Conservation Economics
Dr. Ankur Awadhiya, IFS
Indian Forest Service
Indian Institute of Technology, Kanpur

Module 12
Case studies
Lecture 3
Economics of Environmental Disasters - II

Namaste! We carry forward our discussion on the case studies and we shall be looking into the Economics of Environmental Disasters. And one disaster that we want to discuss here is The Love Canal of New York which ranks in one of the top 10 environmental disasters in the world.

The story begins in the year 1894, when William T Love begins the canal building. So, Love Canal is named after this person William T Love and the idea was to develop a planned industrial city, a model city of sorts that would be having all the modern facilities and to bring water to this city, this canal was done. So, this is an old map that is showing us that this is the site of the model city and this was the proposed canal that was being made.

In the year 1903, the Hooker Chemical Company was founded and it used to make chlor alkali products and it was founded in an area very close to this proposed site. This chemical factory was developing materials through the chlor alkali process which is a process in which the brine solution is electrolyzed to get sodium hydroxide and chlorine.

Now, in this process, certain other chemicals can also get formed because the brine is not a pure salt in water solution and so different kinds of compounds can also be formed. At the same time, the industry very soon because it was profitable, it was very soon expanding into a number of other chemical industries.

Whenever we have certain chemical processes, there will be certain waste products that will be generated. Because there is a reaction that is going on, there will be certain by products. Now, these by-products need to be treated, before they are dumped into the environment.

But as in the case of the Minamata disaster, here too the people who were running this factory, they wanted to go for a cost cutting measure. So, in place of treating the chemicals, they wanted to shift to a process in which they would just postpone the treatment and they would just dump the chemicals somewhere and by that time, the idea of the plant industrial town that had dropped down.

So, even though certain portions of the canal had been dug; but the modern industrial town did not come up. The people who were looking after the waste disposal in the Hooker chemical factory decided that why do not we buy up this land that is already a dug-up land and there, we can store our chemicals.

That became an idea for the Hooker chemical corporation. So, whatever waste materials would

be produced in this plant, it would be dumped into the canal and it would be dumped in the form of barrels that were full of these chemicals. Now, with this thought, the Hooker Chemical Corporation took over the Love canal.

It took it over in 1942 and for the next 10 years, it used it as a dumping site. Now, after a while, when quite a lot of chemicals had been dumped into this canal, what happened was people started to realize that this land is now soon becoming a liability. Why?

Because there are a number of drums that are full of chemicals and these chemicals are also corrosive chemicals. So, they are heating up the drums from the inside. There is a piece of land that is dug up that is all piled up with chemicals that are there in drums and the chemicals are eating up the drums and so, on any day an accident can come up.

What would have any responsible cooperation or any responsible form done in such a scenario? They would have taken these chemicals out, probably treated them. Because just keeping the toxic materials into dumb in the drums at a site is not a solution, it is just a way of postponing things; nothing else. But what this firm did was something very preposterous, they sold this land.

It so happened that in the surrounding area a new colony was coming up and the Hooker chemical company sold this piece of land, this canal to the Board of Education. The Board of Education was looking for a site on which to construct a school and these people said ok this is the site that is available, you can have it and you can have it for just 1 dollar.

Now, what is happening here? If the Board of Education was getting this piece of land for 1 dollar that should have rung a bell. There is something wrong with the site; otherwise, why would somebody give it to us for just 1 dollar. But then, these people again were looking at profit and loss, they took up this land.

If you look at the agreement that was signed, there was a caveat in the agreement. Prior to the delivery of this instrument of conveyance, the grantee herein has been advised; now here, the grantee is the board of education, has been advised by the grantor which is the Hooker Chemical Corporation that the premises above described have been filled.

In whole or in part, to the present grade level thereof with waste products resulting from the manufacturing of chemicals by the grantor at its plant in the city of Niagara falls, New York and, the grantee assumes all risk and liability incident to the use thereof. ALL RISK AND LIABILITY INCIDENT TO THE USE THEREOF. So, what is happening is that the Board of Education was told that this area is all full of chemical waste, industrial waste and it is right there on the agreement.

