Energy Resources, Economics, and Sustainability

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Week – 05

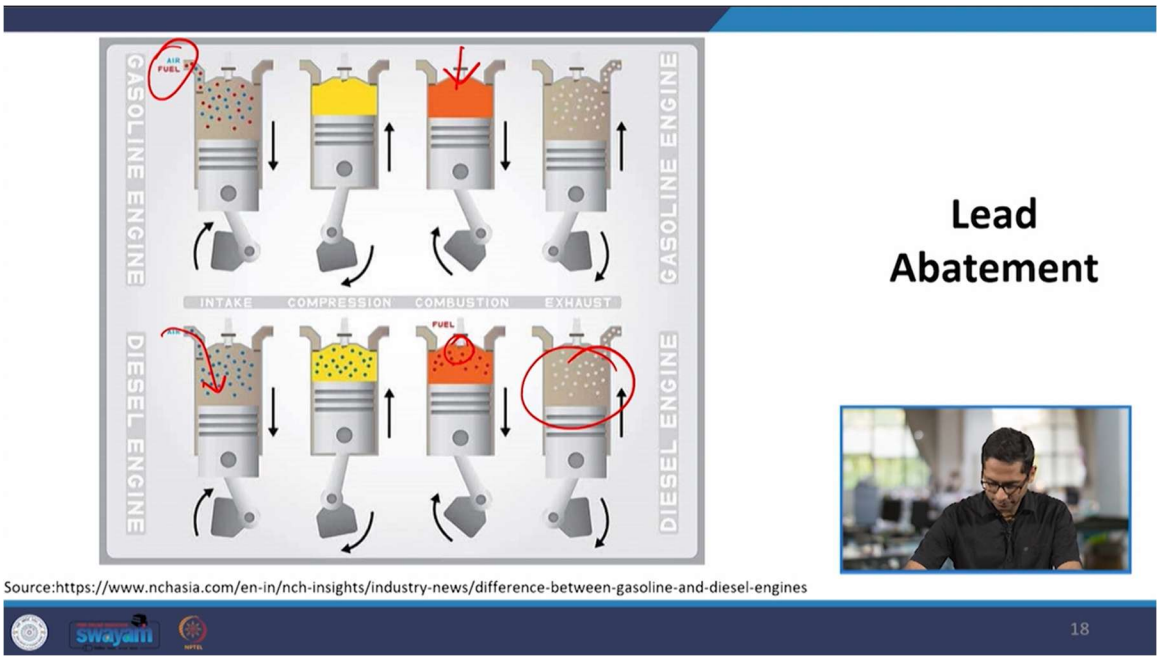
Lecture – 03

Lecture 23 - Recent Successes in Environmental Stewardship-II

Hello everyone. Welcome back to the course Energy Resources, Economics and Sustainability. In the last class, we have been discussing success story with respect to the environmental emissions that work of because of the increased energy use in terms of the fossil fuels and the example was that of SO2 emissions. So, we had seen that in the years 1970s or the 1980s, there was a huge increase in the sulfur dioxide emissions, which later on led to a lot of environmental effects in terms of the acid precipitation, acid rains, acid snows, which led to a decrease in the pH of a lot of water bodies around the world, which led to a major destruction of the marine life. Further, the destruction was also felt in the form of the loss of the historical monuments, which were harmed because of this acid rain and because of the government policies, the public pressure as well as in international cooperation policies were undertaken. And if we talk about the developed world, this kind of problem has been solved to a great extent.

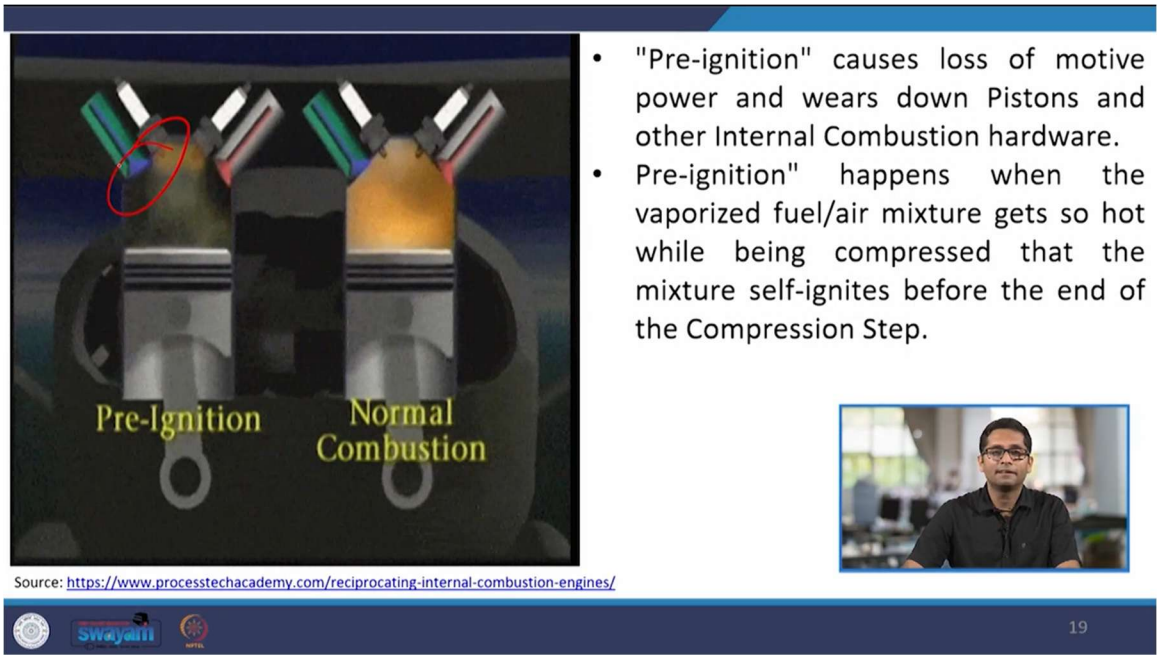
And the emissions of SO2 emissions have been down by 90% in many of the countries. It was also felt that the targets were achieved well advanced of the targeted years. Further, the cost that was approximated for these kinds of targets to be achieved when they were actually realized, the cost that came out were less than 25% or one-fourth of the cost that was initially estimated. Further, this also helped the corporates or the industries come up with new and innovative methodologies, which helped increase the process efficiency for the production of energy and also led to long-term capital gains in terms of better profit in the future.

In today's class, we will try to study two more case studies, one with respect to the lead emissions and the second with respect to the ozone depletion that we have been reading in the past as well. How again these two problems were caused because of the energy production pathways that are primarily through the fossil fuels and how because of the international cooperation as well as the scientific community providing solutions, these problems could be solved to a great extent. So let us start with the problem of the lead. So before we start, let us try to understand the basic difference in the operation of a gasoline or a petrol-based engine or a diesel-based engine. So what you see on the top figure is a typical gasoline-based engine.



