

Conservation Economics
Dr. Ankur Awadhiya, IFS
Indian Forest Service
Department of Biotechnology and Bioengineering
Indian Institute of Technology, Kanpur

Module 12
Case studies
Lecture 1
Economics of Protected Areas

Namaste! Today, we begin with the 12th module which is case studies. This module will have 3 lectures Economics of Protected Areas, economics of environmental disasters part I and part II. Let us begin with the economics of protected areas.

Protected areas are defined under section 24 A of the wildlife protection act 1972. Protected areas means, a national park, a sanctuary, a conservation reserve or a community reserve notified under sections 18, 35, 36A and 36C of the Act. So, the protected area is a national park, a sanctuary, a conservation reserve or a community reserve.

And we have a number of wildlife that are found in the protected areas. What is wildlife? Wildlife is defined in the Wildlife Protection Act 1972 as: wildlife includes any animal, aquatic or land vegetation which forms part of any habitat. What we are saying here, is that if you have any animal or any plant that forms part of any habitat then we will say that it's a wildlife.

And the dictionary definition of wildlife is: wild animals collectively or the native fauna and sometimes flora of a region, which means that it is saying that the native fauna which is the native animals and the native flora which is the native plants. So, those animals and those plants that are found natively or which are indigenous to an area, if we look at a collection of those we will call it wildlife.

Wildlife are divided into these nine threat categories by the international union for the conservation of nature and natural resources. So, we have a red list of different organisms which tells us what the level of threat is. For certain organisms whether plants or animals the level of threat is so large that if we do not protect those animals and plants, then in a short while it is very likely that these plants and animals will become extinct.

On the other hand there are certain plants and animals that are not that threatening so, in that case we may not protect them to such a high extent. Or let us say that it is not an urgency to protect them right away. So, these threat categories are extinct. If an organism is extinct it means that there is nothing much that you can do about it. This organism just does not exist anymore.

Things such as the dinosaurs or the dodo bird are currently extinct, they are no longer found in this world. Certain other organisms are extinct in the wild, which means that we may have a few specimens of these organisms in a zoo, but if you look out in the wild conditions, we do not have any of these organisms left. Then we have critically endangered organisms, endangered vulnera-

ble, near threatened and least concerned.

An organism that is in the least concern such as the common dog or the cow, we do not need to provide them with the level of protection that is urgently required for say a critically endangered species such as the tiger. Then for a number of organisms we do not have the data.

We categorize them as data deficient. And, then we also have certain organisms that have not yet been evaluated and we call them not evaluated. So, there are several species that are in need of conservation, and the higher a species is on this list the more is the amount of conservation that it urgently needs.

This list gives us an idea of how we prioritize things. You will remember it is a principle of economics that there are tradeoffs involved in a number of things, well we would ideally want to conserve each and every of these organisms, but then our time is limited and our resources are limited. If we have to spend our time and resources, we should prioritize those species that require a greater amount of conservation and those species for which we can actually do something.

A scientific way of looking at which species to conserve looks at whether or not they are keystone species. Now, keystone species play critical ecological roles which means that they have an importance that is much greater than their numerical abundance in an ecosystem. So, things such as off season fruit bearing trees are keystone species.

What we mean by a keystone species is that the impact that these organisms have on an ecosystem is much greater than their numerical abundance, so, if there is a forest that is completely dry, and this forest is having a scarcity of food. But, then if you have a tree that can provide food to different animals and birds, then this tree would act as a keystone species.

Because, even though you have a single tree that is providing the food, it is able to support a large variety of plants and animals and keystone species include species such as the ficus trees, banyan trees, peepal trees. So, these are those trees that provide food in the off season, and also their leaves and their branches are all edible and they are large in size. So, if you have a look at a banyan tree; a banyan tree would be supporting say hundreds of organisms from small insects to reptiles to birds.

These sorts of species are known as keystone species; another keystone species is the tiger. Because, if you have a tiger in an area then the tiger regulates the number of herbivores that are there so, the herbivore population is not able to cross a threshold. Because, if there are too many herbivores then it is possible that they will eat up all the vegetation in the area, and the whole ecosystem would collapse. Species that are keystone species need to be given a greater priority when we talk about conservation.

Other species are known as umbrella species; these are species with large home ranges. So, what happens in the case of these species is that they have such large home range requirements, that if you make it a point to conserve these species or the other species in the large home range will automatically get conserved. So, here we have species such as the elephant or again the tiger.

An Amur tiger has a home range of around 800 square kilometers, in India we have tigers that have home ranges of roughly 80 square kilometers. So, if you are conserving the tigers, for each tiger roughly 80 square kilometers of area automatically gets conserved, all the different organ-

isms that live in that 80 square kilometers are automatically afforded protection, because we are conserving the tigers or species such as the elephants.

They also have large ranges. So, the species that have very large home ranges act like an umbrella to provide protection to a large number of species, just because these umbrella species get protected. So, again they should get priority when we are talking about conservation.

And the third is flagship species. Flagship species are well known charismatic species that have captured the public's heart and won their support and funds for conservation. Examples include the giant panda, the humpback whale, and the gorilla.

