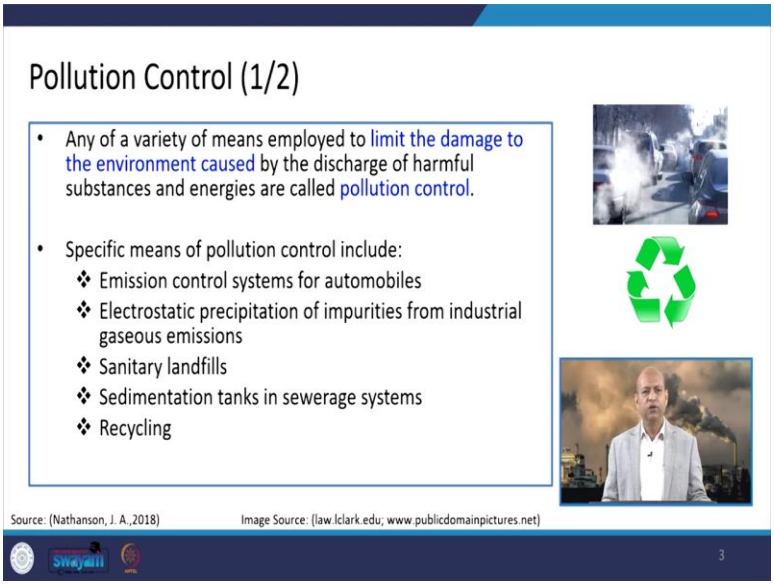

So, when we talk about pollution control, basically we can just revise the pollution-related problem, what are the pollution is issues, what we call pollutant as it is in any environmental component, whether it is air, water, soil, any foreign substance which is harmful to the environment or human health and which is present in any form or quantity which can really damage our quality of life in one way or the other aspect we call that basically pollution.

And the specific means of pollution control basically include like control systems for, emission control systems for automobiles or electrostatic precipitators which are called like ESPs, for impurities basically, particulate matters etc. in industrial emissions. Then if we talk about general pollution issues, then sanitary landfills are also there, which are also sources of greenhouse gases or other pollutants. Then sedimentation tanks in sewage system are the pollution control mechanism basically. Then recycling, reuse, there are many ways basically to control the pollution.

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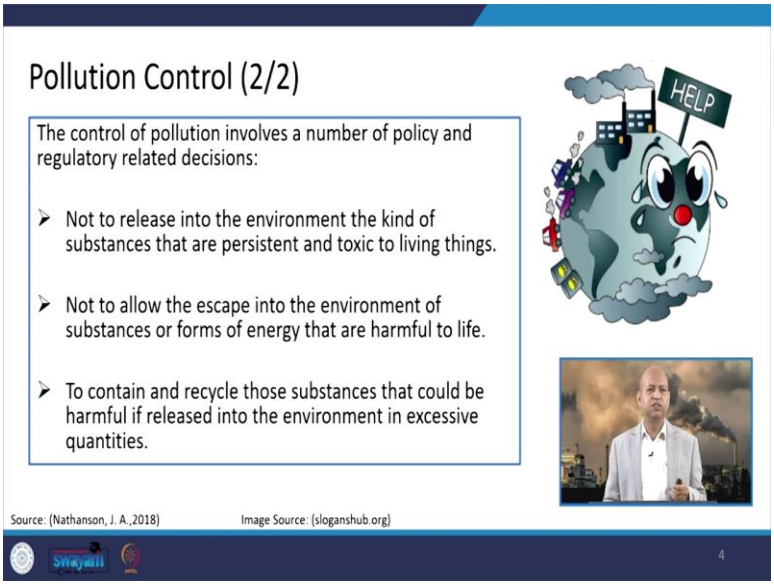

And when we talk about like controlling pollution involving other policy and regulatory issues, then what we do, we basically do not to release into the environment, the kind of substance which is like persistent which can go on for years without disintegrating and it has toxic nature, those like persistent organic pollutants (POPs), those kinds of things, and we do not want to allow the escape of these harmful pollutants into the environment, and we want to contain them or to reduce or recycle these harmful substances before releasing into the environment. So, these are the basic objectives for controlling the pollution.

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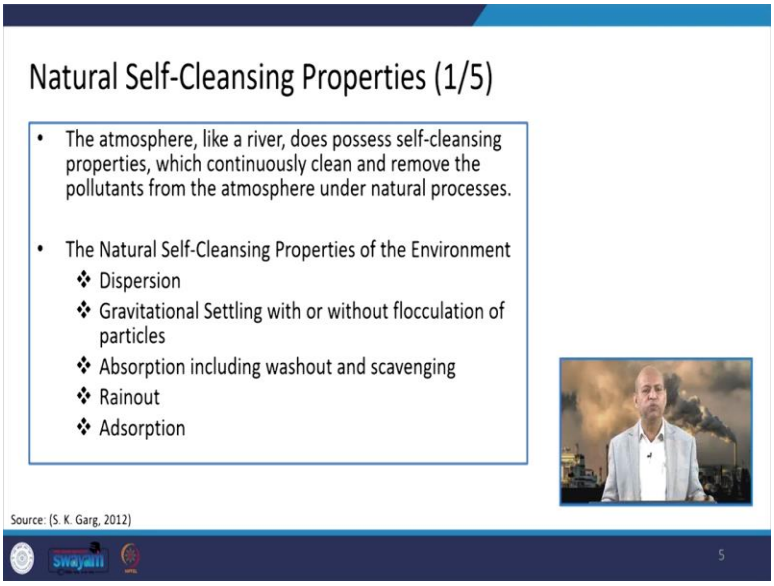

When we come to like, how do we control the pollution, where do we derive this motivation and also the principles. We see in the natural environment there are so many processes which are naturally present there and they have self cleansing properties or capacities like you go for the lake or revivers, whatever pollutants you dump into it, then it has its own mechanism to self cleanse. Means, after some time you will find that that pollution is not present there, but it depends upon the limit basically.

So, the atmosphere also has like rivers it has self cleansing capacity. You emit something after some time the air will be clean. For some time, it will be polluted, but depending upon how much quantity of the pollutants we have released if it is small, after some time it will be clean because it will disperse, it will be diluted or it will be transformed into some other compounds or chemicals.

So, the natural self-cleansing properties of the environment related like dispersion of the pollutants or gravitational settling with or without any flocculation of the particles, it could be like wet deposition, dry deposition. Then there are also absorption like including washout or scavenging kind of phenomena, rainouts or adsorption all these things are present in the nature.

Every day we see it into all components of the environment, whether water and like air. Even in soil after some time whatever waste is there these biological entities like microbes etc. they eat up and then it can be converted into the soil ingredients. So, that way in all components of the environment, there is this property of self-cleansing or getting rid of these pollutants or foreign materials which are exceeding the quantity which is not required in that particular ecosystem.

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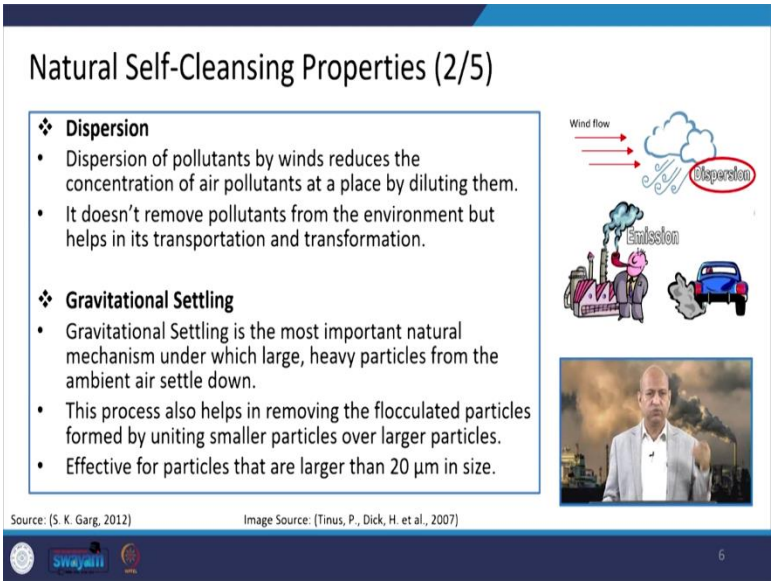

Well, now, if we talk about each of these kinds of natural phenomena which helps us in cleaning the environment or cleaning the environment, so like dispersion. What does dispersion do? Dispersion of pollutants basically like in air through wind so it reduces the concentration in the downwind direction. So, it may be so much reduced that it is not harmful for us. It could be so much diluted. So, that is helping in removing the pollutant from the source to the receptor.