So what happens in a gasoline-based engine is the injection of fuel and air that happens together. So in the first cycle, the mixture is compressed and at the compression, you have the spark plug here which provides the initial spark which you might have seen in your motorbikes or your scooters as well. And because of the spark, there is an expansion of the mixture which leads to the moving of the piston and provides the power for the running of the vehicle. In comparison, in a diesel vehicle, what happens is you just have the intake of the oxygen that happens and then in the compression, when the compression is happening, we would have the injection of the fuel happening. And because of this compression, there is a huge increase in the temperature which goes beyond 500 degrees

Celsius and because of this high temperature, the mixture gets combusted and then because of the gases produced and there is the throttle that is produced and the engine moves further. The basic difference is in a gasoline engine, you would have a spark plug providing an ignition whereas in a diesel engine, what happens is the mixture of air and the fuel is combusted because of the high compression that is happening and because of the high temperature that is reached because of the increase in pressure.



Further, sometimes it is felt in gasoline engines because of the pressure being building up, the ignition happens because of the high temperature reached and that happens before the spark plug ignition is there. So what you see here is the ignition happening before the ignition is provided by the spark plug and because of this, the cycles on the engine are greatly hampered and this also causes some amount of loss to the engine performance. This particular phenomena is also called as knocking which many of you might have read about or studied about and this was a major issue with the operation of the gasoline based engine where the ignition sometimes happened before the ignition was initiated by the spark plug. So the companies or the industries around the world have been coming around or trying to come up with solutions so as to do away with this knocking problem and one of the solutions that came about was the use of anti-knocking agents and one of the major anti-knocking agent that was used in the past was the tetraethyl lead.

Avoiding Knocking

- Autoignition in gasoline engines can be prevented by chemical additives, the most common of which in the past was tetraethyl lead ($Pb(C_2H_5)_4$).
- Tetraethyl lead prevents premature combustion, knocking, and engine damage. The use of this chemical was widely adopted by the refining and automobile industries as an antiknock additive to the petrol in the early part of the twentieth century.
- However, $Pb(C_2H_5)_4$ also combusts with the fuel, and its combustion releases lead oxides to the atmosphere, primarily PbO and Pb_2O, as well as atomic Pb.
- Humans and animals will breathe or ingest these chemical compounds

Source: Michaelides, E. E. (2018). Energy, the environment, and sustainability. CRC press.

So the chemical was this, a molecule of lead that was connected to four molecules of ethyl so that is why it is called the tetraethyl lead and the advantage of this particular chemical when this was blended in a gasoline based fuel is that it helped or like avoid pre-ignition or knocking and the further resulting engine damage and this was the reason that this kind of chemical was used quite widely in the automobile industry as well as the refinery. Now this lead which was entering as tetraethyl lead was also combusted with the fuel that was entering into the engines and this lead would eventually escape to the environment in the form of different oxides of lead which were lead oxides as well as also atomic lead and this lead if it was ingested by the life in terms of humans or animals could cause major breathing problems or also major problems of the lungs and in very extreme cases it is also known to cause death of the persons. So the lead that was emitted because of the tetraethyl lead being combusted in the engines had significant effect on the people that were inhaling it. Again this is a typical example of capitalizing the profits and socializing the emissions or the impacts that we have read or that we have studied in the previous classes that people would want to make the processes that they were using to be highly efficient. So the person who was using these engines had a very efficient use of the engines but the emissions that were being released in the atmosphere had impacted the whole society and anyone or everyone that was inhaling these kinds of emissions felt the problem that resulted from these emissions particularly of the lead.

- A second pathway for the human absorption of lead is via the lead-based pigments and the sweetener lead acetate, which is also known as "sugar of lead." Pigments with lead base have been used for centuries to provide bright colors of yellow ($PbCrO_4$), red (Pb_3O_4), and white ($PbCO_3$).
- Lead-based pigments were used by the paint industries, worldwide, for the manufacturing of paints for artists and for the walls of buildings in the 1980s.

Other Pathways

Source: Michaelides, E. E. (2018). Energy, the environment, and sustainability. CRC press.

Further another pathways that led to the propagation of lead to the environment was the use of lead based pigments or sweeteners. So the sweeteners were basically used quite in the past but the paints were used till quite recently in the 1970s and the 80s where the lead source was used to provide the bright colors like red, yellow and white and all these pigments entered into the walls and if these walls came in contact with the eating habits they might cause inhalation of these kinds of pigments and could cause various kinds of diseases. Again this lead based pigments were used in paint industries worldwide and they were used by different kinds of artists and this was a major phenomena up till the 1980s.

Disclosure of Information on Lead-Based Paint and/or Lead-Based Paint Hazards

Lead Warning Statement

Housing built before 1978 may contain lead-based paint. Lead from paint, paint chips, and dust can pose health hazards if not managed properly. Lead exposure is especially harmful to young children and pregnant women. Before renting pre-1978 housing, lessors must disclose the presence of known lead-based paint and/or lead-based paint hazards in the dwelling. Lessees must also receive a federally approved pamphlet on lead poisoning prevention.

Lessor's Disclosure

(a) Presence of lead-based paint and/or lead-based paint hazards (*check (i) or (ii) below*):

(i) ☐ Known lead-based paint and/or lead-based paint hazards are present in the housing (explain).

_____

_____

_____

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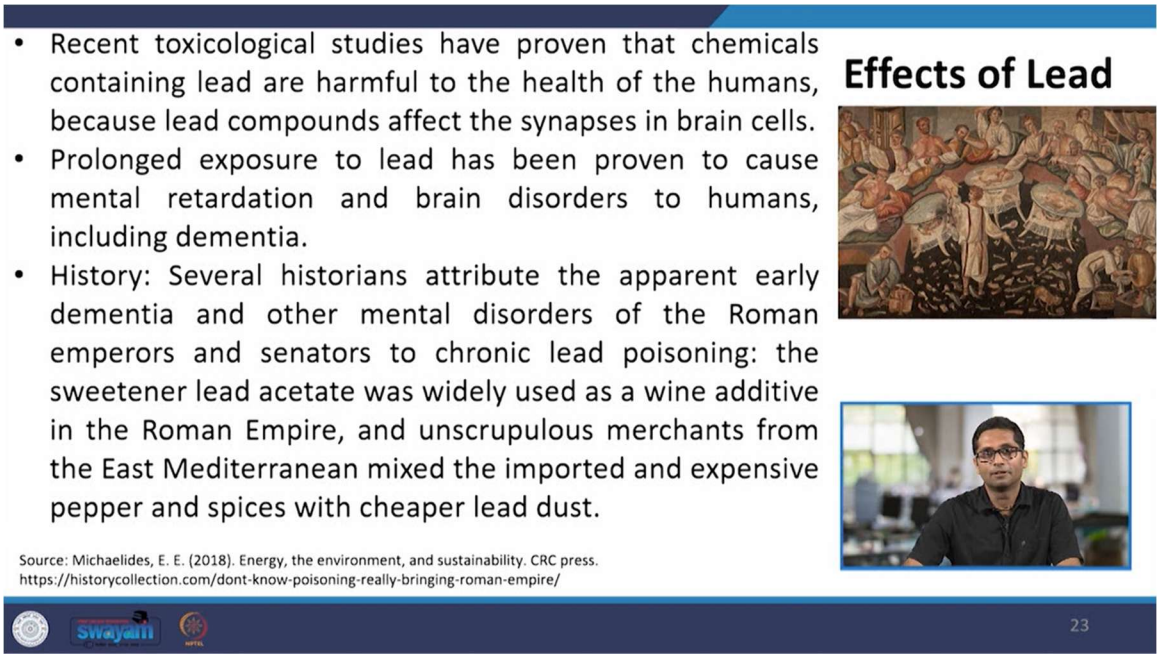
(ii) ☒ Lessor has no knowledge of lead-based paint and/or lead-based paint hazards in the housing.