By this sale deed, the Hooker chemical corporation is giving up all the rights and all the liabilities on this land for 1 dollar and the Board of Education is happily accepting it. It is therefore, understood and agreed that as a part of the consideration for this conveyance and as a condition thereof, no claim, suit, action or demand of any nature whatsoever shall ever be made by the grantee, its successors or assigns, against the grantor.

Its successors are assigns, for injury to a person or persons, including death resulting thereof, or the loss of or damage to property caused by, in connection with or by reason of the presence of the said industrial wastes. It is further agreed as a condition hereof that each subsequent conveyance of the aforesaid lands shall be made subject to the forgoing provisions and

conditions.
So, this agreement is clearly stating that there is industrial waste on this land and these wastes can result in injury, even death of people or damage to property and when this agreement is being signed, it is being signed on the condition that the Board of Education now assumes all the liabilities.
At the same time, there will not be any suit whatsoever against the Hooker Chemical Corporation by the Board of Education or by anybody to whom the Board of Education assigns this land and if the Board of Education later on, wants to have an agreement with anybody else. Then, this condition has to be mentioned there that there will not be any suit against the Hooker Chemical Corporation.
Here we are observing that for one the Hooker Chemical Corporation is trying to give away its liabilities; whereas, the responsible course of action would have been to treat those chemicals. So, it has dumped those chemicals, but it has never treated them. Then when it is giving this land to the Board of Education, at least the Board of Education should have been more careful and especially, when it is being written on the agreement.
Now, the thing is many people just do not read the agreements, when they are signing them and this is exactly what is happening here and when we are talking about things which are industrial waste that can lead to death, then this is not something that should be taken lightly. But this is exactly what was done in that. So, this is the caveat in the agreement.
And later on, what happened? Schools and houses were constructed on this land and here, you can notice this white residue that is coming down. So, in this aerial photograph, you can observe that this is the site on which the canal was there. So, you can see the site here.
So, this was the site and on this site, now people have constructed houses, people have constructed a school and there is also white residue that is coming up. Now, in the beginning people do not care much about any residue. If you go and purchase any new property, you will just think that ok things are fine. This is just the color of the land. But then soon enough, people started to notice a number of other things.
In their residences, people started to observe that wherever there was a basement, some black colored toxic residue was coming in and this residue was smelling like anything. So, it was smelling like industrial waste and it was sweeping in and whenever they tried to clean it up, the next day again this residue came in.
There was no release from this industrial residue and it was getting inside the homes. And now, when the residue is getting inside the homes, it means that people are now directly getting exposed to these chemicals these ways. Then, people started to observe that on certain pieces of land, holes started to appear with chemical smelling black liquids.
Now, why do we have a hole? Because remember that these chemicals were dumped in drums and these chemicals were often corrosive. They were starting to eat up the drum from inside and whenever they got a leak, the chemicals would get out of the drum. But what happens then? You have a drum and this drum is full of toxic industrial waste and this is corroding.
When it corrodes, there will be certain holes that get developed on the body of the drum. Once that happens, all this chemical seeps up. Now, the chemical is outside and inside, the area is now

vacant. Now, once you have such a situation, you have a drum that is empty and this empty drum is beneath a layer of soil which is exerting pressure.

Once that happens, the drum might collapse and when it collapses, we start to observe such kinds of holes. But then, the residents, who were taking up the properties in this brand new location, did not know that there is this chemical deep inside. So, holes start to appear, toxic residues start to rise. Here you can observe that on the ground, we are observing different kinds of residues; different colours.

Black sludge is coming on the ground. People are directly getting exposed to all of these. Waste barrels are rising to the surface. Here you can observe a barrel that has come to the surface. Why is it coming to the surface? Because again, when you have these chemicals inside and when these chemicals are getting leaned down, then these chemicals can react amongst themselves.

Once that happens, in a number of cases certain gases can be produced and gases because they have a larger volume, so they start to exert a pressure. Once they start to exert a pressure, the drum would slowly rise to the surface because it is getting pushed from beneath and this is what we are observing, waste barrels start rising to the surface.

Here are the waste barrels that you can observe that have come up to the surface. And so, this is again a collapsed barrel head and toxic waste residues that have risen to the surface. And once all of this is happening, then people start to protest. So, the Love Canal Homeowners Association protest targeting the federal government was held outside the Niagara Falls, New York, Department of Health building.