In between there is transportation, transformation of the pollutant that happens, then gravitational settling also occurs like particulate matters which deposits on surfaces of the earth, on the buildings etc. So, gravity settling is there, gravitational settling is there depending upon the size of particulate pollution. Particles which are of very small size, they may hang around for longer period otherwise they can come with the wet deposition also with precipitation and so. So, those kind of gravitational settling is also there.

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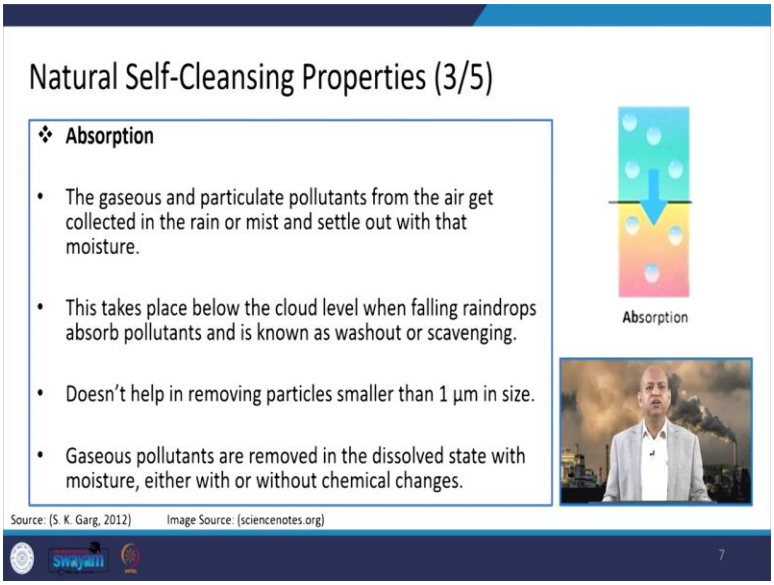

Then absorption like gaseous pollutants can get mixed into the rainwater or mist, so absorption is there on some surfaces of solvents or something like that, which can be used in devising or having these mechanisms in artificial manner also, and then like gaseous pollutants basically removed when in the digital state they are like in the moisture so that is through chemical changes or wet deposition.

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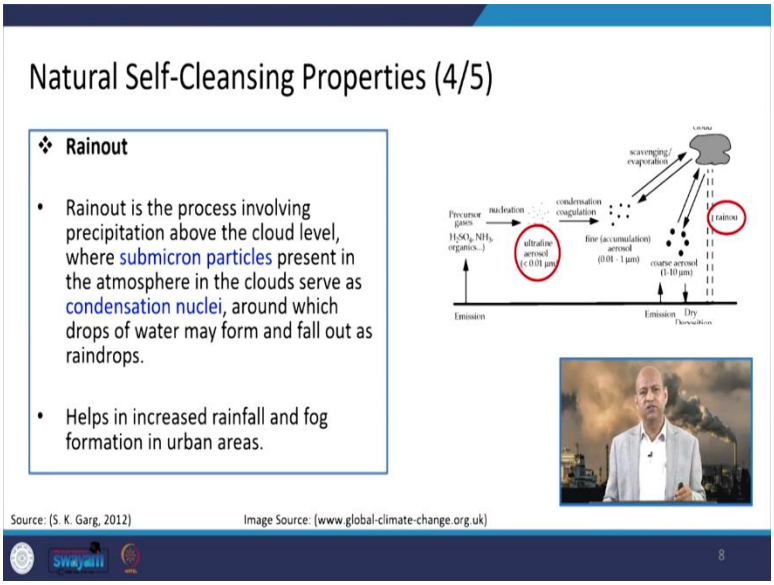

Then rainout, the same thing like submicron particles, they also help in condensation. So, they act as nuclei for creation of the clouds, where is submicron kind of these particles. They are important

for cloud formation. But it depends like what is the size of those particles. If they are very small, then there will be clouds, but droplets will be so much small that rain will not be there. So, it is called as suppression of the rain. So, that change in the rain patterns can be due to pollution also. If the larger particles are there, large size of droplets are formed then precipitation maybe more. So, those kinds of things also are there in rainout phenomena.

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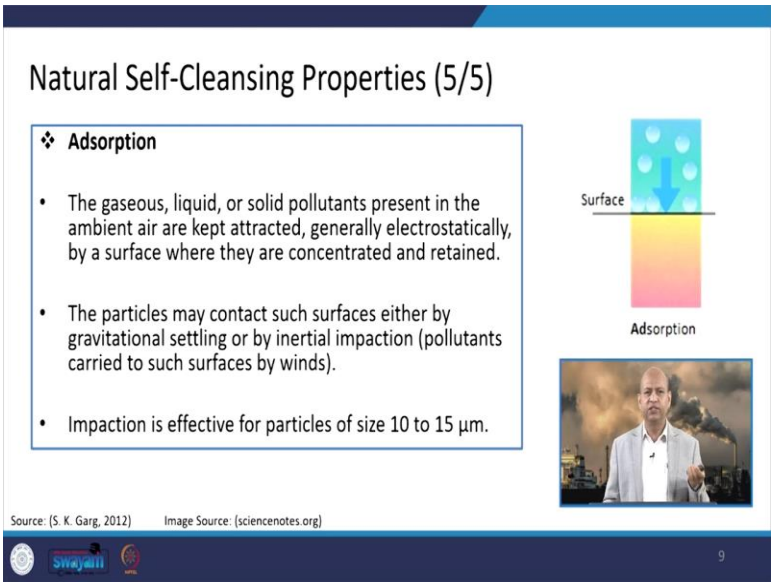

Then adsorption is there, like on surfaces, for example, like activated carbon or those kinds of surfaces it can be absorbed. So, those things we have to see. Otherwise, in nature it is like on the particles, for example, gaseous components they get attached to it and calcium sulfate, magnesium sulfate, those kind of chemical, transformation of gaseous pollutants of SO_2 etc. can take place.

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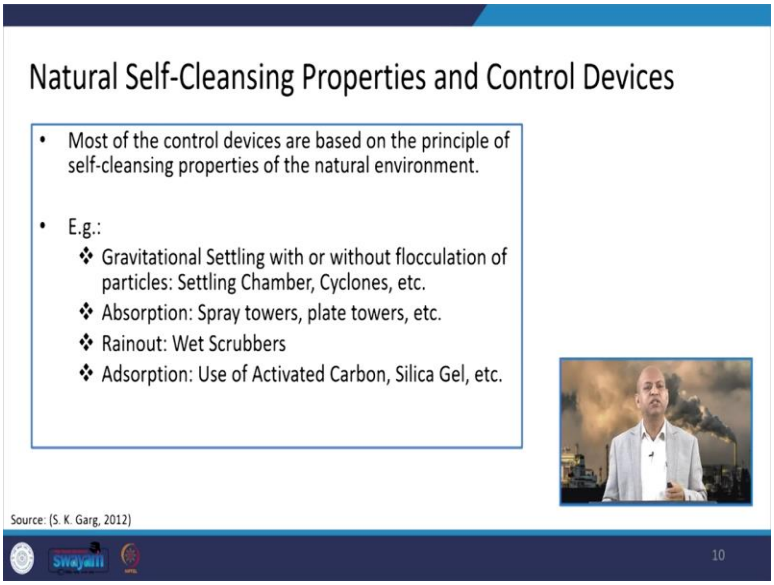

Well, so most of these control devices which we will discuss in brief are based on these principles of natural self-cleansing properties which are present in the nature. So, like gravitational settling with or without flocculation particles which are used in settling chambers or cyclones. In cyclones, basically, we allow this gas to pass in a round manner with centrifugal force and then particles are removed when they strike to the surface.

Absorption like spray towers or plate towers they are used for this absorption phenomenon, rainout like wet scrubbers and then adsorption using activated carbon or silica gel so they use this principle of adsorption. So, that way in this list that all these natural principles are being used to devise some sort of equipment for reducing or capturing the pollutants from several sources.

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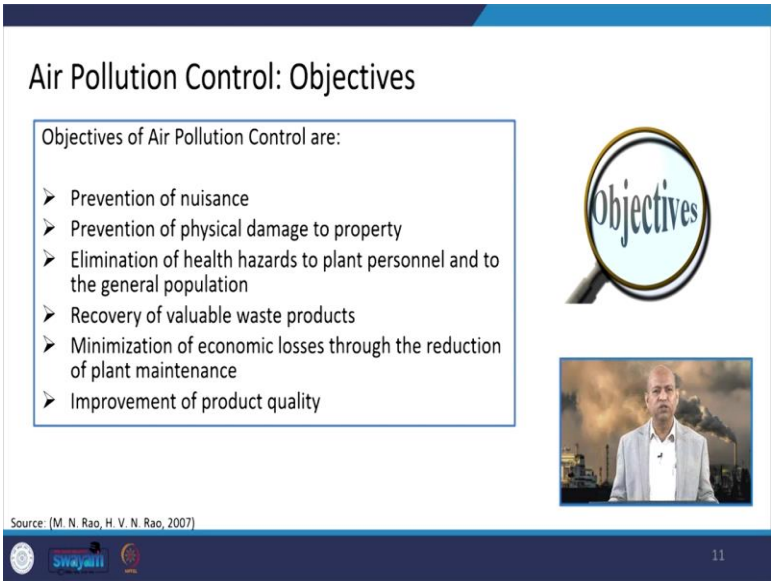

Well, now if we talk about the objectives of the air pollution control, so what is the objective, as we know? Objectives are like prevention of the nuisance because of these pollutants or prevention of physical damage because of these pollutants nature, then elimination of health hazards to plant or people when they get exposed to these pollutants.