(b) Records and reports available to the lessor (check (i) or (ii) below):

(i) ☐ Lessor has provided the lessee with all available records and reports pertaining to lead-based paint and/or lead-based paint hazards in the housing (list documents below).

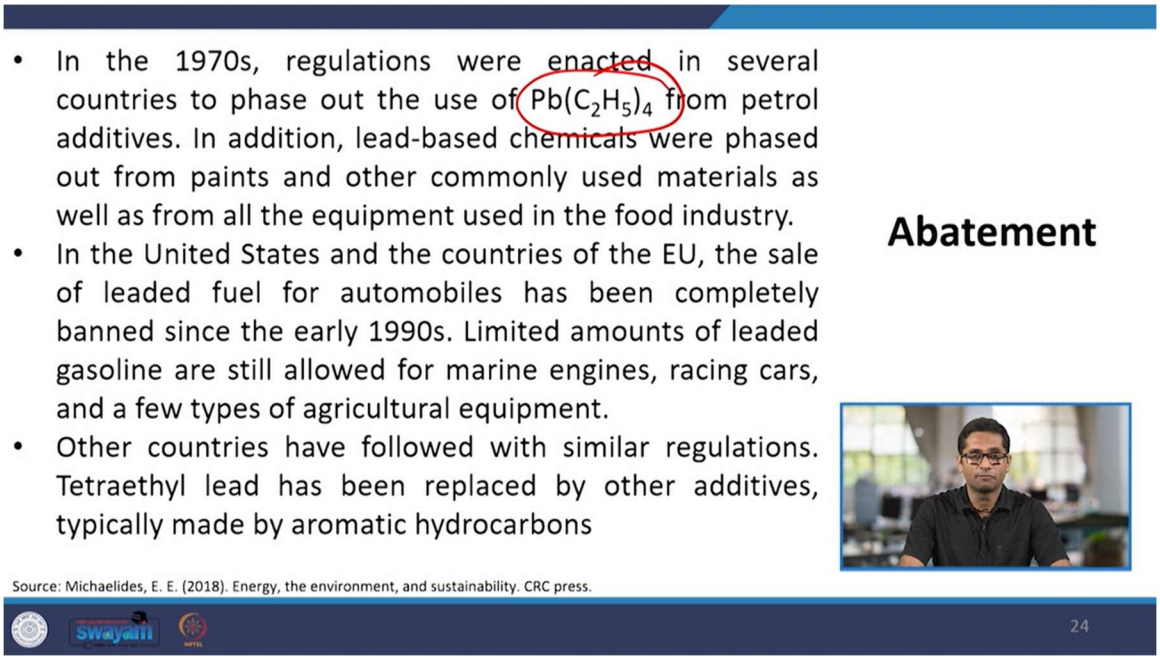
Source: https://dot.ca.gov/-/media/dot-media/programs/right-of-way/documents/rw-manual-exhibits/chapter-11/11-ex-48-rev-0721-a11y.docx

For the typical example could be like this is the agreement that I personally signed when I rented a house in one of these countries and the building that I was renting was made in the 1950s and they had said like they are using lead based paint and lead based so they wanted me to be aware of the paint that was used almost 50 years back in the painting of the apartments that I was staying in also had significant health effects. So this was a policy that was adopted and is currently being adopted like if you rent any old countries in one of the developed worlds they would make you aware that lead based paints were used in those in like furnishing those buildings in the past and that still might have some kind of effects on your health in the present as well.



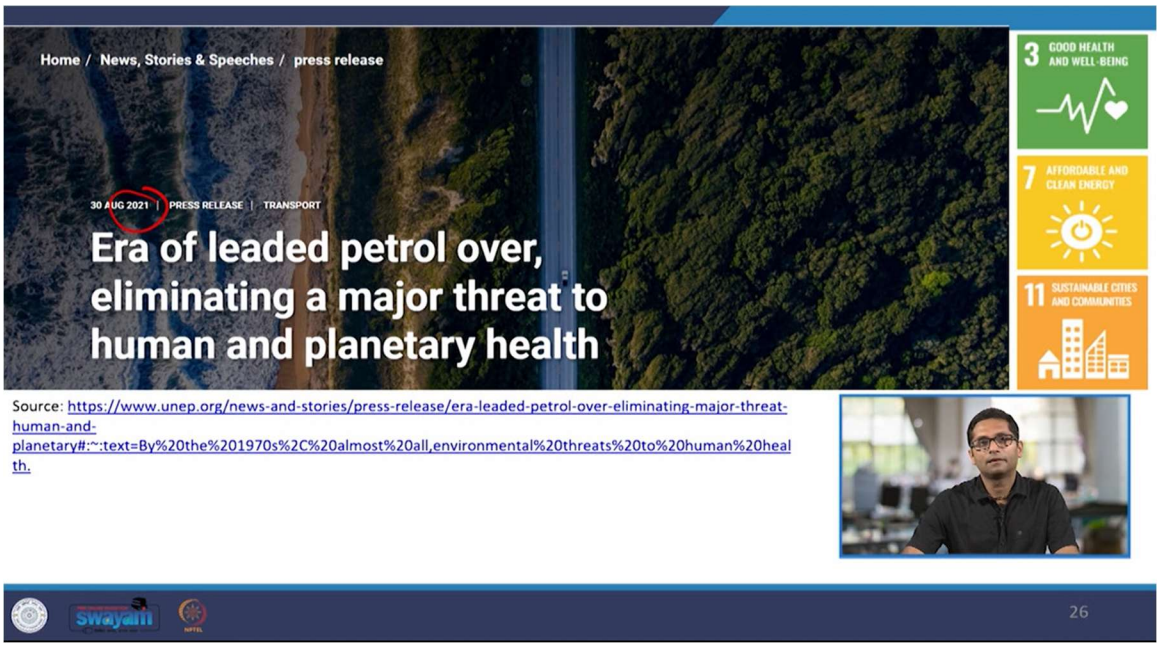
So and also if you study about the recent toxicological studies they have proven that the chemicals that come up with lead could significantly affect the synapses of the brain cells and a prolonged exposure to this can cause mental disorders, brain disorders in humans as well as in different species as well. An interesting case today could be like the historians, a lot of historians have attributed to the not so good behaviour of the mental disorders that were prevalent in the Roman emperors in like a thousand years back or more can be attributed to using lead as a sweetener so the Romans were using lead based sweeteners for their wines and other liquors that were drinking which slowly affected their thinking pattern and led to different kinds of brain disorders and this is attributed to the lead

poisoning. Further it has also been reported that the merchants in the Middle East or in the eastern military were mixing some of the spices and peppers with a cheaper lead dust which also led to a lot of brain related diseases and made people do like all kind of like not so good behaviour.