When we talk about flagship species these are those species that attract people. It is possible that a few of these species are beautiful species such as the peacock. So, peacocks are a flagship species because they are beautiful. People want to see peacocks or you could have species that are very majestic such as the tiger. So, a tiger becomes a flagship species because people are in awe of seeing a tiger. Or you could have species that have religious significance such as the elephants.

Now, these species that are the flagship species, they occupy a space in the hearts of people. And so, when you want to conserve these species it is easy to get funds and it is easy to get public support. So, those species that the public likes should also be given a higher priority in conservation. So, these are the flagship species.

Now, when we do conservation we try to look for those species that make all these three definitions. So, if there is a species that is a keystone species which means that it has a very large role in the ecosystem. It is an umbrella species which means that it requires a large home range, which would automatically give protection to a large number of other species. And, if it is also a flagship species which means that people want to conserve this species, they are and it is easy to get funds and public support, nothing like it.

We always look for those species that are at the conference of all three of these. A good example is the tiger. Because a tiger is a keystone species it's a flagship species and it is also an umbrella species. So, by protecting tigers or by allocating funds for the conservation of tigers, we are able to achieve a lot of our goods of conservation.

Now, in this context it is prudent to remember. Why are these species threatened, why are we doing this conservation at all, why are we setting up these protected areas? So, we had seen earlier that there are a number of factors that lead a species to extinction.

So, there are factors that act at large population sizes and there are factors that act at smaller population sizes. And, we can summarize these factors with the acronym HIPPO: habitat loss, invasive species, pollution, human overpopulation and over harvesting are the factors that have been driving species towards extinction. And, when we are talking about protected areas, they protect the animals and plants that are inside from these five things.

When we want to protect species against these factors of extinction there are two modes that are there with us. We can either take the species out from the natural environment, and give them a very high level of protection, say in a zoo.

What happens in a zoo is that you bring the animals from the natural environment, you keep them in controlled conditions, where they get sufficient amounts of food, sufficient amounts of

water and a very good veterinary care. That is one way. The other way is that you can protect these species when they are out there in their natural environment.

That brings us to two modes of conserving wildlife, we can go for an ex situ conservation, which is conservation which is off the site that is conservation outside the natural habitat. Such as in the case of zoos or aquariums, or we can have in situ conservation which is conservation on the site which means that conservation done that is within the natural habitat such as a national park.

How do these work? In the case of ex situ conservation, it is required for critically endangered species, because it provides urgent intervention so, in the case of critically endangered species. Because the numbers are so low, we need to give them a very high level of intervention and very intensive management which may not be possible in the wild conditions.

So, ex situ conservation is probably the only way out, to conserve those species that are critically endangered. So, in the case of ex situ conservation we designate areas with suitable conditions and we create facilities. So, in the case of ex situ conservation an area will be selected to make a zoo.

And, then we will create the facilities for a zoo. That is we will surround this area with say a wall, we will provide means of bringing in water means of bringing in food. We will create facilities such as a veterinarians office, say an operation theater and things like that, and once these are done the species are moved into these designated areas for their survival and breeding. And, in a number of cases we also do ex situ breeding of these animals, the captive breeding of animals.

So, what will be done is that these animals that are critically endangered, they are brought into these zoos and they are allowed to breed and when the population goes up. Then, it is also possible that we can later release them into their natural habitats. So, that is ex situ conservation.

It has a number of advantages, it allows better control of variables such as climate, diseases, diet and so on. Because it is a small area the intervention is much more intensive and so, it is much easier to provide them with standardized conditions. It provides opportunity for close observation to better understand the species and the proximate causes of its extinction. So, it provides us with an opportunity to understand the behavior of animals.

Suppose in a zoo environment you get to know that this animal avoids breeding, if it is exposed to too much sunlight. Then, probably when we release these animals back into the natural environment, we will make sure that we release them into an area that has a very good canopy cover. Such kinds of observations are extremely indispensable, when we want to conserve the organisms. And, then they also permit intensive interventions such as in vitro fertilization, embryo transfer and so on. So, we can provide all sorts of modern scientific advancements and medicines to these organisms.

However, it also has certain disadvantages, because we are taking the animal out of its natural habitat and we are conserving those few animals, but in this process we are not conserving the habitat. It is possible that you remove all of the critically endangered species individuals from the natural environment, bring them to a zoo, do a captive breeding, but in the meantime their natural habitat gets destroyed completely.

That would defeat the purpose. So, this is one disadvantage. It can be planned for only a few

species at a time because it is very expensive. We are doing an intensive intervention. So, the costs go up and when the costs go up, then it is difficult to do it for a very large number of species or a very large number of individuals.

Some wild behaviours may get lost because we are not keeping the organisms in a wild setting and so, it is possible that while a few of these organisms are able to survive and breed. But, they will lose out on their natural behaviours like, where to look for food or how to hunt. So, this is another disadvantage: captive bred and raised individuals may then find it difficult when they are reintroduced.