So, if we reduce pollution or control the pollution then we are eliminating those kinds of possibilities or recovering valuable waste products sometimes. It is also important. You can capture this sulfur dioxide in terms of sulfuric acid or those kinds of phenomena can also be there or minimization of economic loss through the reduction of plant maintenance. Otherwise, these pollutants like as of acidic nature, they will damage the equipments etc. and maintenance cost will be more otherwise if we do not control, capture these kinds of pollutants. Improvement of product quality is also the part of this objective of controlling the air pollution.

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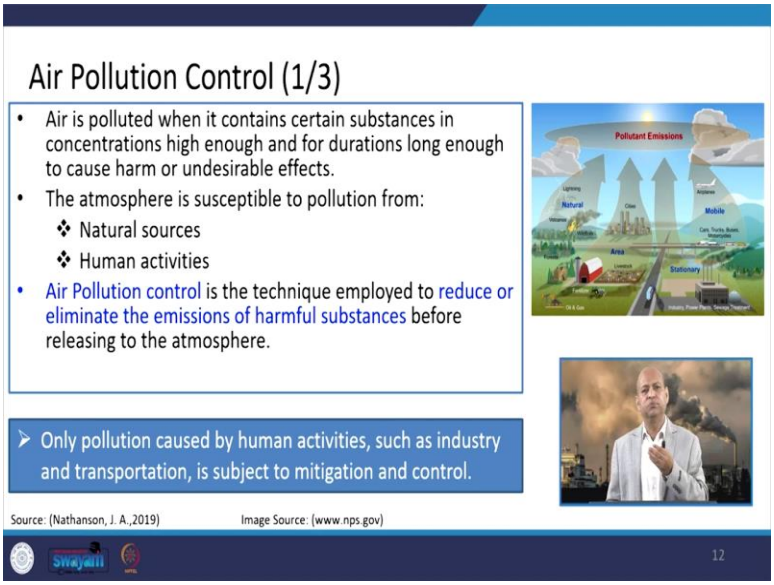

So, basically, there are natural sources of air pollutants, human activities are also the sources. So, what we do when we devise some new equipments, basically we focus on manmade activities like industrial emissions, power plant emissions or mobile source emissions from vehicular tailpipe etc.

So, we do intervention those kinds of technological intervention to reduce or to control the emissions. So, that is the part of basically of this whatever air pollution control strategies we talk about. Otherwise, natural sources are there and they are beyond our control. For example, dust storms are there in summer. We cannot control them. That is of that size that scale.

But of course, we can intervene the same in the sense like we can be in house when this storm is very intense or something like that. So, we can prevent ourselves, but controlling those phenomena is very difficult. Similarly, volcanoes, they are natural sources. We cannot control those emissions, but from industries, from these manmade activities, if pollution discharge or emissions are there, we can control them and this talk is basically to control those kind of emission sources.

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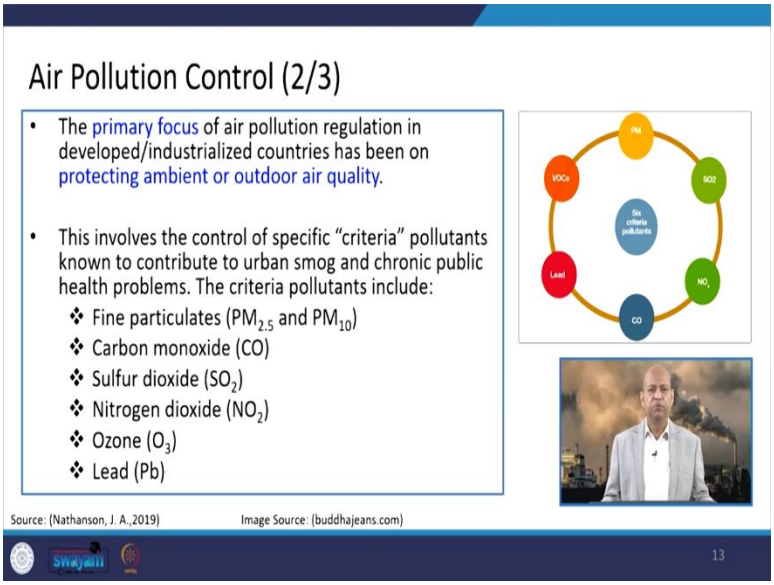

So, the primary focus, of this regulation or in developed countries, it has been focused on protecting ambient or outdoor air quality. Otherwise, nowadays, indoor air quality is also very important. We have studied about impacts of indoor air quality. So, the controlling of indoor air pollution sources is also very critical nowadays. Earlier it was more on outdoor side. So, more current technologies, interventions came into existence for outdoor and ambient air quality control. Now, both are there basically.

And when we talk about controlling air pollutants, we are trying to control like particulate matter $PM_{2.5}$, PM_{10} or carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, lead, and we generally call them criteria air pollutants. What is criteria air pollutants, criteria air pollutants have certain threshold limits. They are harmful when they exceed the standards. And if they are below those inner limits, then it is fine means we can tolerate them.

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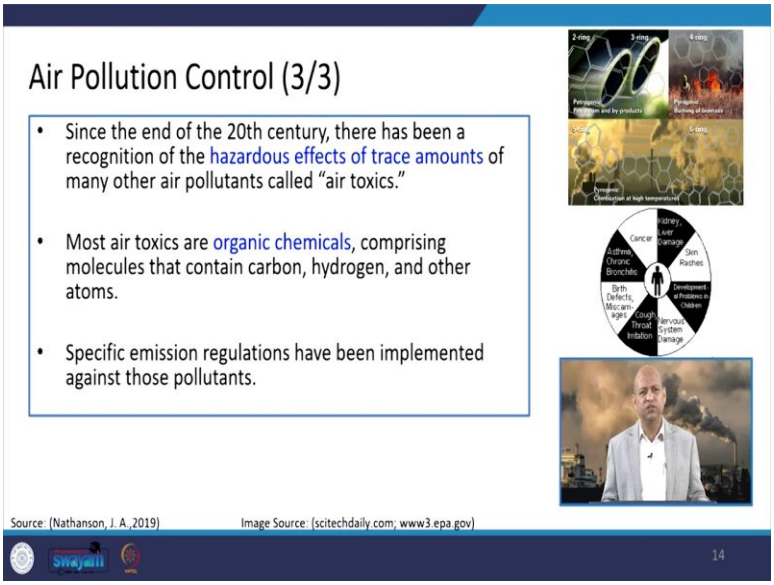

But there are toxics which are they do not have this kind of threshold limit. They may be very harmful like carcinogenic elements or some other toxic chemicals which can change our internal system. So, those are very kind of hazardous pollutants and we do not call them criteria pollutants. Those are non-criteria air pollutants or health hazard pollutants. So, there may be like pesticides etc. or those kind of things are there, which also we control, we want to control if they are being emitted from different sources, manmade activities.

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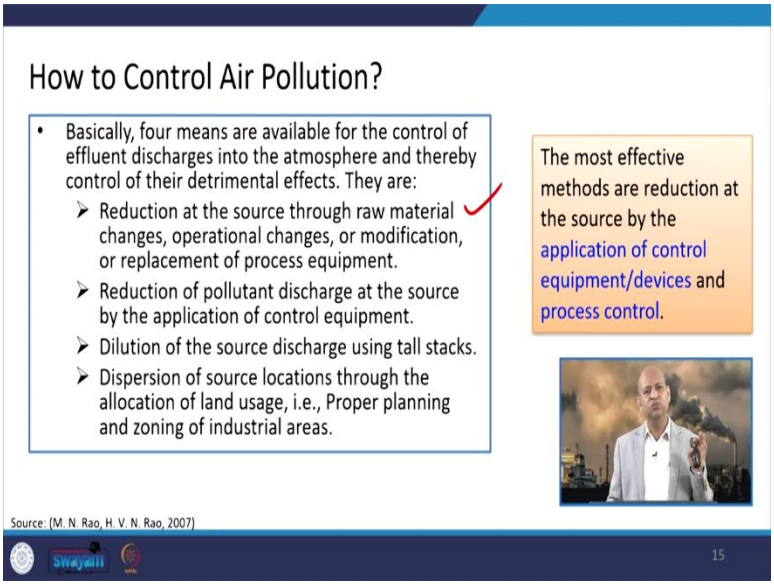

So, how to control? We do whatever activity we are doing through policy measures or technological interventions, basically, we are either reducing at the source. So, these very important aspect like first of all we try to reduce reduction at the source through raw material change, through operational change, processes change or modification or replacement of process equipment. So, that you just get rid off at the source itself, rather than controlling after it is being exhaust, after it is being emitted. So, whether it is better that you control at the source itself that is the best policy.