Now people are starting to hesitate. They are asking what is this residue that is coming into our homes; they are asking that ok, the site where this school is constructed, all these drums are coming to the surface and the pupils are playing with these drums, they are playing with these chemicals.

Now, if there are these industrial chemicals or these chemicals that have such strange smells and our children are playing with these chemicals, won't they have a negative impact and if there is a negative impact, what is the government doing? This is what they are asking. Now and when such a thing happens, the government did an environmental sampling. An environmental sampling was done in all of this area. And this is the result of the kinds of chemicals that were identified.

Benzene, which leads to things like narcosis and skin irritation. This is an acute effect. Acute effect is something that happens quickly. For any of these compounds, we have certain acute effects which happen in a short period of time and we have certain chronic effects that happen over a long period of time.

So, if you have this chemical, the acute effects and the chronic effects for most of the chemicals, they are already known. When this environmental sampling was done, then if any chemical was found, people can now know what the impacts will be. Let us look at the impacts.

Acute leukemia which is blood cancer, Aplastic anemia which is again another blood disorder, Pancytopenia, Chronic lymphatic leukemia, Lymphomas, Anemia, Neutropenia that is all these different kinds of blood disorders are propping up. Paralysis, Respiratory and cardiac arrest, Visual defects, Deafness, Respiratory distress, Death, Liver tumors.

So, we are observing that all these different kinds of chemicals like benzene, toluene, benzoic acid, linden, trichloroethylene all of these are now be found in this area and there are certain acute effects like narcosis, irritation or liver damage, allergy, anesthesia; but there are also these chronic effects a lot of which are cancers.

So, we are observing that these chemicals over the long term can result in cancers, they can result in things like blood disorders or they can result in paralysis or they can result in neurological disorders. So, we are observing all different kinds of disorders because of these chemicals. Now, if you are living in an area that is having these chemicals and the government has done a study and found out that these chemicals are actually in that area; what will you do? People started to panic; people started to agitate a lot.

In this case, the health impacts also told that the relative odds ratio for miscarriages among women living on the canal was 1.49 or nearly one and a half times the expected rate within the general population. That is these sorts of health damages, they were not just theoretical; people were actually observing that the rate of miscarriage or abortions in this area was a lot higher than that in the general population.

So, the situation was pretty alarming. The Hooker Chemical Corporation started a propaganda war. They started to say that no, we are not the culprits; we are the people who actually built this area, we are the people who provide jobs to people in this area and so on. But still, they are not telling the people they are not coming out and telling them that ok, so and so wastes are there in this area. It is for the investigators to find out what is inside.

But what the government did was to make a Remediation plan. Now, what was this remediation plan? There was this Love Canal that was all filled up with the chemicals. The remediation plan was to cover it up with a top layer of soil so that water does not seep in. Whenever there is rain and if water seeps in, then the chemicals find it much easier to come out.

One step in remediation was to cover it with a layer of topsoil so that water does not get inside and any water that falls, it should get out of these channels. Then, there were these canals dug so that the residues that were getting into the basement, they got an area to move out. So, these trenches were dug and, in these trenches, the idea was that the chemicals that were seeping into the basements would get into these trenches and they would slowly flow out and there, they would be collected and perhaps treated.

So, this was the remediation plan that was made and also, the waste barrels that people could find out, were removed from this area. This is a barrel. And you can look at the scale of the operation, so many barrels of toxic waste that are there in the canal are now being removed. But people are still panicking. The residents will start to evacuate. This is a family that is picking their belongings to evacuate to safer housing; houses get abandoned.

This new colony that was set up in this area that was having a prime property or a prime location, now it is getting abandoned. The house rates fall like anything and the residents are moving away. The school that was built was demolished .And the remediation work, it involved a lot of earth moving, bringing of holes and removing the chemicals.

But still even today, it is a long-standing problem. Why? Because we still have a large number of base barrels that are still there in the neighbourhood; they are still corroding the area, they are

still influencing the surroundings. We still have that smell in the area. Now, the thing to remember here is that if the Hooker Chemical Corporation had decided to go with the well-set plan that whenever you have a chemical waste, you should not release it into the environment, you should treat it.