Because they are now completely dependent on human intervention, they do not know how to hunt for food. In that case once you try to release them back into the environment it is possible that they will just not be able to cope with the conditions. Then, it may increase the chances of inbreeding if it is not planned properly, if the spread books are not maintained properly, it is possible that brothers and sisters or parents and offspring might breed with one another.

In that case the number of recessive disorders will go up and then finally, it is also costly. Now, throughout this course we have observed that price or cost act as very good indicators about different activities. So, if it is costly and money is one input that you are able to provide, then you will have to also look at the trade off. Can this money be better spent in protecting the habitat than in setting up a zoo.

So, these kinds of questions need to be answered. Examples of ex situ conservation include zoos, aquaria, captive breeding facilities, botanical gardens, bambusetas, arboreta, seed banks cryopreservation facilities, such as tissue culture sperm bank ova banks and so on.

In all of these what we are doing is that we are taking the organism, or its body parts away from the natural setting. And keeping them in a very scientifically managed facility provides a very intensive intervention, with the hope that probably some day in the future, we will be able to release them back into the environment once the numbers have gone.

So, this is ex situ conservation the other mode of conservation is in situ conservation which is conservation on the site. In this, areas in the natural habitat are designated as reserves, national parks or protected areas. And, in these ecological monitoring and interventions, such as active management are done and legislations are required to maintain these areas after test protected areas.

What we do in the case of in situ conservation is that first of all, we designate a place as an in situ conservation facility, such as a national park or a wildlife sanctuary or any other modes of protected areas. Now, different countries may be using different terms, but you get the idea. So, the first step is to use legislation to designate an area as a protected area, or as an in situ conservation area.

Once we have done this designation, then laws will be used to ensure that people do not enter into this area or to regulate the movement of people into this area. And, also we do active interventions: that is active management such as control of forest fires or control of invasive species or provisioning of water. So, all different kinds of active management are also done in these areas.

It provides several distinctive advantages the species continue to live, in their natural environ-

ment which means that the natural behaviours are maintained in these areas. Then, this is less disruptive and more importantly it is less costly, because the only cost that is involved is doing a legislation, to designate these areas as protected areas.

And probably do a bit of protection, a bit of habitat planning, we do not have to set up facilities such as veterinarians office or an ot or cages for individual organisms, you do not have to bring in food from outside to feed these organisms and so on. So, it is much less costly as compared to an ex situ conservation facility.

Then, protection of the natural habitat provides protection to other species as well. So, if you are trying to conserve tigers by creating a tiger reserve, then not only is the tiger protected. But, the other species that live in the forest also get protection automatically. Whereas, if you are trying to conserve tigers using ex situ conservation facilities, you would have brought the tiger outside, you would have conserved the tiger, but when its habitat gets destroyed then the other species will also be in peril.

And so, a distinctive advantage of in situ conservation is that it provides protection to other species as well. Then, even in the case of ex situ conservation the animal will need to be released somewhere in some point of time. Once you have done the captive breeding in the case of ex situ conservation you have now a large number of animals. So, they will have to be released back into the environment.

If you only did ex situ conservation you only maintained these individuals in the zoos, and their natural habitats got destroyed in that case where would you release these organisms. So, in situ conservation is also important together with ex situ conservation, because it keeps certain portions of the habitats of these organisms intact so that you can release them there later on. These provide suitable areas for such releases and they also double as places for scientific studies and public awareness and things such as tourism.

The disadvantages include requirement of very large areas, because in the case of in situ conservation, what we are doing is that we are designating very large areas as protected areas. So, the area requirement or the land size requirement is much greater. In the case of ex situ conservation such as a zoo, you can keep animals at a much greater density.

But, in the case of in situ conservation such as a tiger reserve or say a national park you will have to keep these animals, in the natural settings in which case it will require a much greater area. There is less intensive protection and management, because the areas may be encroached upon or the animals needed poached. Why? Because these areas are so large that it is not possible for you to man all of this area at all times. So, it is possible that a poacher might get into a national park and kill a few of your animals.

Which is very difficult in the case of an ex situ conservation facility, because we have erected huge walls. And, also because in the case of an intensive intervention, it is very easy to keep an eye on each and every animal, probably you could even make use of CCTV cameras. But, in the case of in situ conservation this becomes difficult because the area is so huge. Then, there are always the threats of diseases and disasters, because it is a large area you are not able to manage everything at all points of time.

And, a large establishment is required in each case; establishment in terms of people who are go-

ing to man the area establishment in terms of vehicles, because these are large areas. So, you have to go to two different areas to observe these animals to protect these animals. In that case you might even require say forest rest houses in certain locations. A large amount of establishment may also be required in the case of in situ conservation.

Now, when we say that we are going to do an in situ conservation, there are certain traditional ways of creating the protected areas. How did the kings of the bygone eras used to make a protected area? One option was to look for beautiful areas. So, if an area is a beautiful area the king would say ok, these are such beautiful areas let us make them into a national park. Lush green mountains, lakes, beaches - they used to be converted into protected areas for the enjoyment of the king.