Then reduction of pollutant discharge at the source by the application of some control equipments. You can capture it. Or dilution of the source discharge using tall stacks, means if you are not able to control at the source, then at least you control before emitting into the air. When it is coming out of the tall stacks or chimneys, if it is taller, then chances are there it will be diluted before reaching to the ground level. So, exposure will be minimum.

That is why these tall stacks are there. Although in early stages, these stacks were meant for to give the draft pressure, because of pressure difference you need less mechanical energy to helping the burning of the fuel, but later on it was known that these tall stacks also help in dispersion of pollutants, dilution of pollutants that is why these are important in terms of controlling mechanism also.

Then dispersion of source location through the allocation of land uses like proper planning, zoning, industrial zones, areas, land use, land planning, those kinds of things, you can have Greenbelt in urban areas around the industrial locations. So, those kinds of things are also there to control the, these air pollution. And the most effective methods in that way that the reduction at the source, whether by application of control equipment or devices or by the process control, so it is better if possible please control at the source itself rather than controlling after it is being emitted means before just emission to the air.

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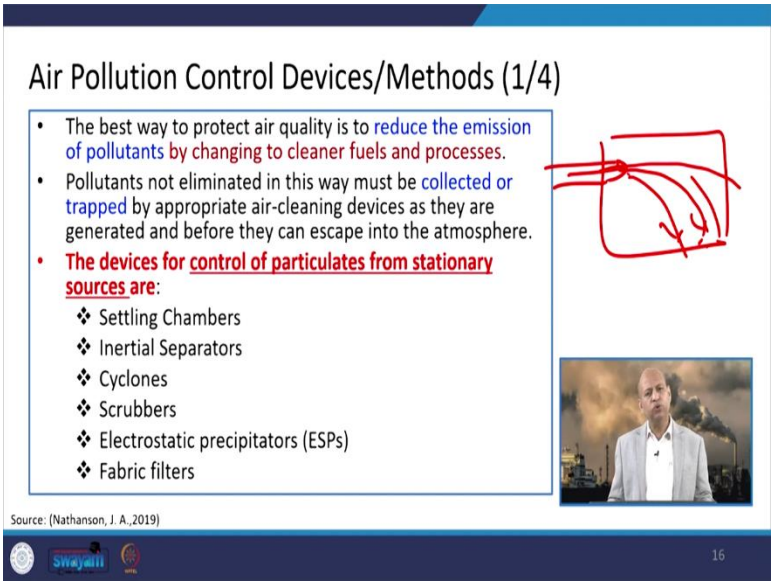

Now, if we talk about like, the like devices for controlling particulate matters from stationary sources, so what are those devices? So, important devices are like settling chambers, these are very simplest devices settling chambers like room size depending upon how much emissions of these dust pollution is there. These are very simple kind, means inlet is there, outlet is there, like this is settling chamber. So, inlet is there. This pollution will come here then outlet is there.

So, when it goes up to this, the particles go by this gravity. They are collected, but efficiency is very less and only large particles are removed by this process. But this is important activity when we want to reduce the load on the secondary kind of devices, like you are using expensive devices to control then better you have settling chambers if it is possible. But it requires a lot of like space. It is not so popular in city itself where land cost is very high.

Then inertial separators are there by inertia, means by impaction inertia is there. Then we will see what kind of those separators are. Then cyclones can be there, scrubbers can be there. And cyclones again by centrifugal force we reduce the, this velocity of the inner particles when it strikes to the surface and they slide down and you can collect into the hopper. Scrubbers, when some solution is there where we can capture the pollution. These wet scrubbers they can be useful for particulate matter as well as gaseous pollutants also.

Then for particulate matters these ESPs are very good. They are although like costly at initial stage, but efficiency is very high, electrostatic precipitators. So, they by this ionization kind of

phenomena, they can capture the particulate matter. Fabric filters are also there, but it depends upon what is the temperature of exhaust gases. Very high temperature, it is not recommended because of fire hazards etc.

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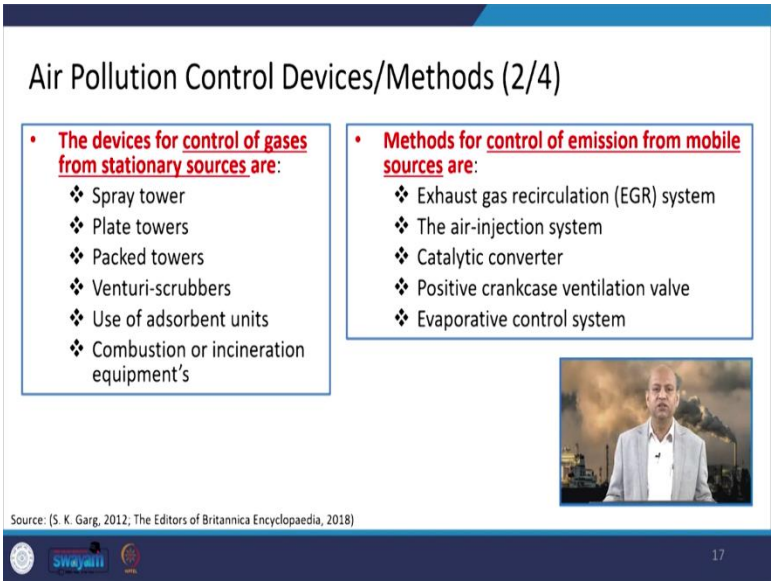

When we talk about devices for controlling the gaseous pollutants from stationary sources, then there are different equipment like spray tower, so spray is there, gas is going from down, so gas goes up by buoyancy and thus and then spray is coming down. So, it captures the gas, some reaction may happen depending upon the solution. But it generate wastewater. So, again it is changing the pollutant from air pollution to the water pollution, but at some locations it is important.

Then some plate towers maybe there or packed towers maybe there, then venture-scrubbers can be used or use of adsorbent units or combustion or incineration equipments are also good, but it is expensive because it needs, to generate you need calorific value and also electricity and that fire kind of thing and there are issues. I mean, although it is good because it converts the pollutants into the CO_2 and complete the combustion is possible.

Then if we talk about emission control from mobile sources, then basically like we can use the Exhaust Gas Recirculation system, (EGR) or the air injection system can be there, catalytic converter could be there, positive crankcase ventilation wall can be applied, then evaporative

control system can be there and they are being used in cars etc. So, we will see in detail one by one.

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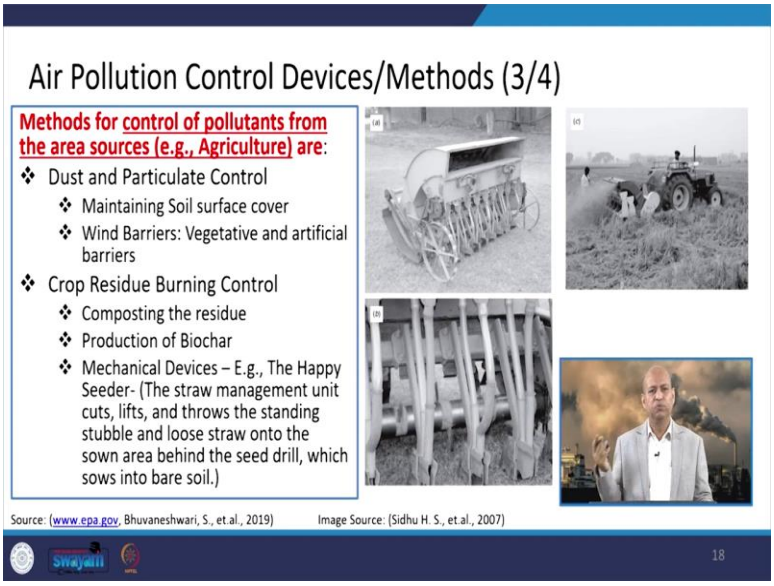

Then if you talk about like we have talked about point sources, stationary sources, mobile sources, if we talk about area sources, there are also ways to control the pollutants like from agricultural field. So, dust and particle control can be there by maintaining soil surface cover and wind barriers or vegetative and artificial barriers can be there to prevent the resuspension of the dust or windblown dust those kinds of things. Otherwise it happens because of like when we are doing some agricultural activities, lot of this dust pollution can be there.