If they had followed that principle, then none of this would have occurred. But because this treatment involves an externality. If they dumped these ways and if they came up with an agreement that they are not responsible for any of these, the person who is buying this takes all the responsibility and these kinds of loopholes, permit people to go on polluting and when these chemicals get released, the negative impacts are faced by the whole of the society with very tragic consequences.

This is something that we need to keep in mind, that these kinds of environmental disasters occur because there are certain corporations that are providing jobs to people. This is what Hooker corporation also said in the propaganda war, that if we were not here, you people would not be having jobs. If we were not here, you would not be having this new society in the first place; they would not be prosperous in this area.

But then, when we talk about things like prosperity, when we talk about things like employment, it does not mean that people should be ready to take up employment even at the cost of their health. That is to say if there is a development that is happening in terms of higher incomes or in terms of employment or higher standards of living, then we cannot say that this development will be done without any thought about the costs that are important.

Because in a number of cases, in the short-term people would only look at ok we are getting employment, we are getting a higher job, we are getting a job in this factory. But then, in the long term, the consequences are felt by them, by themselves or by their children. And in a large number of cases, we have observed that whenever there is a corporation that knowingly or unknowingly pollutes the environment, there are human costs also involved.

So, while the corporations are giving prosperity, they are also giving a lot of human costs, they are also giving a number of diseases, they are also giving a large number of deaths and it is as a society that we need to understand and we need to decide what we need. Are you only looking at the short term or are we also serious about what will be the impacts for our children and our grandchildren?

Because whenever anything wrong happens, in this case as well whenever the residents got to know that there are industry chemicals, they started to protest against the government. Why doesn't the government do anything? Why doesn't the government give us compensation? Why doesn't the government evacuate us?

So, in the last resort, people will always go to the government; but then, the corporations also have to be made responsible for their actions. Only then, will the corporations stop doing such kinds of environmental damages. So, this is a very important learning from the issue of Love Canal. Another case is The Delhi Smog. Every year, in the winter months, our natural capital suffers from a very huge amount of pollution that results in smog.

Smog is a term that refers to smoke plus fog; so, this is the smog. So, when we talk about the Delhi smog, it is a situation where we have a huge amount of smoke and foggy conditions

because of which that smoke gets attached to the fog particles and that results in a heavy amount of pollution.

So, here, if you go to Delhi in the winter months, you will find a situation like this. So, there is smoke everywhere and the conditions are fogged. You do not have a very good amount of visibility; you cannot look far out. The media has been calling it things like a Gas Chamber and the government has also been doing something about it like distribution of masks to students so that they do not suffer from the negative health impacts of this smog. But the question is what are the reasons for this smog? This smog is a big environmental disaster.

The environment is not good, the environment sometimes is dangerously toxic. People are suffering from health impacts from running nose, running eyes, allergies, cough, asthma, to even things like heart diseases that are resulting because of this huge amount of pollution. The governments are very concerned about this. But the thing is if you want to stop pollution, you at least need to know what is causing this pollution.

Now, when we talk about the Delhi smog, when we talk about the Delhi winters, it is important to know what are the conditions like; what are the weather conditions like; why do we only get this smog in the winter seasons, why don't we get it in the other seasons? Because if we talk about the sources of pollution things like cars; so cars and other vehicles, they are flying throughout the year.

Why don't we get this condition in the summer season? What is so special about the winters? If we talk about things like thermal power stations, they are working all the time. If you talk about things like construction activities, burning of waste, it is happening at all times. Why do we get smog only in the winter season?

If you look at that weather profile, we will find that the maximum and the minimum temperatures are like this. So, here we are observing from 1st of October to 14th of November and in this period the maximum and the minimum temperatures are going down which means that this is now the beginning of the winter season.

And in this period, the precipitation on the rainfall is 0, which means that if there are any pollutants in the air, there is no rain to wash them down. If there was any rain in this period, then probably the amount of pollutants would have gone down because the rain would have brought them down from the air to the ground. But what we are observing is that in these months, there is absolutely no rainfall or even when we get rainfall, it is so small that it does not play a big role.

But the temperatures are down and the relative humidity is very high. In the morning the relative humidity is close to 100 percent. Now, if this relative humidity touched 100 percent, then we would have rainfall. But here the relative humidity is very close to 100 percent; but it is not touching 100 percent.