In certain cases certain high species diversity areas used to be converted into protected areas, such as the silent valley national park in Kerala or in certain cases those areas that harbor unique animals endemic organisms that are found nowhere else would be converted into protected areas. Such as the Gir National Park in Gujarat that is the only home of Asiatic lions in India. But, in a number of cases these become a bit too haphazard and based on the whims and fancies of the reserve creator.

So, with time we have shifted from these traditional ways of creating protected areas, to the scientific ways of creating predicted areas. In the scientific way we look for those areas that are high in species richness, species endemism and that have a moderate level of threat to the species.

What is species richness? Species richness refers to those areas where you have more number of species per unit area. So, if we look at say things like global mammalian richness. There are certain areas that have a large number of species per unit area and there are certain areas that have a smaller number of species per unit area.

So, we can look at global mammalian richness, or we can look at amphibian richness, then we can also look at the number of species that are under threat. So, there are certain areas such as in Southeast Asia that have a much greater level of threat than say an area in North America. Then, we can also have a look at different categories of species such as the number of amphibian species in death threat.

What we do is that we look for those areas that have high species richness, which means these areas have a large number of organisms. And, if you create a protected area in one of these locations, then we will be able to afford protection to a very large number of species. Because these are the areas with high species richness, we look for those areas that have a high degree of endemism. So, if an organism is only found in one area, you will have to provide protection in that area.

Because, if you do not do that, that species will become extinct very soon and we look at those areas that have a high degree of threat, or at least a moderate degree of threat. Because, if we have an area that does not have any threat, say an island that nobody ever goes to. So, in that case, because our time, money and resources are limited, then it is much more prudent to make a protected area probably in a threatened region than this Island.

Because, even if you did not convert this Island into a protected area, the species would have re-

maintained fine there would not have been any difference or there is no impact of making a protected area in such a location. So, we look for these three criteria and those areas, which have all these three high degrees of richness, endemism and threat we call them as biodiversity hotspots. These are the biodiversity hotspots in the world and in our country areas such as the Western Ghats are a biodiversity hotspot. Because we have a very large number of species that live in these areas, there is a very good amount of species richness. We have a number of species that are only found in the Western Ghats such as a number of the amphibian species. So, there is a very great amount of species endemism.

And the Western Ghats are also threatened because people want to cut these forests and convert them into certain other uses. In that case these areas also have a high degree of threat. So, these areas that are the biodiversity hotspots, they need to be afforded greater amounts of protection.

And, in this case we should also have a look at the threat triage that we have. So, if there is an area that has a very high degree of threat, then probably it is already a lost cause. Because by that time you would be able to convert this area into a protected area, maybe set up mechanisms for the protection of this area, set up mechanisms to do habitat management, by that time, because of the high level of threat probably, it would already been taken over on the other hand if you have a location that has a very low degree of threat. There too it does not make any difference whether you make a protected area or not. Because, the animals or the organisms in this area would remain fine, whether you make a protected area or not there is absolutely no threat in those areas.

So, the areas which have a very high degree of threat or the areas which have a very low degree of threat, they are not that preferred. But, those areas that have a medium degree of threat are more preferred because, in those cases we will be able to put in a much greater impact by converting those areas into protected areas.

So, we need to keep in mind that threat triage is built and we should also keep in mind the gap analysis. The gap analysis approach tries to identify holes in the existing network of protected areas, that are primarily in locations that are or were historically uninhabitable for humans due to their heights, prevalence of diseases, or other reasons.

And creating some protected areas in human dominated areas may fill the gap allowing a different set of species to thrive. Now, what we are saying here is that in the case of the existing network of protected areas, people normally went for those areas traditionally that were not of much use.

So, you would hardly find a protected area in or near a town or a city, you would only find protected areas in those mountains that were very difficult to reach or those areas that were infested with mosquitoes and malaria, because of which people did not want to go to those areas. So, the rulers used to convert those areas into protected areas.

Now, because we have inherited such protected areas. So, a number of protected areas today are in those locations that are not built within reach. Whereas, those areas which were which could be dominated by humans, such as the plane areas. They were completely converted into agricultural lands. Now, gap analysis says that because we created our earlier protected areas in the mountains, we are able to protect the mountainous species, but we did not create any protected areas in the plane areas. So, if we have a chance let us at least create a few protected areas in the

planes or those locations that are human dominated. Because, once we do that we will also be able to provide protection to the species that live in plane areas or those areas that have become human dominated.

So, that is gap analysis. You take a map, mark out all the protected areas and look for the gaps, and those gaps are the areas where you should be making them protected areas, that is the gap analysis and whenever we are making a protected area. Whenever we have the chance to make a protected area, there are certain principles of reserve design that should be kept in mind. Whenever, we are making a protected area go for a larger size. So, big is better than small.

Why because a bigger size means more number of habitats, which means a higher species diversity that you will be able to afford protection too. If you make a very small protected area, then you will be able to provide protection to less number of species and less number of habitats. But, if you are able to construct a large size reserve, then you will be able to provide protection to a large number of species that live in the diverse habitats that you have converted into the protected area.