Then crop residue burning control could be through like composting the residue or production of the biochar. Then mechanical devices are also there like happy seeder and those kinds of straw management unit cuts, lifts and throws the stubble, the loose straw onto the sown and this can be basically used in a better way. So, those kind of mechanical systems are available that those can be converted into compost also into some manure also there are also ways. So, that is a way to control the area source of agriculture waste pollution generation sources, otherwise people burn it and that is not good because it pollutes a lot of ambient air environment.

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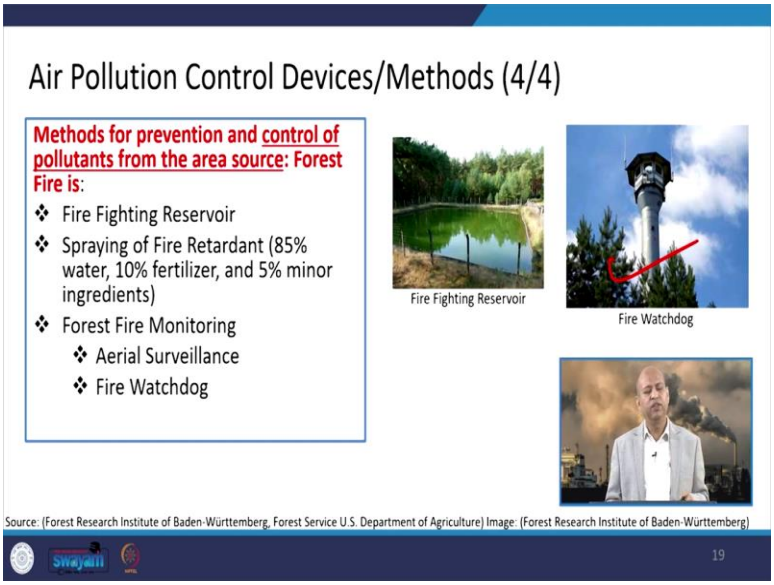

If we talk about like area source control of forest fire etc. then there are ways like fire fighting reservoirs are made, and if fire occurs then it can, this water can be used and there are some systems. Then spraying fire retardants are there like 85 percent water, 10 percent fertilizer and 5 percent minor ingredients are also there. Then forest fire monitoring systems could be there through aerial surveillance and fire watchdog could be the there. And that way at the beginning if you control the fire of the forest then it is easy, otherwise if it spreads then it is very, very difficult to control fires. You might have heard in several countries it occurs in the summertime and a lot of forest areas are burned because of several reasons.

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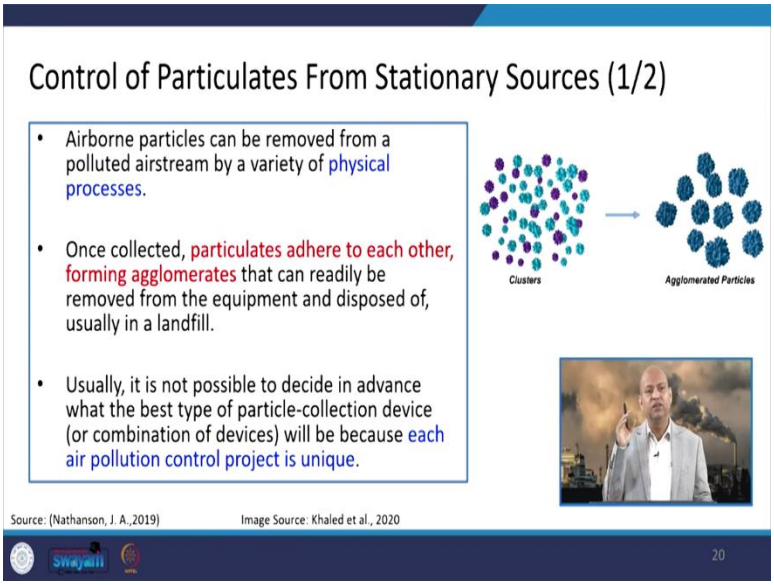

When we talk now by one by one like control of particulate pollution from stationary sources, then there may be like physical properties which we can use, because like particulates with particulate matters or particles which can adhere to each other so they can form agglomerate large sized particles and it is easy to remove them or they can get settled down by gravity also.

So, these are the ways. But each air pollution control project is a unique one. So, we cannot apply one kind of device everywhere. And we have to see what kind of particle size is there, what kind of particle density is there. So, that way you have to design a particular system to control the particulate pollution.

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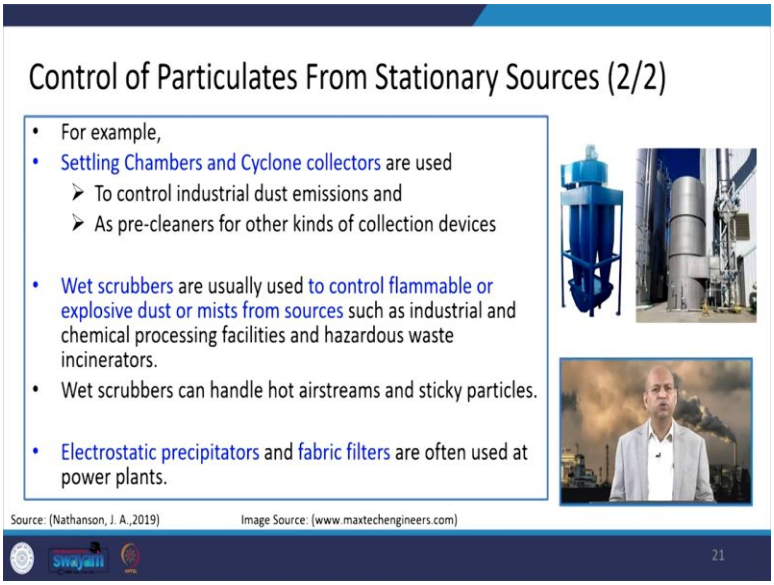

Well, examples are there like settling chambers can be there, cyclone collectors could be there like this one. So, by centrifugal force, you can remove these particulate matter and it goes down then you can collect into the hopper. And these devices are important into the sense like control industrial dust emissions are easy and then it can also be act as like pre-cleaners, before other kinds of collection devices we employ, because otherwise the load will be more on those sophisticated devices. So, better you use either settling chambers or cyclone collectors.

Then wet scrubbers could be there and they are like depending upon flammable or explosive dust etc. so those wet scrubbers can be used in that sense, like mist etc. those can be used by wet scrubbers. Then if you talk about electrostatic precipitators and fabric filters, they are also very popular and in particularly power plants, coal-based power plants, a lot of particulate pollution is there and that can be controlled through ESPs or fabric filters.

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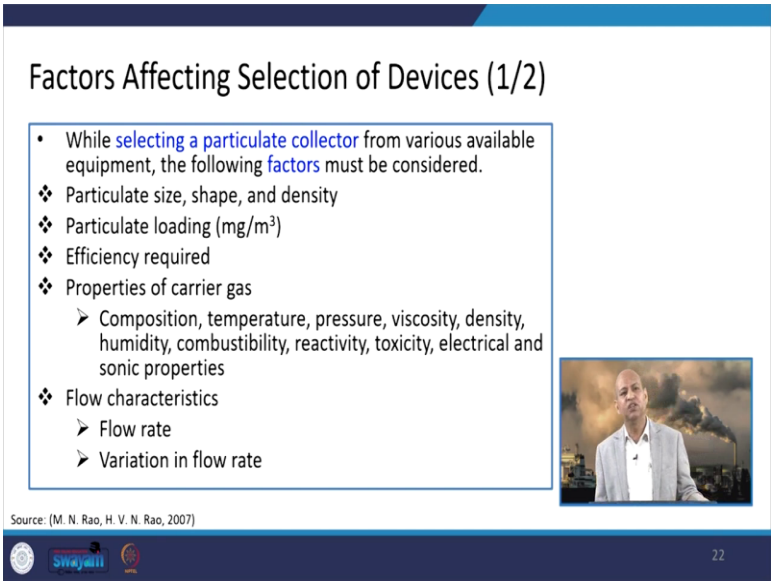

Well, when we talk about different factors which affect the selection of the device, which kind of device is more applicable, then there are certain factors, like what is the size of the particle, what is the shape of particle, density, then loading means how much milligram per cubic meter or gram per cubic meter or kilogram per cubic meter it is being emitted that will also influence the decision on what kind of device we need to select.