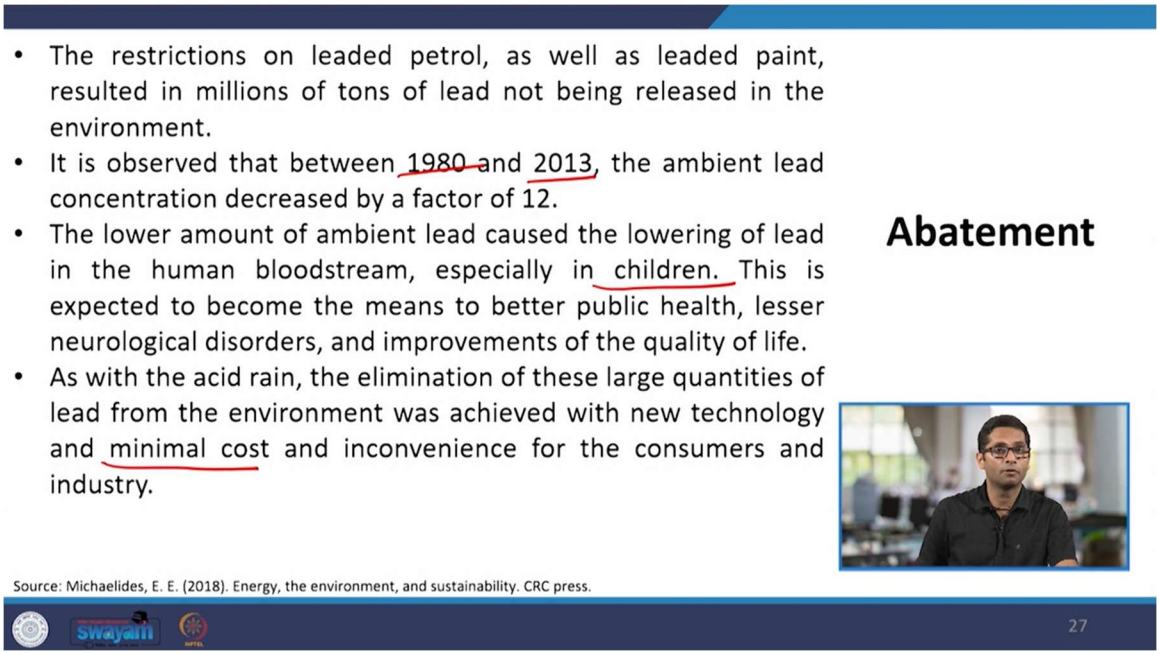


So in the 1970s people felt that or through the help of the scientific understanding that these lead based emissions were not good for the environment and people who inhaled in the long term and they started looking for alternates to the tetraethyl lead and so with the concerted efforts by the scientific community as well as the industries as well as the governments coming together the replacements were found and slowly the tetraethyl lead which was used as an anti-knocking agent were replaced by much more nature friendly chemicals and if you see today like most of the developed world has banned the use of lead throughout the automobile industries just some limited amount of lead is currently being used and that is also for some kind of marine engines, racing cars or few types of agricultural applications but if you say far and wide like most of the applications of lead have been phased out we don't use these kinds of chemicals anymore there have been some kind there might be some countries who are still using it but they also have came up with targets to remove it as soon as possible from the supply chain of automobiles.

So if you have gone for filling up of your vehicles, patrol based vehicle either cars or two wheelers and it's a common sight that you would read that the patrol that you're filling is often is prefixed by un-leaded. So this specifically means that there is no lead that is used for the patrol which was earlier used as a knocking agent and this is why this term is becoming common nowadays because the gasoline or the patrol that you are using to fill up your vehicles has very little to no lead and which means they are very less environmental emissions of lead that is happening from the combustion of petrol leading to lead based oxides.

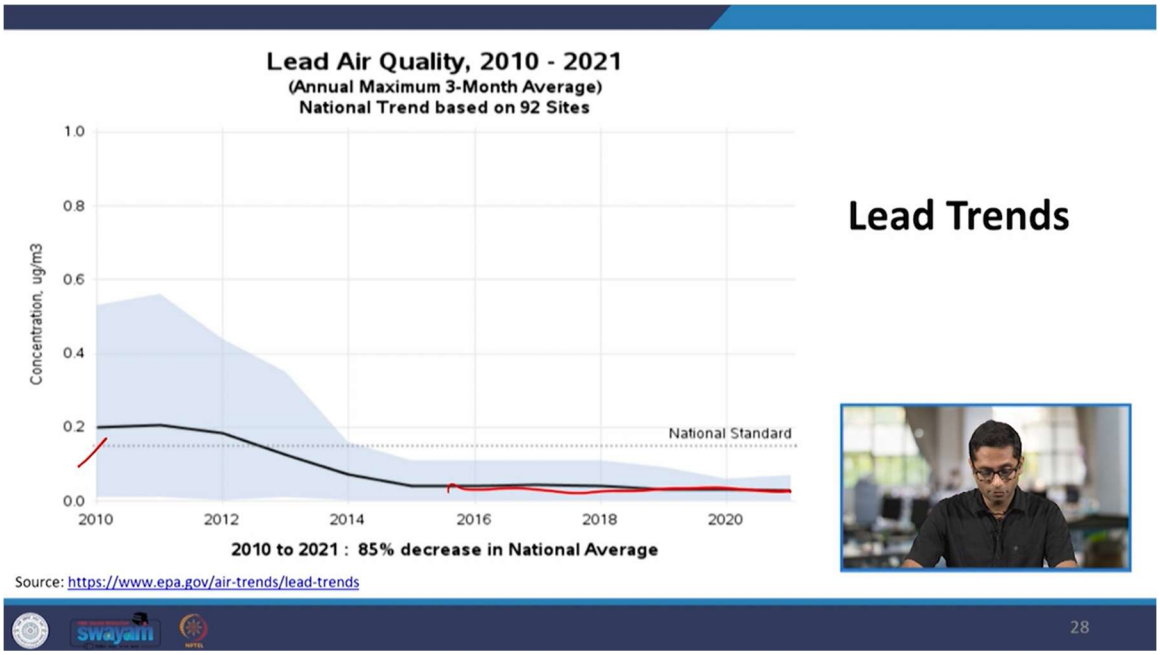


Further a similar thing can also be seen on the different portals so this is the portal of the UNEP, United Nations Environment Programme and there was an article in the year 2021 which said that the leaded patrol is over as an error like the major threat that was being faced by the humans and the planet as a whole has been averted and there are very less lead emissions as compared to one that were experienced in the 1970s or the 1980s that were causing a lot of problems and one of the major sufferers of these kinds of emissions were the young children who were quite prone to problems which were resulting from these emissions.