Second thing is that they are more secure and easier to manage per unit area. Why are they more secure? Because, in larger areas we have larger populations, if you have larger populations then they are less susceptible to extinction. Because, you will only have those factors of extinction working there that work at the larger population sizes, but the factors of extinction that work at smaller scales the stochastic factors will not work in these larger areas.

So, the populations are inherently more secure from extinction, then in the protected areas you need to protect the perimeter. Because, the perimeter is where people can get into whereas, the species get protected in the area. Now, as you increase the size of a protected area the ratio of perimeter to the area of of this reserve, it reduces which means that it becomes much more cost effective to provide protection to this reserve.

So, the larger the size of the reserve it has the smaller perimeter per unit area, which makes protection more cost effective. Then, these are also less vulnerable to catastrophes, because smaller catastrophes will not impact the whole area.

Another principle is that one big is better than several small of the same total area, which means that if you have an option of making one big reserve, or four smaller reserves, or five smaller reserves, and the total area is the same in both the cases you should probably go for the largest sized one not a number of smaller ones. Why?

Because, these smaller ones will not be able to support those species with large home ranges. So, they will be only able to support those species that have smaller home ranges. Whereas, this large area will be able to support those species that have smaller home ranges, but also those species that have larger home ranges. So, one big is better than several small of the same total area.

But, then if you cannot make one big one if you only have the option of smaller ones, then go for those smaller reserves that are close together. Because they minimize the isolation, what happens is if you have these reserves that are close by the animals may go from one area to the next area.

And in that case it may be able to support at least some of those species that have higher home ranges. So, closer species minimize isolation. So, they should be preferred; those reserves that

are very far from each other should be less preferred.

Then, you should go for a cluster approach, if the species are together in the form of a cluster it is more preferred than a linear arrangement. Because, in the case of a clustered approach the species from this reserve can go to this reserve, and it can also go to this reserve, the species in this reserve can go to this reserve, but also to this reserve.

So, the amount of movements increases whereas, if you have the results that are lined up in a linear fashion, then the organism says this reserve can only go to this reserve. So, the movements are more restrictive in a linear fashion. And, if possible go for a circular looking reserve, because circular reserves have less biotic pressure which means that the influence of humans that are there in the periphery say if it reaches to this distance. So, at least this area in the center will be protected. So, the core area of the reserve will be protected.

Whereas, if you have a reserve that is linear in structure, in that case the influence of the humans in this place will probably go to more than half the area of this reserve. And, in that case everywhere you will find an influence of humans and so, the level of protection in a linear reserve will be much lesser.

But, then we also have a number of linear reserves and we have already observed that in the case of the Mudumalai Tiger Reserve, if you make a 10 kilometer buffer from the habitations, you will find that the whole of the reserve is completely covered with these buffer areas. So, the circular reserves need to be promoted more than linear reserves such as these.

And if nothing else happens at least maintain the connections, because through these connections we can ensure that the organisms have free movement. And, in that case some species that have larger home range requirements, they will still get some level of protection.

But, if we have these reserves in the form of Islands what will happen is that in the absence of movement, we will find a large amount of inbreeding in each of these different reserves. And once that happens the level of protection goes down.

Now, we routinely make use of these approaches whenever we are making new protected areas. So, for instance in the state of Madhya Pradesh when we were looking for new sanctuaries we looked at biodiversity intactness. Now, the biodiversity intactness index tells us the level of biodiversity that remains in different areas.

So, if you look at this map, these sections that are darker in color have more biodiversity, these areas that have a lighter color have actually lost their biodiversity over several years. Whenever we are making a protected area we should ensure that there is a high level of species richness or biodiversity. So, these areas which are dark in color need to be selected.

Then, through a gap analysis we can look at those areas where you already have the reserves. And make results in those areas that are away from these and when we try to maintain the connections what we do is that suppose you consider this reserve and this reserve. So, here you have the Madhav National Park and here you have the Panna Tiger Reserve.

Now, we know that tigers take this route when they go from Madhav to Panna and in that case if you make a reserve here in the center. Then, probably it will be much more effective than, say, creating a reserve here, where the animals do not move. So, in this case we are making use of gap analysis, we are making use of gap analysis to understand where we should be making these

reserves.

So, we try to maintain the connections. We try to enhance the connection and we try to do it in a way where we can get the larger size areas and in those locations where we do not have the sanctuaries, but we do have transit paths of animals. Now, in the case of Madhya Pradesh, the tiger is the most important animal in terms of conservation, because it is a keystone, flagship as well as umbrella species. And so, when we are focusing on tigers, we should look at the routes that the tiger takes when it moves from one location to another location. So, this is what was done to identify the locations where we can have newer sanctuaries.

Now, once we have looked at what a protected area is, how do we make a protected area and what is the importance of a protected area. Let us now have a look at the economic analysis of protected areas. When we make a protected area what is the benefit that we can provide to people so which brings us to the ecosystem services from protected areas. Now, ecosystem services are the services that are provided by a well functioning ecosystem in these protected areas.