Then efficiency required, whether you want to remove it 99 percent or 95 percent depending upon whether it is only the device or it is pre-cleaning device. So, that way you have to see the vectors. Then there are properties of carrier gases also like what is the composition of that gas, where this particulate matter is present in, temperature, pressure, viscosity, density, humidity, combustibility or reactivity, toxicity, electrical and sonic properties, all these things really help us to decide or device what kind of equipment is necessary. Then flow characteristic like flow rate, variation in the flow rate, if it is very fluctuating then again simple devices are better, otherwise it would be difficult to employ the sophisticated devices to control when fluctuation rate is very high.

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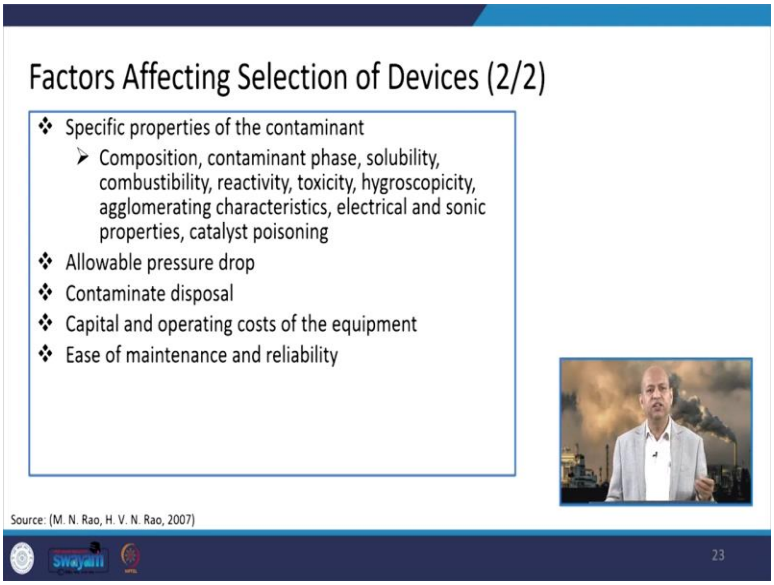

Then there are like specific properties like contaminant phase, solubility or combustibility as we have seen earlier. Then what is the pressure drop or contaminant disposal and then ease of the maintenance and reliability all these factors influence which kind of device we have to select.

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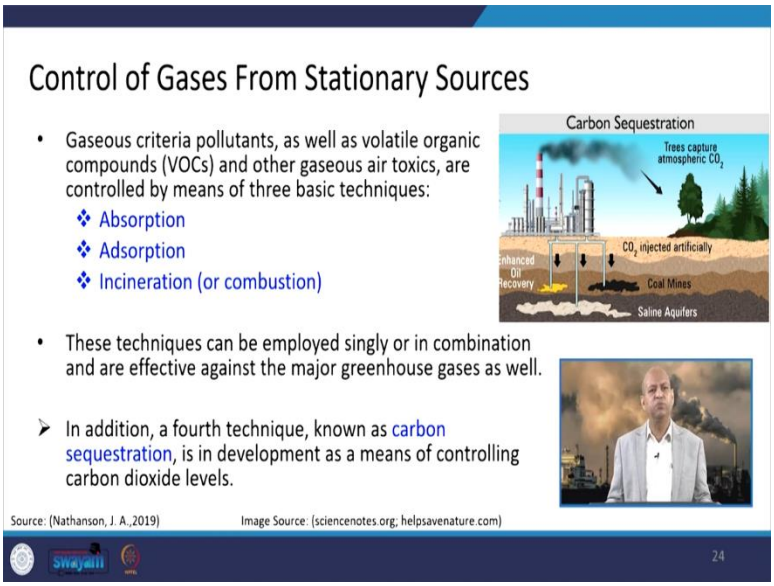

Then if we talk about control of gases from stationary sources, so we see like absorption or adsorption or incineration any kind of thing is applicable depending upon the properties of these gases pollutants like these are hydrocarbons or volatile organic carbons or air toxics. So, combustion can be there if air toxics are there. It is better to burn them completely. Then these

techniques can be employed as a single device or a combination of different devices basically. And the fourth technique like carbon sequestration is also emerging to control or to capture the CO_2 emissions, carbon dioxide emissions, because of this greenhouse related problem.

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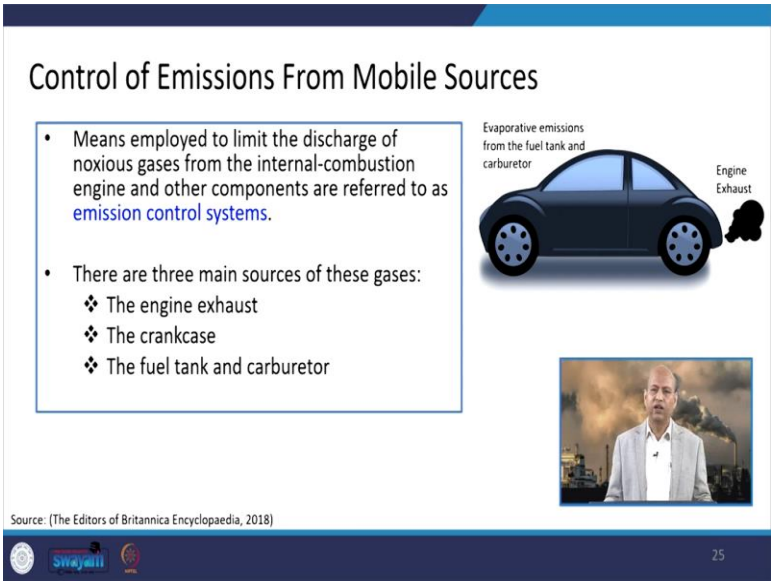

Well, when we talk about controlling mobile sources, then there are three main sources of gases or emissions from cars etc. like engine exhaust or crankcase or the fuel tank and carburetor. So, at these points different kind of mechanisms are employed for controlling the emissions.

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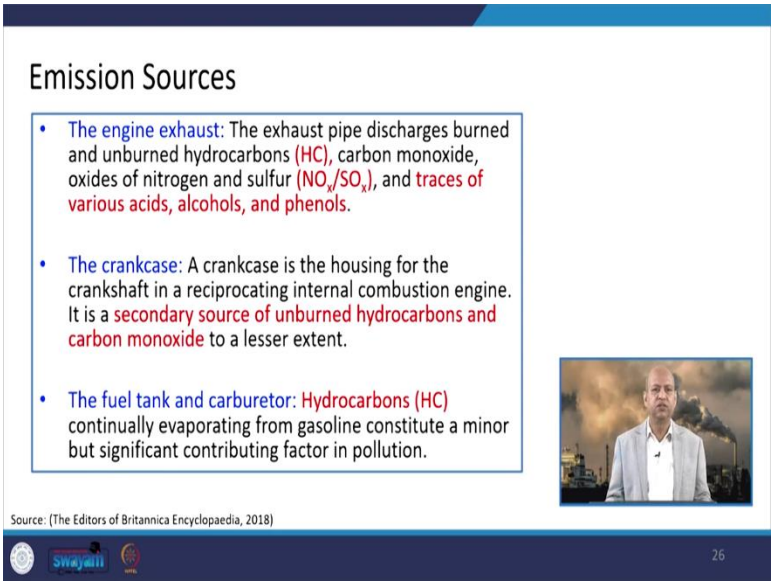

So, in engine exhaust like the exhaust pipe discharge, which are like burned or unburned hydrocarbons are emitted, carbon monoxide is emitted or oxides of nitrogen and sulfur are also emitted, then traces of various acids and alcohols and phenols. The crankcase related emissions could be like secondary source of unburned hydrocarbons and carbon monoxide. So, that is from the crankcase. Then fuel tank and carburetor could be responsible for emissions of hydrocarbons due to evaporation and this, these are minor but significant contributing factor in pollution. So, we have to control them also.

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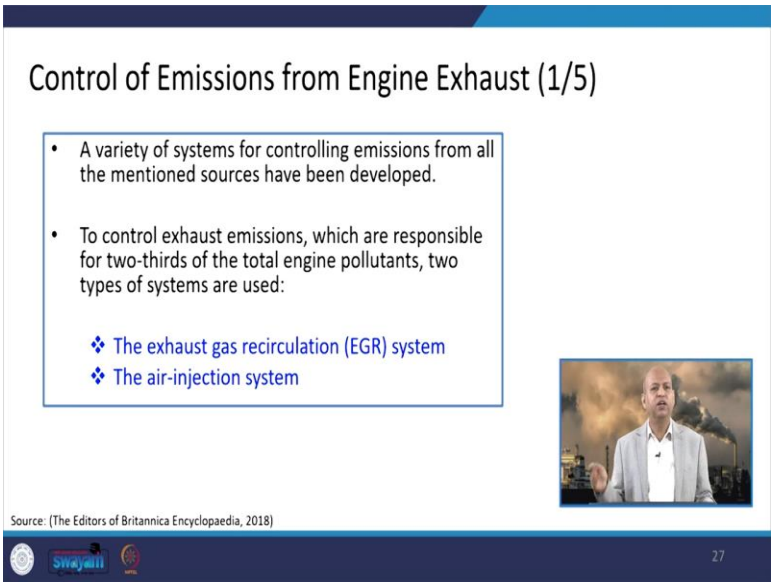

So, variety of systems for controlling emissions from all the mentioned sources have been developed. And the control exhaust emissions which are responsible for two-thirds of the total engine pollutants, two types of systems are used basically like the exhaust gas recirculation (EGR) system or the airline injection system.