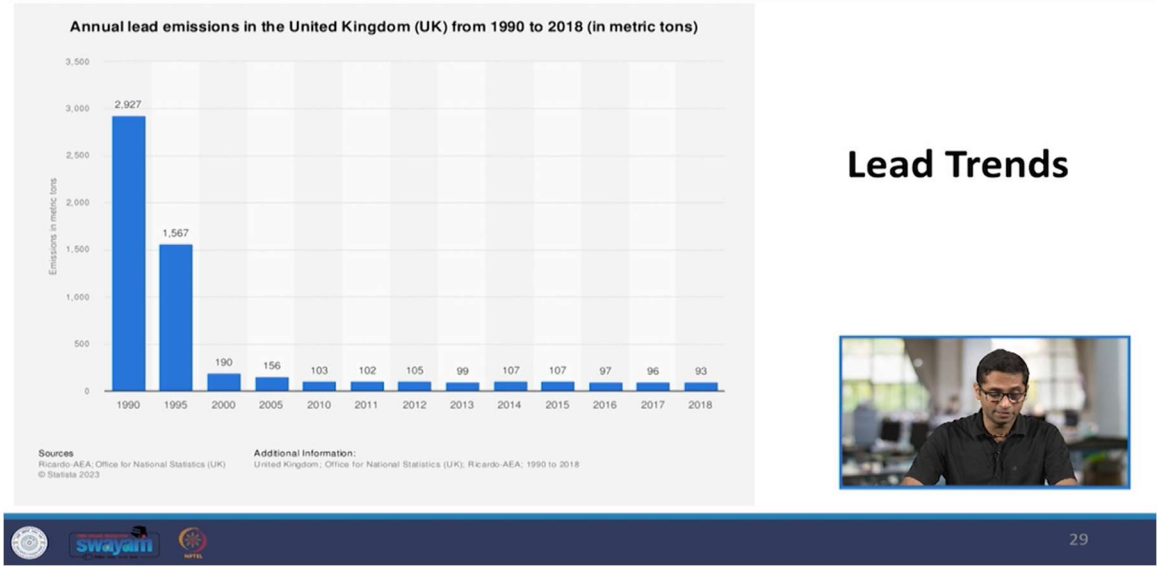


So if we consider today, majority of the world has done away with lead emissions that were resulting from the consumption of different fuels and if you see that also these kinds of restrictions have also led to the paint industry where tons of lead were being used. So again the different types of alternates have been found and if we see between the years 1980s and 2030 the lead concentration in the atmosphere has decreased by a factor of 12 so this is again a huge advantage. The lower amount of lead has led to the lowering of the blood lead level especially in the children which were at the most risk of poisoning because of lead and other kind of neurological disorders which was spreading because of this and something similar to the acid rain the elimination could be achieved quite fast and there were major industries involved, there were major countries involved.

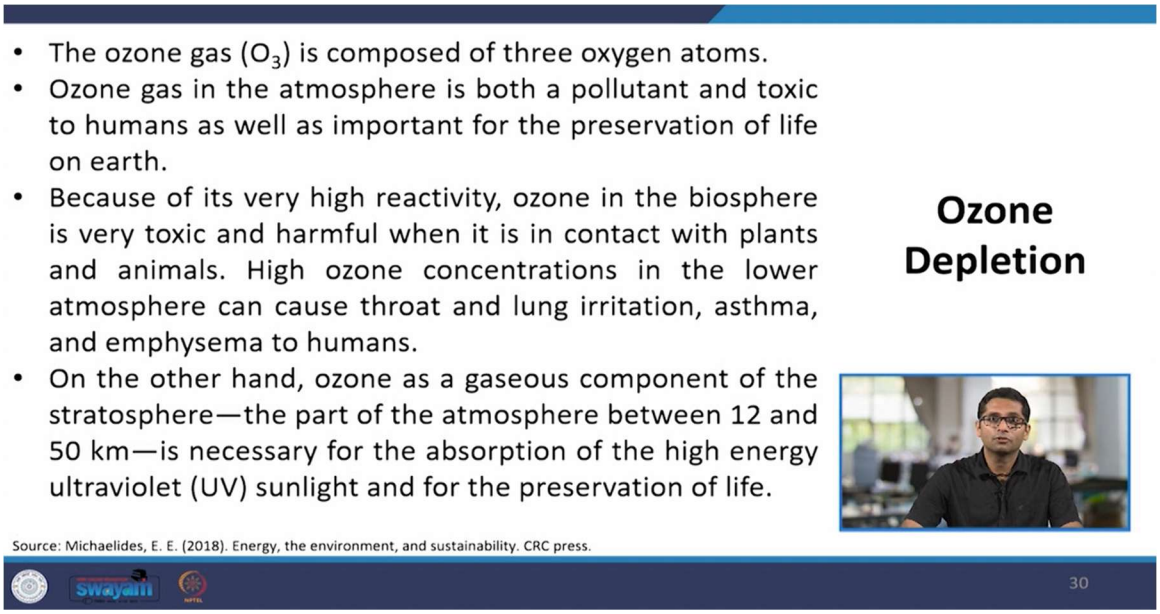
Further the cost that was incurred was not very much. It was a minimal cost and the inconvenience that was suffered by the consumers and the industry was also found to be minimal. So although there were initial expectations that this might cause a lot of overwhelming of the supply chain because of the petrol being changed to a different version this was never experienced. Furthermore the advantages that were derived from this kind of change were much more than the problems that would have been felt on those years.



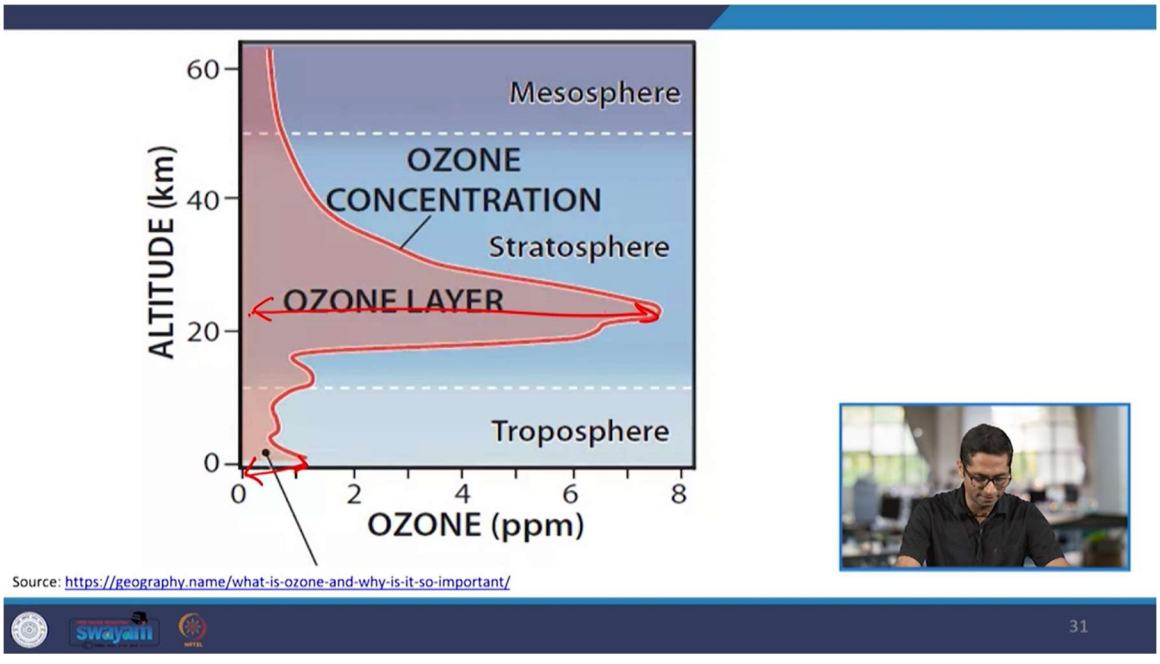
So this again was a major case study that is attributed to be a success story as well as abatement of a major emission that was resulting from the energy industry and if I look at the lead based emissions and this emissions are for the US and you can see that the emissions have been continuously going down and almost stagnant or like below the national standards. So the national standard was around 0.15 micrograms per meter cube. So these emissions have been below the standards beyond the year 2013 and further.