Ecosystem services are defined as the benefits that people obtain from ecosystems, again a cost benefit approach. If you want to make a protected area you will have to convince people that it is going to be of benefit to the people. So, we have to do a computation of the benefits that we can provide to people whenever we are making a protected area. So, this is bringing us to the culmination of conservation economics and you can get an idea of how to do conservation.

It is important to make use of economics to tell people that this project is going to be economically beneficial to the people. Especially because we are living in a democracy, so it is very important to convince the politicians and the policy makers if you want to do conservation. And, if you do good conservation you are going to provide benefits to the people of your state or your country. This is why a study of ecosystem services becomes very important.

Now, ecosystem services are divided into provisioning services in which case the ecosystem provides something in the form of materials, such as food or medicines. So, if you have a well functioning ecosystem, you can get hold of certain medicinal plants or you can get hold of certain amounts of food from this area. So, this is known as a provisioning service.

Now, this provisioning does not just mean that you should allow people to get into the protected area and approve these medicinal plants. But what it is saying is that if you maintain your area as a protected area, then a number of these species will also come out in the form of say seeds and through which you will be able to get these resources for the people who are living in the vicinity. So, provisioning services include things like food and medicines.

We also have several regulating services such as the regulation of local climate, the biological control of pest populations and so on. So, it has been seen that in areas that are close to the protected areas the level of insect infestation is much lesser, because the protected areas harbor a large number and variety of birds. There will also be a large number of insectivorous birds, and these birds will provide protection to the farmlands that are near the protected area.

So, this is an example of a biological control over the pest. The farmers that live in the vicinity do not have to spend that much amount of money on purchasing insecticides. So, this is a regulating service another regulating service is the regulation of the local climate or the microclimate. So, the areas that are close to the protected areas have a more amiable climate, it does not be-

come that hot in summers it does not become that cold in winters. So, that is a regulating service in the form of climate regulation.

Then, these ecosystems also provide supporting services in the form of soil formation and nutrient cycling; they also provide several cultural services, such as recreation, educational uses and religious uses. So, these are different services that a well functioning ecosystem provides to people. We have provisioning services, regulating services, supporting services and cultural services.

And to do a valuation of these services we can make use of economic models. Now, if you remember, a model is a simplified depiction of reality, but the best thing about a model is that it allows us to do computations in a simplified manner. One such model is the InVEST model, investors integrated valuation of ecosystem services and tradeoffs an integrated valuation.

So, you are incorporating a number of variables to do an integrated valuation; valuation of ecosystem services and also of the tradeoffs that you need to make, tradeoff in terms of say if you have 100 rupees. If you spend these hundred rupees into the functioning of a protected area do you get say 105 rupees out of it or do you lose 5 rupees and you only get 95 rupees in return.

That is a tradeoff. You have certain amounts of funds every government has certain amounts of funds. And, if the government uses them in construction or maintenance of a protected area, then probably those points cannot be used in other locations, say for health care or for education sector, or for setting up of a new industry or for laying of new roads.

So, there is always a tradeoff. The InVEST model helps us to understand that if we are putting 100 rupees into the functioning of the ecosystem services. Because of making a protected area or protecting a protected area, what is the return that we get out of it. So, that is something that this model also tells us. So, this is a GIS based suite. GIS is geographical information system.

So, in the case of GIS we make use of the information about where different things are located, where the water sources are located, are they located close to the villages or are they located in the interior of the protected areas, which would mean that they are far away from the villages. So, these are the kinds of information that we make use of: where does the river flow, where are the hills, where are the mountains, where are the planes.

And, we make use of all such information because we are using the geographical information. So, this is a GIS based suite of open source software models for mapping and doing valuation of ecosystem services. It performs computations using spatially explicit data and models. So, the data and the models that we use are also based on where different things are located, they are spatially explicit.

And, the final results can be in the form of biophysical information such as the tonnes of carbon that were sequestered, or we can get the results in the form of economic information that is what is the value of that amount of sequestered carbon. So, you can ask this model to give you a result of that; that so much amount of tonnes of carbon dioxide were sequestered by this protected area in this year, or it can give you what is the market value of that amount of sequestered carbon. Similarly in the case of water resources, similarly in the case of other services such as the provisioning or the supporting services.

So, let us now have a look at what kinds of services we model here? The first thing or the first

ecosystem service that the protected area gives you is employment generation. Because, there will be a large number of gypsy drivers that get employment, there will be a large number of guides that get employment, there will be portals that are set up because tourists are coming to this area.

Now, when the tourists come they will require a number of services, and all of these provide employment to people. Now, what is the amount of employment that the protection that the protected area generates? Is, given as the sum of the number of man days into the wage rate. So, how many man days of employment were generated, what was the rate at which these people got paid?

So, we do a multiplication of both of these and you sum them up for all the people who are getting employment, because of the protected area. So, this is giving us a value of the employment generation. Fishing benefits; which is the sum of production into the market prices. Now, in some protected areas we do permit fishing, especially in the buffer areas.