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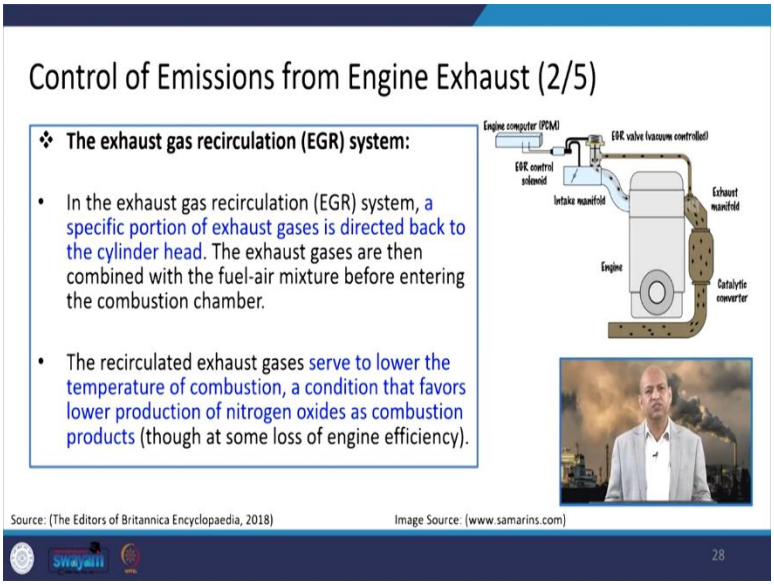

So, we will see what is the difference in EGR or Exhaust Gas Recirculation system basically what happens. This specific portion of exhaust gas is directed back to the cylinder head and this exhaust gases are then combined with the fuel-air mixture before entering into the combustion chamber. So, they are again burned. So, the recirculated exhaust gases serve to lower the temperature of combustion and which helps in reducing the production of oxides of nitrogen though at some losses of the engine efficiency. But it is a kind of net you know beneficial kind of activity that happens.

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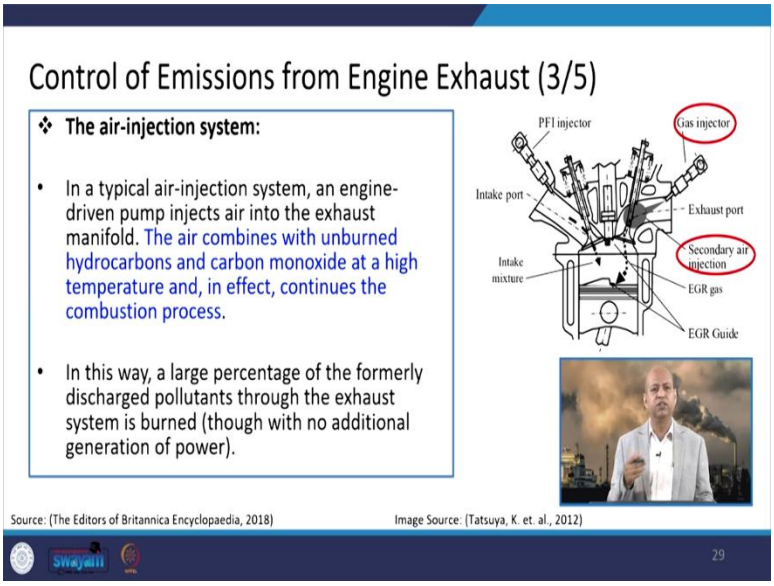

In air injection system what we do basically, the air combines with the unburned hydrocarbons and carbon monoxide at a high temperature and in effect continues the combustion process. A large percentage of formerly discharged pollutants through the exhaust system which is burned through the, with no additional generation of the power, but it is burned, so that it is converted into carbon dioxide and those final products of the complete combustion.

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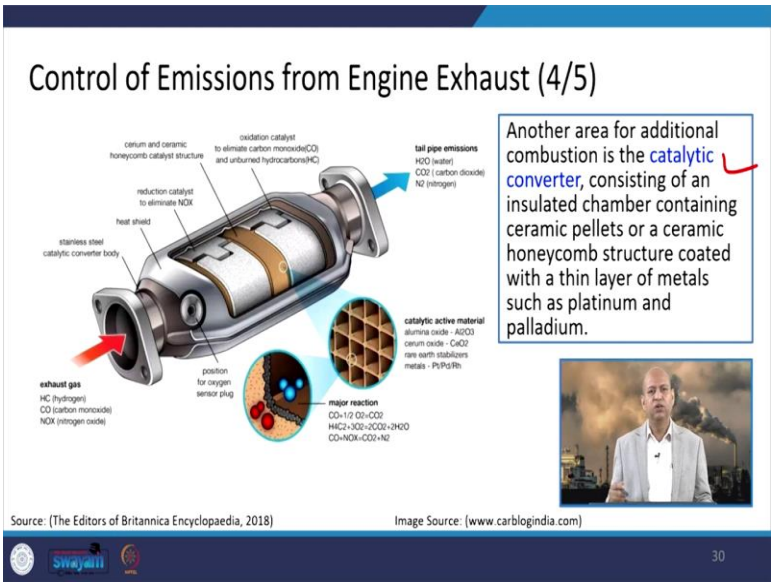

Then there is another way of controlling these emissions from engine exhaust and that is basically the catalytic converter. So, these are, catalytic converters are consisted of insulated chamber which contains ceramic pellets or a ceramic honeycomb structure which is coated with a thin layer of metals such as platinum and these palladium kind of thing. They are like catalyst to convert gases into, these harmful gases into non-harmful gases.

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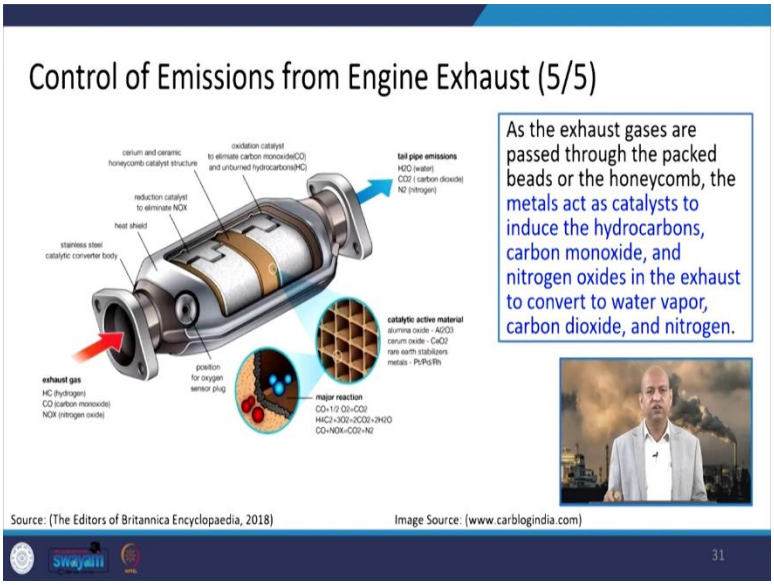

So, these metals basically induced the harder hydrocarbons, the carbon monoxide and nitrogen oxides in the exhaust to convert to water vapor or carbon dioxide or nitrogen so which are presenting that most well which are not harmful for us. So, these are carbon monoxide or NO_X related emissions can be converted or hydrocarbons are etc. can be converted into water vapor, carbon dioxide and nitrogen that way.