Something similar was also found in the country of UK where the emissions if you see in the 1990s were quite high. The cumulative emissions were of the tune of around 3000 metric tons a year but coming till the year 2018 it was just 93. So again three orders of reduction that have been felt in the emissions of lead which is again a major achievement in terms of the emission abatement that was happening and this again came up with the scientific community coming up with innovative ideas, came up with innovative anti-knocking agents which could replace the common chemicals that were used quite in an orderly and an accelerated fashion.

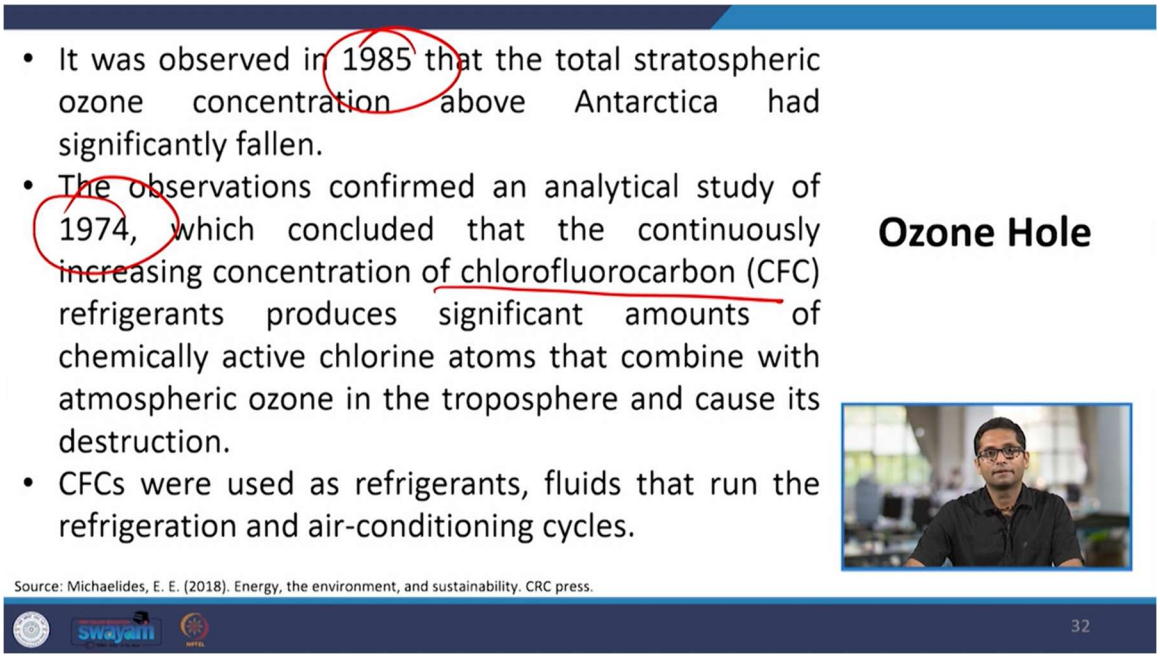


Let us also try to look at another case study with respect to which was similar to lead and sulphur abatement and that is the ozone depletion. We all might have heard about ozone depletion at some part of her life. It is basically a gas O3 which is three moles of oxygen being combined together and we find ozone to be playing a dual role. So if there is any ozone like in the troposphere that is in the sphere or in the biosphere like something that we have access to it is a fairly toxic gas. We would not want to have any interaction with ozone and a lot of ozone is being formed because of the different automobiles. Further we also have the so called good ozone that is found in the stratosphere that is the region that extends from 12 to 50 kilometers. Most of us would not be reaching that kilometers in our life span but it is where a lot amount of ozone is felt and a major function of this ozone is that it captures the harmful UV radiations that come from the sun and does not let them reach the surface of the earth. So if we see it captures almost all of the UV-C radiations and around 90% of the UV-B and almost 50% of the UV-A radiations and the result is preserving the life on earth. If the ozone layer was not to be present all the life on the earth might have also been sterilized it would not have been possible to some extent. So the ozone that we have plays both a good role and bad role. So whenever it is present in the biosphere with which we have access to it might cause problems like lung and throat irritation, asthma and emphysema. Whereas in a good job it is preventing the UV radiation from reaching the surface of the earth.

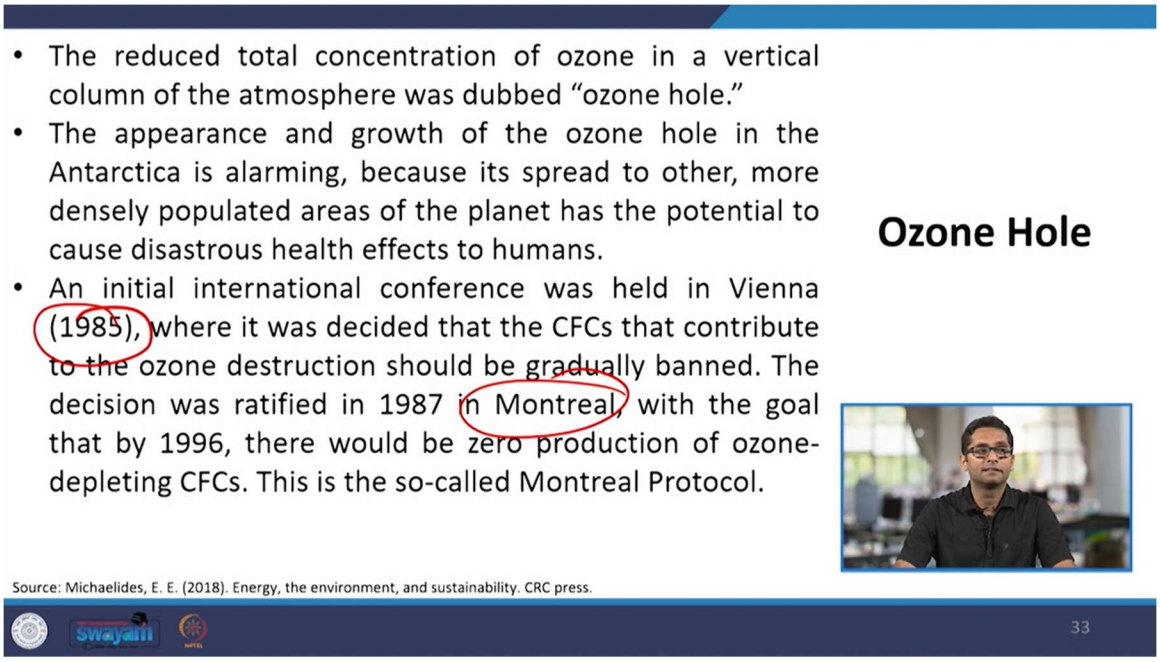


So if we look at the concentration of the ozone it is mainly find in the ranges from around 20 to 40 kilometers and where the ozone concentration is again not very much but relatively on a higher level. So the highest level of ozone concentration in terms of parts per million reaches around 7 to 8 ppm and that is where we have the ozone layer somewhere on the height between 20 to 40 kilometers and we also have access to some amount of ozone roughly around 1 ppm which is resulting from the automobile industry.