So, we are not getting rain. But when the relative humidity is close to 100 percent, it would mean that it will be very easy to generate a fog. Now, what is the fog? In the case of a fog, the water that is present in the form of water vapor in the air, gets condensed on the smoke particles or on the dust particles and becomes very small water droplets. Now, these droplets when they are suspended in the air, they behave very much like a cloud and they reduce the visibility. So, that is a fog.

In the morning time, the relative humidity is so high that it generates a very good condition for a fog. In the afternoon, the relative humidity goes down; but still, it is close to or above 50 percent, which means that the fog will not dissipate very quickly. In these seasons, if the air heated up, then the water droplets that had condensed on the dust particles would again evaporate back.

But then because of the low temperatures, we are not seeing that condition. So, the relative humidity decreases, but it does not decrease sufficiently enough, probably because of the cold conditions. Then, if we look at the wind speed; now wind plays a very important role because if there is wind, then it would probably take the pollutants away from the area.

If there is an industry and this industry is giving out smoke and if there is a wind movement, then what will happen is that this smoke will move to far away areas. So, it gets diluted. But if you look at the wind conditions, we will find that the wind speed is also progressively decreasing.

The wind speed was close to 4 or four and a half kilometers per hour in the beginning of October; but by the middle of November, it is now less than 1 kilometre per hour. So, now there is no wind to take the pollutants away and, in these conditions, we observe a phenomenon that is known as temperature inversion.

Temperature inversion. Now, what does that mean? In normal circumstances, the air near the ground is hotter than the air that is upwards; that is, as we move from the ground level to higher altitudes, the temperature goes on decreasing. Now, that is the normal temperature profile that we observe.

That is, if we look at a vertical profile if this is the ground level. So, here the temperature is high and at a location that is upwards, the temperature is low. Now, this has a very important role in our normal climatic functions because at higher temperatures the air is less dense which means that the hot air tries to move up and when it moves up because in this case, the air above that is denser, the air below is lighter.

This air tries to move up and somewhere this air will try to go down. In normal circumstances, the air is moving from the ground to the upwards locations. But what happens in the case of temperature inversion is that we have a situation that is opposite to that.

In the normal circumstances below is hot above is cold and so, the hot air rises and takes the pollutants away. So, if we have this industry, the smoke is going up. In the case of a temperature inversion what happens is that the above air is hot and the below air is cold. Now, the cold air being denser, it does not rise and so, any pollutants that get released, they get trapped in these lower layers.

Essentially the upper layers of air which are hotter are acting as a lid on the top. Any pollutants that come up in the bottom layer, they will get entrapped here. Now, why do we have such a situation? This is happening because in the normal circumstances, the sun would have been heating up the ground. So, the sunlight is able to pass the air and when it reaches the ground, then it heats up the ground because it gets absorbed by the ground surface.

What happens is that in the normal circumstance, we have the sun and we have this ground layer and the heat of the sun is able to heat up this ground layer. So, this gets heated up. When this ground air is heated up, it means that the air that is surrounding this area is also heated up.

So, now, the temperature of air in this area is high; whereas if you look at a point above, then the

sun rays are able to cross or pass through the atmosphere, so it does not heat up the atmosphere that much. In these upper locations the temperature is low. This is a normal circumstance; the ground gets heated up heating up the air that comes in contact and the air that is on the top is colder and so, this warm air continues to rise.

In the case of temperature inversion, what happens is that in this winter months, the sun is farther from this location and so, this ground is not getting heated up that fast and so, the bottom layer is now not that heated up. The heating is now not happening. Once that happens and because you have a great amount of strong or you have clouds which are preventing the light of the or the heat of the sun to reach to the ground, what happens is that the ground does not get heated up that fast and once the ground gets cooled up and it is not getting heated because of the sun.

Now, we have a situation when the ground layer is colder. So, this area is now colder. Colder means that the surrounding air will also have a lower temperature, but the air that was there on the top is now relatively warmer. So, what is happening is that the air on the top is not getting heated up in the case of a temperature inversion.