If there is a buffer area and it is getting water from the protected area or it is a part of the protected area, and it is also getting benefited or protected, because of the activities in the protected areas, what is the amount of fish caught and what is the market price of that fish. So, when you do a sum over the production into market prices you get the fishing benefits. We compute the fuel wood benefits again production into market prices, fodder benefits, production into market prices.

So, we are doing all these different kinds of valuations. Timber benefits: how much is the amount of timber that can be extracted especially in the buffer areas. Where do we permit extraction? We do production into market prices. Bamboo benefits: production into market prices. Non timber forest produce: this includes things such as honey, lac, medicinal plants and so on.

So, in the case of non timber forest produce, you also have a market for honey, you have a market for lac, you have a market for the medicinal plants that you get out of the forest. So, here again we can do production into market prices the sum of all the NTFPs that you are getting in this area.

Gene pool benefits such as the resilience of ecosystems and avenues for future use of biological compounds, or other products computed using the benefit transfer method. Now, what we are saying here is that if you conserve an area as a protected area, you are making the ecosystems more resilient.

Which means that if there is a release of pollutants into this area your ecosystem will not collapse that easily, then an ecosystem that was not given this protection. Because, as we had seen in the case of large infrequent disturbances, if a biological community is already disturbed or is already half disturbed and you give it a single disturbance and it will collapse.

But, when you are maintaining a system as a protected area you maintain the organisms in this ecosystem in the best possible state. And so, they are much more resilient to any impacts or any disturbances such as say, because of the release of pollutants or because of an oil spill or because of a forest fire. So, we get genepool benefits in terms of resilience of ecosystems.

You also have avenues for future use of biological compounds and their products, which means that if we have a new disease that comes up. Then, we will have to look for medicines; we will

have to look for those compounds that can help us fight those diseases. Now, a number of plants and animals have certain compounds that are known as metabolic compounds.

Now, these compounds can play a role in protecting us against diseases, a good example is the quinine that we get from the bark of cinchona trees. Now, quinine is something that the plant manufactures not because it is an anti malarial, but because it provides a certain degree of protection to the plant, other animals do not eat that plant insects are less able to invade into this plant. But, then because this plant produces quinine and if humans get malaria, they can make use of this bark to extract quinine to work as an antimalarial drug.

And a number of medicines such as artemisinin are also derived from different plant products. Now, if we have a large amount of biodiversity, there is a greater chance that we will have access to one or more of such compounds in the future when we need them. So, these are genepool benefits: the benefits that you are getting, because you are maintaining a good genepool and a good biodiversity.

Now, these kinds of benefits are computed using benefits transfer method, which is a method to estimate the economic values for ecosystem services, by transferring available information from studies already completed in another location and or context. What this means is that suppose in a protected area in some other country or in some other part of your country calculation has been made; to make evaluation of the kinds of benefits that we get to make an economic evaluation of the benefits that we get, we can make use of such studies to incorporate the results of the analysis that was done there into our protected area. That is known as a benefits transfer method. We can compute the valuation of these genepool benefits using the benefits transfer method. You do not have to do a valuation at each and every protected area, but in certain protected areas you can do a more intensive valuation and you can make use of those results in your protected area of study. Then, we can find out carbon sequestration benefits which is the amount of carbon that has been sequestered multiplied by the market prices, or we can even make use of the social cost of sequestering this carbon.

Carbon storage benefits which is again total storage into the social cost of carbon. What is the social cost? The cost of impacts that is caused by the emission of carbon dioxide. So, what we are asking is if we did not sequester this amount of carbon, if we did not store this amount of carbon then this carbon would have been released into the environment. It would happen there in the atmosphere, it would have played a role in global warming and in climate change.

Now, because of climate change, because of global warming, there are a number of extreme climatic events. We are seeing more floods, more droughts, and things like that. Now, what is the social cost, what is the cost that people are suffering, because of that amount of carbon that is there in the atmosphere? That is the social cost of carbon.

We can do carbon storage benefits as total storage of carbon multiplied by the social cost of carbon. We can look at water provisioning benefits. What is the amount of clean water? That is given by this protected area multiplied with the market prices. We can look at what are purification benefits, which is the water that is purified by a protected area multiplied by the average cost of treating water.

Or we can look at soil conservation and sediment retention benefits. The amount of erosion that

was avoided by this protected area multiplied by the cost of damage that was avoided, we can look at nutrient retention benefits.

The amount of nutrients that were retained multiplied by the cost of artificial fertilizers, that would have been required if you were not retaining these nutrients. Biological control of pests computed using benefits transfer method, moderation of extreme, events benefits, pollination benefits, nursery for various species benefits.

Habitat for various species benefits, cultural heritage benefits, recreation benefits, air quality benefits, water assimilation that is being done by the protected areas, what is the benefit because of that. What is the benefit from regulation of climate? We can use it; we can have a look at all these different ecosystem services that are being provided by the protected area and do an economic valuation of that.

Now, what sorts of results are obtained? So, if we look at the valuation of Panna Tiger Reserve, we are getting flow benefits of around rupees 70 billion in a year of which direct benefits are 0.78 billion, indirect benefits are 53 billion option benefits are 15.65 billion stock benefits, critical ecosystem services kinds of services.