But in this example we are talking about the ozone layer that is preventing the UV radiations and that is found in the stratosphere. So what has happened in the past and we have also tried to understand this in the previous classes that because of the different kinds of refrigerants being used and this refrigerants majority of it was also coming from the air conditioning industry were released in the atmosphere and this chlorofluorocarbons would react with the ozone breaking the ozone molecule and decreasing the concentration of ozone in this layer. So ozone hole when we use the term ozone hole it is not a hole in the two sense it is only that because of the reaction of the ozone with the chlorofluorocarbons the concentration of the ozone at particular instances has been reduced. So with the decrease in the concentration of the ozone at certain places the UV radiations could reach the earth surface and this might lead to harmful effects and causing different kinds of cancers.

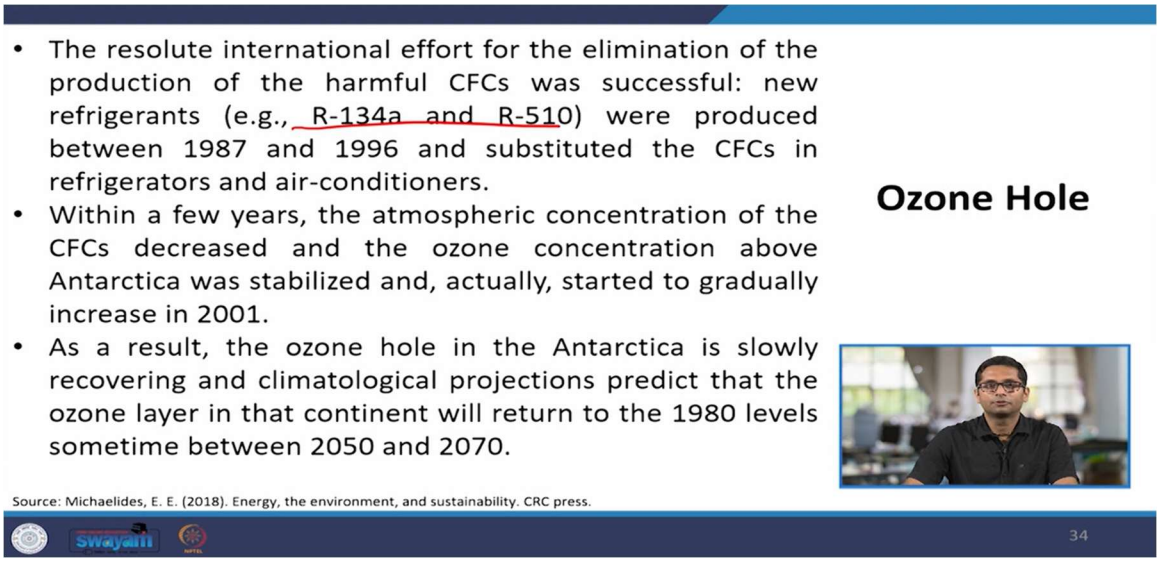


So again if you go back into history like the first ozone hole was observed in over Antarctica and this was the year 1985 and beyond before that even there were studies in the 1974 and this is precisely the example that we studied in the previous class as well where there was a study that was negated or that was confronted by DuPont because DuPont at that time was a major industry that was manufacturing refrigerants and but it was later on it was found that there is indeed a decrease in the ozone concentration over Antarctica and one of the major reasons for that decrease was the chlorofluorocarbons which were the refrigerants that were used for different applications and the result was that they were combining with the ozone molecule breaking it and decreasing the concentrations.



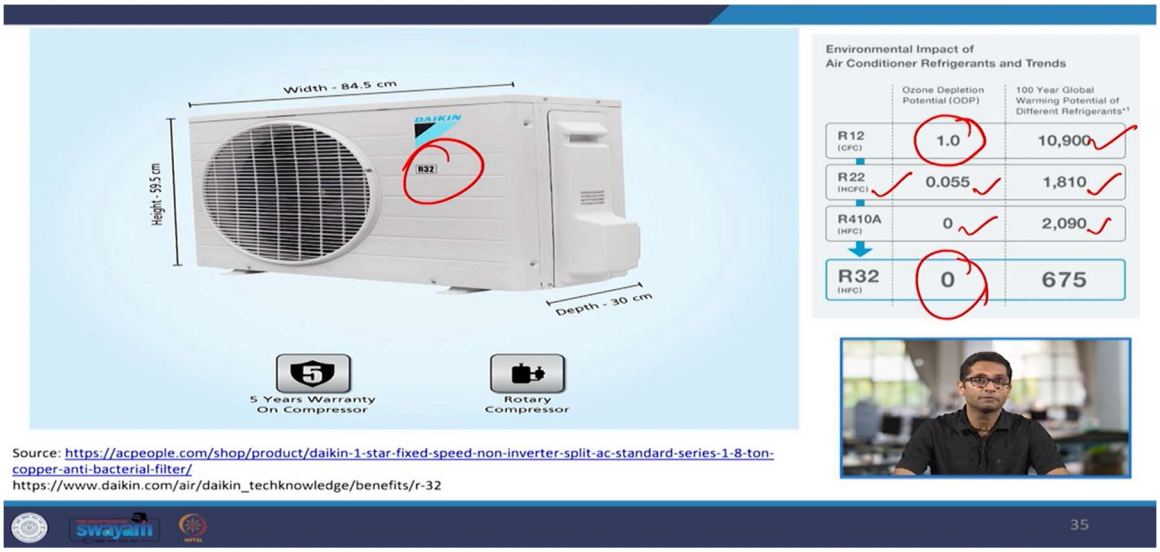
So what happened beyond that was the countries around the world got together and they found that the situation over Antarctica is alarming and it could very well spread to other parts of the world which are much more densely populated and if that was to happen the effect could be even more because a zone hole over Antarctica does not had much contact with the human population but if that was to happen over other countries which are much more populated the effects on the health of the people could be even more disastrous there could be much more cases of cancers or other causes of morbidity or mortality could increase. So the company so the different countries came together in Vienna and

there was an international conference in Vienna where they decided to phase out the use of CFCs in an orderly manner they set up the targets and finally there was a decision that was made in the city of Montreal Canada in the year 1987 that by 1996 which is in the next 10 years there would be zero production of the ozone depleting CFCs. So the countries came together and signed it an international agreement so as to produce almost zero amount of CFCs in the next 10 years and this is also known as the Montreal protocol which is again seen as a success story in the past.