What is happening is that the ground is not getting heated up which means that the ground is getting very cold and due to that the air that is surrounding the ground is also getting cooler. Now, in such a circumstance, we have a condition where any pollutants that are released, will get trapped here.

And if you look at the level of pollutants in Delhi in this period, this is what we see. So, on the right we have the air quality index. So, we move from good to satisfactory, to moderately polluted, to poor, to very poor, to severe and this is the air quality index some indices for these different factors of pollutants.

PM10 is particulate matter that is of a larger size. PM2.5 is particulate matter that is less than 2.5 microns and we have nitrogen dioxide and carbon monoxide. And if we look at the PM10 level, we will find that the PM10 level is this line and it is now getting very close to very high values which is entering into the severe conditions.

If you look at PM2.5 that is even larger and in certain portions of the month that is after say 7th of November, it has already reached a level that is having severe health consequences. Now, the question is why do we have these conditions; why do we see this peak; why do we see this peak? What is causing this pollution?

To understand that, we can look at different pollutants in a differential manner. Now, why is that important? This is important because different pollutants have different sources. If nitrogen oxides are going up in the air, it means that the vehicles are the primary cause of pollution. Why? Because nitrogen dioxide, nitrogen oxides get released during the process of internal combustion that is happening in the vehicles; whereas, if the sulfur dioxide levels go up, it means that the majority of pollution is happening because of the role of thermal power plants which are burning coal. Because coal has sulfur inside and so when coal is burnt, it also releases sulphur.

If you look at a vehicular exhaust, it has a very minimal amount of sulfur and so, by looking at nitrogen oxides versus sulfur oxides, we can make a correlation whether vehicles are more important in this pollution or whether the stationary sources like thermal power plants, are more important. Now we will look at each and every pollutant in a differential manner.

The first pollutant that we are observing is ammonia. Now, this curve is showing the amount of ammonia or the concentration of ammonia with reference to the percentage of October beginning. So, if in the beginning of October, we assume that the percentage is 100 percent, how does it shift throughout these months of October and November. It moves from close to 100 percent and it is roughly stable till around 20 October; but after that, it starts to increase and then, it reaches to a maximum at around say 7th or 8th of November.

What releases ammonia? If you look at the sources of ammonia, we will find that the major sources enable manure followed by mineral fertilizers; especially, the nitrogenous fertilizers, followed by this one 13 is biomass burning, followed by things like crops and their decomposition, human waste, soils under natural vegetation.

The common thing that you will notice here is that ammonia is released from biological sources like animal manure, burning of crops, burning of residues, human waste. So, all of these are organic substances. And if you look at animal manure, now there will hardly be a change in the amount of animal manure that is being generated in different months because it is not that in the months of October and November.

We get animals from different areas that come to Delhi and so, the amount of animal manure goes up. That is not the situation. Similarly, if we look at mineral fertilizers. So, yes, some amount of fertilizers are added; but then if we look at this time, this is the the time around Diwali and around Diwali, there are no new crops that are being sown. So, fertilizer application can also not be a reason. Why? This ammonia is being generated in a large amount.

Soils under natural vegetation or human based, or crops and their decomposition, are again not very important sources. They are important sources, but they are not that important because there will not be a major change in these factors in the months of October and November as compared to in the other seasons.

Now, of course, because we are having a condition of temperature inversion, so any ammonia that is released into the air that gets trapped and so, it will play a role in increasing the concentrations. But then, one important factor here is biomass burning, which is shown here in pink and where do we get biomass burning?

Well, this is a satellite image that is telling us where we were observing signs of burning or fire signatures on 15 of October. Now, here we can observe that in major parts of Punjab, Haryana and Western Uttar Pradesh, we are seeing a very large fire signature. Now, this is because in those areas people, once they have harvested the crops, and most of the harvesting has been done through machines these days, so, whatever stubble remains, that is burnt in preparation for the next agricultural season. Now, the question is why would somebody burn these stubbles? In earlier days, what people used to do is that they would bring the animals onto the field; animals especially goats, goats and sheep they used to be brought into the fields and they used to eat up all the stubble and the manure that they used to release that, also used to act as a fertilizer for the next crop.