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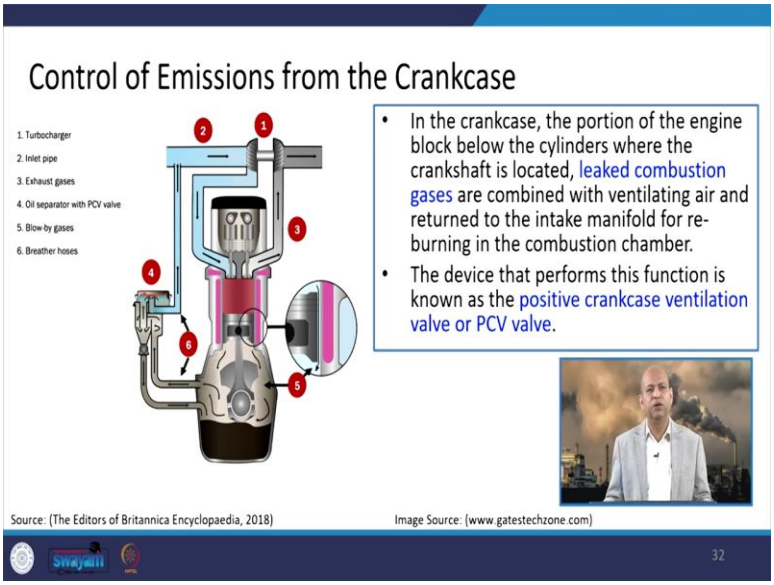

Then in crankcase, the portion of the engine block below the cylinders where the crankshaft is located, the lead combustion gases basically which are combined with the ventilating air and then

it is returned to the intake manifold times for reburning in the combustion chamber. So, this device basically performs the function like a Positive Crankcase Ventilation valve or PCV valve it is known as. So, that way again it helps in reducing those kind of leak related emissions and they are burnt and converted into harmless products.

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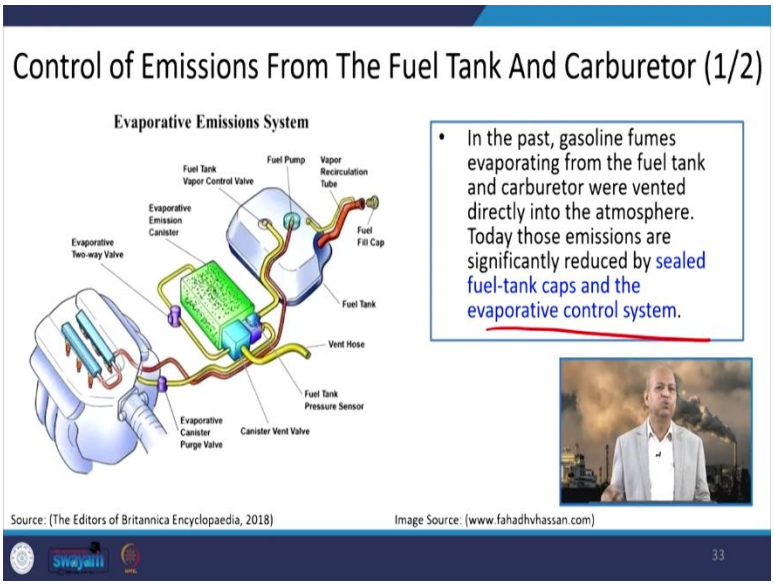

Well, in fuel tank and carburetor there are like evaporative emissions can be there. Earlier there were no subsystem, nowadays subsystem is available. So, these evaporative emissions are also like they are taken into these particular chambers where they are captured. And the sealed fuel tank caps and evaporative control system is employed for removing these particular emissions which could be because of evaporative emissions. So, that kind of evaporative emission system is developed to capture those hydrocarbons etc.

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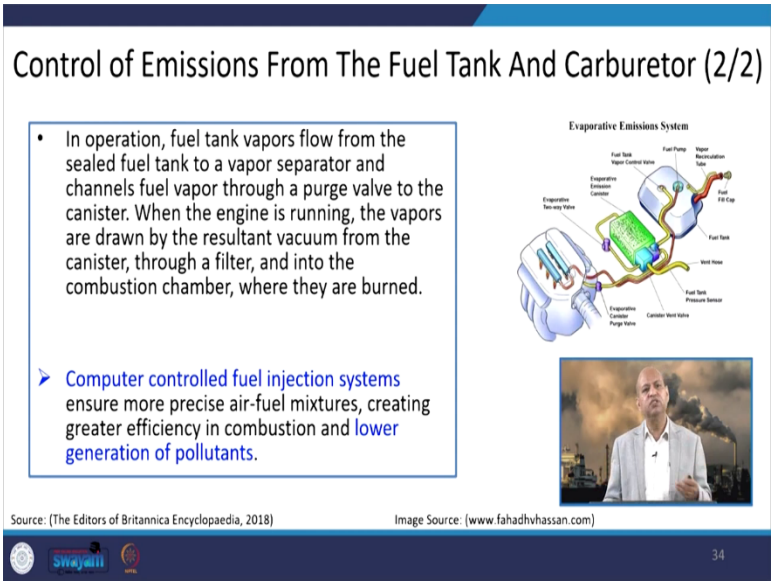

Well, this computer control fuel injection system can be there which ensures more precise air-fuel mixture basically and it creates greater efficiency in combustion process and lower the generation of pollutants. So that way it is a win-win situation. You are capturing the pollutants, you are also helping into having better combustion process.

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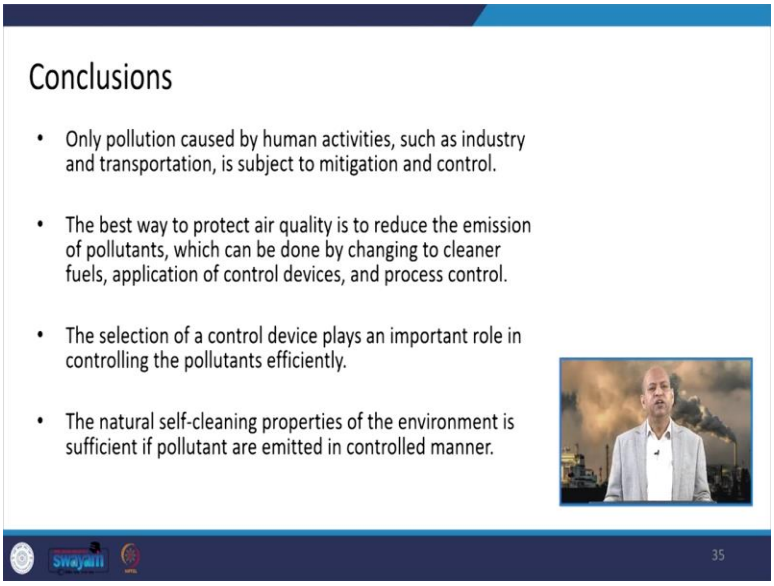

So, all in all, we can say that these kind of devices controlling equipments of air pollutants, they are based on natural phenomenon which is known as self-cleansing principles of the nature. So, various equipments are designed on the basis of those. So, the only pollution which are caused by

human activities such as industry or transportation, they are subject to the mitigation and control. Basically, when we are talking about air pollution control, so we are talking about only the controlling air pollution emissions from human activities.

And the best way to protect air quality is basically to reduce the emission of pollutants at the source itself. And means having cleaner fuels or application of control devices and process control at the source itself so that you do not need to clean the air afterwards when it is coming out from stacks etc. Then the selection of control device can play very important role in controlling the pollutants efficiency.

So, depending upon the nature of the pollutant, nature of the industry, you have to see which kind of pollution control device you have to employ or design, maybe you have to design specific pollutant control equipments depending upon that unique facility. the natural self-Tcleansing properties of the environment has been employed in revising or designing these particular controlling devices.

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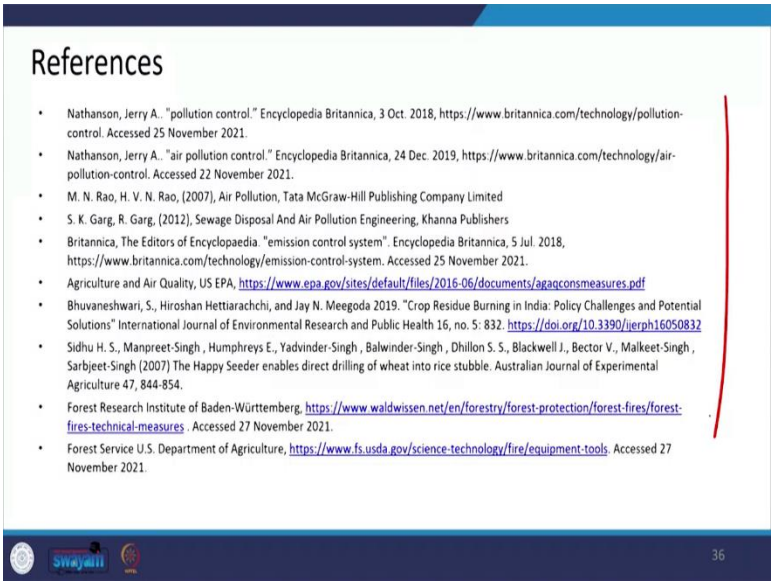

Well, this is all for today. These are the references for additional information. Thank you for your kind attention. See you in the next lecture. Thanks again.