So what happened was companies were like companies started to find better alternates to the CFCs which are earlier used and they came up with new and new refrigerants few examples being HFCs or HCFCs or hydrochlorofluorocarbons and examples could be R-130, 4A and R-510 basically representing the type of refrigerant that they were using and the result was that the countries could achieve the target of 1996 quite well and the CFCs were almost substituted with better refrigerants by the year 1996 and if we consider by the year 2001 scientists felt that the ozone hole over Antarctica has stabilized and it has also started gradually increasing or increase in concentration or like it is the health of the ozone layer was improving which was a positive sign and based upon the estimates the different climatological projections have said that if the same pattern continues by the year 2050s or 2070s the ozone hole would fill to what it was before the 1970s or the pre-industrial era. So that again was encouraging figures that something that was a major concern to the environment in the past has started to improve the ozone hole is slowly

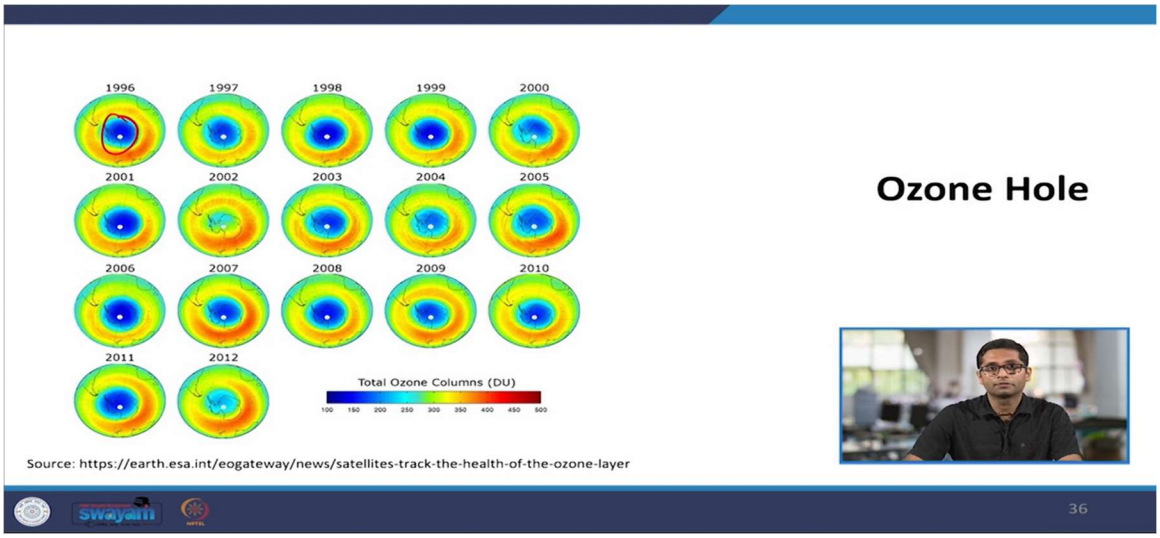
healing because of the effect of the different types of policies that have been adopted by the global governments as well as the industry is coming up with innovative and new and new refrigerants that are good for the environment and doesn't cause any effect to the ozone hole and the effect is expected that in the coming years by the year 2050 or 2070 the ozone hole would be back to its original concentration and that in fact was an encouraging result.



And just to give an example so like you might be using different kinds of air conditioners in your companies or in your homes or in educational institutes you would read there are certain kinds of refrigerants mentioned like in this case it's R32.

So what was happening earlier the companies were using certain kind of refrigerants which were having a good amount of ozone depletion potential or a good effect on the ozone further at that time the GHGs were not very specific so companies didn't paid an effect on the global warming potential we will understand these terms in the future when we are coming in the LCA aspect but just to give an example so later on the companies discovered something called as the HCFCs which had somewhat of a lesser ozone depletion potential but they also had a lesser global warming potential but as we proceeded they also found that even the global warming potential had to be reduced so this came up with the discovery of HFCs but the problem of global warming potential continued to persist if you consider today the companies are using some kind of refrigerant that have almost zero ozone depletion potential which means they would have

almost zero effect on the decay of ozone layer but they had slightly also have a slight effect on the global warming potential of CO2 emissions but so far because of the growth of technology coming up with innovative ideas like ozone depletion could be catered to and this also helped in bringing down the effect of global warming which was again coming from some of these refrigerants.



So this is again the ozone hole how it has been quite prominent in the 1990s you can see the concentration so it was basically the concentration decreasing and the scientists have predicted that in the 2010s or the last decade that it has now slowly started to heal and is expected to be better in the coming years or so. So if I was to conclude from the study that we have been studying three different examples which was the abatement of lead, the mitigation of acid rain and the recovery of ozone layer and all the three problems were in some way related to the energy industry or the use of fossil fuels at a mass scale to produce different kinds of energy applications. They have been major issues in the 1970s and the 1980s but the international community came together the international scientific community could analyze the data come to the conclusion and come up with proposed innovative solutions. So these are the types of solutions that would require us from changing the loose wind loss situation that we have been discussing in the previous classes to win-win situation or shifting the curve from one wind loss situation to another wind loss situation wherein there is some amount of loss because of going towards innovative technology but overall it is good for the industry in terms of the profit that it makes in the long term as well as the effect on the environment is minimized.

Conclusions

- The abatement of lead, the mitigation of acid rain, and the recovery of the ozone layer are environmental success stories.
- The international scientific community analyzed the data, drew its conclusions about the threats, and proposed solutions to the leadership.
- With concerted international effort, the cause of the threat was eliminated; healing processes were initiated, and the results of these processes have proven to be successful.
- The technical community played a significant role in the three processes of environmental remediation: sulfur scrubbers were developed for power plants; lead-free antiknock substances were invented and massively produced; and refrigerants that do not affect the atmospheric ozone were substituted.

Source: Michaelides, E. E. (2018). Energy, the environment, and sustainability. CRC press.

And again we should give equal credit to the international efforts or the international community that came together bringing like keeping aside their differences and coming up close with like to the countering a common threat that was either the lead or the acid rains or the ozone coming up with possibilities with nicely sort out targets and helping each other reach those targets well in time and like the technical community played an equally important role. There were innovations of new technologies like sulphur scrubbers were innovative, lead-free anti-knocking agents were discovered and refrigerators that do not affect the atmosphere or ozone layer were also came up they were invented in a small amount of time and also substituted in the industries. This helped bringing down the environmental emissions meeting the environmental regulations and also helped those companies build up a good image for the future and as well as making their processes much more efficient for the future that helped them realize even greater profits. So we have discussed a few success stories and in the future classes we are going to come up with the problem of the global climate change or the CO2 emissions. We will try to understand how this problem could be very different from the success stories that we have discussed now and if there is anything we can learn from this previous success stories and could be applied for the future.

With that we end today's class. Thank you.