But that was being done when the fertilizers were or the chemical fertilizers were not available or they were very expensive. These days because of advances in technology, advances in industrial production, we have reduced the cost of fertilizers, especially things like urea and so, now, it is

much more cost efficient to just purchase the fertilizers and put them into the field.
Now the goats and the sheeps are not used to that large an extent. At the same time, when in the early days people used to harvest their crops, they used to do it with sickles and when the crops are cut using sickle, the amount of stubble that is generated is very small; but with harvesters, the amount of stubble is also very large.
In a field that has a very small size of stubble, something like this, it is difficult to burn the speed because the fire will not spread from point A to point B. But what is happening now is that with the harvesters the size of the stubble is very large and so, if the farmer puts this portion on fire, the fire is very easily able to reach the other areas of the field.
And so, now, it is much cheaper, much more effective to just burn the field and this is what we are observing in these satellite fire signatures. In these areas of Punjab, Haryana, in Western UP, we see a major fire signature that has not been seen in the other areas. Primarily, because in the other areas, our agriculture is not that mechanized; people are not using harvesters to that large in extent and so, it is much cheaper to just cut these stubble and use them as heat in the other areas and this fire signature continues.
This is 15th of October, this is 25th of October here again Punjab, Haryana and Western Uttar Pradesh, you see a major fire in these areas. In other areas as well, we are now starting to see the fire signatures as more and more agriculture is getting mechanized. But even today, primarily, it is Punjab and Haryana in Western Uttar Pradesh, where this crop field burning is happening.
This is 4th of November, again Punjab and Haryana are burning; this is 10 of November. Now, in all this period, the majority of the wind is coming from the North-Western direction, which means that if Punjab and Haryana are burning and we are getting winds in this direction, it shows that all of this smoke can reach our capital of Delhi.
So, we have observed two things; one is that the ammonia level is going up which is telling us that there could be biomass burning. We are observing biomass burning in the satellite imagery and the one conditions are such and especially in the beginning of October, that they are able to bring this smoke to Delhi.
Now, the wind direction is from the North-West to the South-East, but the wind speed is very low, which means that the wind will bring this pollutant or all this smoke; but it is not a fast enough wind to carry this away to larger areas. It is now getting accumulated and because of temperature inversion, there is also no chance of this pollutant getting higher up into the atmosphere and getting lost and so, it gets on accumulating in the air. So, this is one reason.
Let us now look at another pollutant; nitrogen dioxide. Now, this is again the percentage of October beginning. So, it goes on increasing. Now, if we look at sources of nitrogen dioxide, we will find that the majority is the mobile sources and these mobile sources are the vehicles.
What happens in the case of petrol or diesel vehicles is that we have internal combustion engines in which petrol and diesel are burnt at very high temperatures. Why do they play a role? Well, our air is more than 70 percent nitrogen and at very high temperatures that are there inside these internal combustion engines, this nitrogen can react with oxygen and give out nitrogen oxides.
That higher temperature is not there in most of the other fire sources and so, our kitchen fires or normal fires will not generate that much amount of nitrogen oxides as will be generated by these

internal combustion engines and so, the mobile sources are the largest sources of nitrogen oxides. In this period from October to November, it is not that the number of vehicles are going up every year; it is not that we are bringing vehicles from other areas into Delhi so that we can have more of nitrogen oxides. But what is happening is that because of the temperature inversion, any amount of nitrogen oxides that are given out by these vehicles, they will remain trapped in the Delhi air and so even though the numbers are not increasing, but because the nitrogen oxides are not getting out. So, the concentration increases. So, vehicles also play a role.

Next, let us have a look at sulphur dioxide. Now, here again sulphur dioxide goes on increasing. We see a very sharp increase around the 21st of October and after that, it goes down, but then it remains high. If you look at the sources of sulphur dioxide, the largest sources are electricity generation and industry and if you look at the mobile sources, they are very small sources.

This is because when coal is burnt for electricity generation in thermal power plants, the sulphur that is there present in the coal, that also gets burnt and becomes sulfur dioxide. Also, in a number of chemical reactions that occur in industrial processes sulfur dioxide is released.

But then, the amount of sulfur that we have in petrol or diesel is already very low and so, vehicles do not form a major chunk of the release of sulphur dioxide in the atmosphere. So, these are the major sources. Now, what we are observing with this is that the electricity generation or the industries in Delhi and surrounding areas are also playing a role in the Delhi smog. But then, how do we explain this huge rise around the 20th?

Well, this is because we had the festival of Diwali here. During the festival of Diwali, people burn crackers, people burn fireworks and sulfur is a very important component of the explosives that are used in these crackers. When these crackers are burnt sulphur oxides get released and this is one explanation that can tell us why during this period, we saw this heavy rise in the concentration of sulfur dioxide and once this concentration has increased, then it remains high for the rest of the period, which means that the cracker burden is also playing a role.

So, different components are playing a role. We saw the role of biomass burning, we saw the role of automobiles, we saw the role of industries, we saw the role of the crackers. If you look at other substances like carbon monoxide. So, the concentration increases, it roughly doubles from the beginning of October.

Now, here again, it is not that more and more of incomplete combustion is happening in this period. But what is actually happening is that because of temperature inversion, the carbon monoxide that has been generated is not able to move out. But this is also telling us that a lot of incomplete combustion is happening and quite a lot of incomplete combustion also happens when the municipal wastes are burned.

If there is a fall of leaves and if people just burn that, then that would also release a lot of these chemicals that would release ammonia, that will release carbon monoxide. And when we look at all of these chemicals together, then we also have a lot of reactions that are happening that is when we have ammonia that is high and when we have sulphur dioxide that is high, we can have the formation of ammonium sulphate in the atmosphere or in the air.

Now, this ammonium sulphate will be in the form of a particle and this is what we are observing here, that the concentration of PM10 and PM2.5 is going up. This is because of a large number

of photo reactions that happen when you have these huge concentrations of pollutants in the air. So, because of these chemicals, these chemical reactions, we have the formation of a large number of particles.

Many of these particles are also getting released into the atmosphere because of things like construction activities. So, whenever there is a construction activity, there will be a lot of dust that gets released; a lot of dust also comes up in the form of the smoked particles in the vehicles or whenever uh the waste is burnt or a lot of it is also coming from the agricultural waste that people in Punjab and Haryana are burning and the wind is bringing them on today.

So, what we are observing is that there is not one source of the pollution in Delhi or the smog in Delhi, there are a large number of sources and these sources include primarily the changed weather conditions. Because of temperature inversion, the pollutants get trapped; they have nowhere else to go and so, if people were more sensitive, they would try to stop any release of pollutants whatsoever in these months because in these months, if any pollutant is released, it will not go anywhere away.

If you just remain there indeed. So, if you want to bring these pollutants down, you will have to act on all of these sources. We cannot just say that yes vehicles are the culprit, so vehicles should be banned or that only the agricultural waste burning is a culprit, so that should be banned or that industries are a culprit and industries should be banned.

No, this is a cumulative effect of all of these different sources that are acting together and so, everything needs to be done in moderation. All sources of pollution have to be brought down because the weather conditions are such that the pollutants will not go away. But then, a large fraction is also being generated by the agricultural waste, the thermal power plants in industries and the automobiles. So, they will also have to be toned down.

To sum up, there are certain environmental disasters that are easy to explain because they are the result of the greed or the procrastination of a few actors such as the Love Canal tragedy. If the Hooker Chemical Corporation had treated the waste before dumping, this disaster would not have happened.

If the Hooker waste corporation had decided that before giving up this land to the Education Board or for the construction of buildings nearby, they would have treated the waste; then, this disaster would not have happened. If the people who bought this land, the Board of Education, had looked into the agreement that they were signing and had taken action, this disaster would not have happened.

But in this case the consequences were faced by so many people who lost their homes, who had to suffer from bad health. Now, in certain other environmental disasters such as the Delhi smog, there are routes of a large number of factors from weather to things like agricultural waste burning, to vehicles, to electricity generation, industries and so on.

In such disasters that are a result of a large number of players that are all contributing to the disaster, it becomes more of a social responsibility together with an individual responsibility to curtail these sources of pollution. Because after all, whenever we release these pollutants into the air, it is we ourselves, and our children and our grandchildren that will have to suffer the consequences and so, it is in our own interest to become more environmentally friendly,

environmentally conscious.
That is all for today. Thank you for your attention. Jai Hind!