So, in total what we are getting is that we are having an investment multiplier. So, we can add up all of these different benefits and then we can figure out what the investment multiplier is. Now, what is an investment multiplier? An investment multiplier asked the question that if the government, or if the public spend 1 rupee into the protected area what is the return that they get out of it.

So, suppose the government invests 1 rupee in the health care sector, then people are more healthier if they are healthier then there is an increase in the economic output. What is that level of economic output? What is the bang for the buck that we are getting and what are the benefits that we get? So, for any investment we can look at the investment multiplier. And here we are observing that the investment multiplier, in the case of Panna Tiger Reserve, is as high as 1939.36.

Now, this is especially because if you have a protected area, there are hardly any costs involved, because you only have to maintain that area's minimal level of protection and minimal level of habitat interventions. But, then nature does everything else for you. So, it is a very good investment multiplier meaning that it is a very good investment opportunity for any economy.

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

Conservation Economics
Dr. Ankur Awadhiya, IFS
Indian Forest Service
Department of Biotechnology and Bioengineering
Indian Institute of Technology, Kanpur

Module 12
Case studies
Lecture 2
Economics of Environmental Disasters - I

Namaste! We carry forward our discussion on Case Studies and in today's lecture we will have a look at the Economics of Environmental Disasters. What is a disaster? A disaster means a catastrophe, a mishap, calamity or a grave occurrence in any area, arising from natural or man made causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property and or damage to, or destruction of environment. And is of such nature and magnitude has to be beyond the coping capacity of the community of the affected area. So, what it means is that a disaster is something that is a grave occurrence in any area and it may occur because of natural causes or manmade causes.

So, we can have natural disasters or we can have manmade disasters. Good examples of natural disasters are things like floods or hurricanes or volcanic eruptions. Good examples of manmade disasters are industrial disasters. So, you can have natural disasters or man made disasters and disasters may also be caused by accident or negligence.

Now, a common property of these disasters is a substantial loss of life or human suffering or damage to and destruction of property or damage to or destruction of the environment; that is a common feature is that either human lives get lost or there is human suffering. In certain cases people might get sick; people might get injured. Even though they are not dead because of a disaster, it leads to a very huge amount of human suffering because of a disease or because of, say, an injury.

Or in certain cases, there might be a destruction of property or a destruction of the environment. And these are of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area; that is it overwhelms the resources and the coping capacity of the local community and in that case we will call it a disaster.

Now, disasters can be natural disasters such as earthquakes, landslides, tsunami, flood and so on or we can have human made disasters such as industrial accidents, oil spills, war, terrorist attacks and so on. So, there are all these different kinds of disasters. Now, in the case of the management of disasters; we have certain definitions.

The first is risk; risk is the effect of uncertainty on the objectives or a combination of the probability of an event and its consequence. So, risk is a combination of probability of an event and its consequence. Which results in an impact on this uncertainty on the objective of normal management.

When we talk about risk; we talk about what is the probability of such a disaster happening, what is the probability of a flood in your area, what is the probability of having a tsunami in your area and should there be a flood; what would be its consequence? Now, consequence would depend on whether your area is, say, up lying or low lying, how much is the given density in that area, how much are the infrastructure levels in that area, and what is the quality of infrastructure.

So, there are a lot many things that are involved. This is a combination of the probability of an event such as the probability of a flood and the consequence of that event; that is to say the consequence of a flood in your area. Risk perception is the way in which a stakeholder views the risk, based on the set of values or concerns.

So, it depends on the stakeholders needs, issues and knowledge. It is the way in which a stakeholder views a risk, based on a set of values or concerns. Now, for a single risk; the level of perception might be different in different stakeholders. Because there are people who might not perceive the risk at all because there could be people who just do not think that there could ever be a flood in their area. There are a number of people who say that there is absolutely nothing like climate change that is happening.

These people are completely oblivious to the occurrence of the risk. On the other hand, if somebody is more knowledgeable; then they would have a very different perception of risk; they would not think that this risk of a flood coming to the area is because of a previous karma.

But they would think that this is because of, say bad management of the water resources in the area. So, the perception of risk varies with different stakeholders and it is the view or the way in which the stakeholder perceives the risk, based on a set of values or concerns. A person who has a lot to lose in a disaster would have a very different concern from say a bystander. So, a person who is living in India will probably have a very different view of say drought in Australia than an Australian; who is living in Australia.

Which is why the perception of risk varies between different stakeholders. Then, we have risk management; so if there is risk; it has to be managed. Risk management is the coordinated activities to direct and control an organization with regard to risk. So, it is a set of coordinated activities; so it is not a one of solution it is a set of coordinated activities that all aim to direct and control an organization with regard to the risk. So, in the case of risk management; we will talk about how we quantify the risk.

And what are the kinds of steps we should be taking to minimize the risk and should the disaster occur, what are the kinds of preparedness that we would make so that the amount of risk is minimized. Next we have the risk management system which is the set of elements of an organization's management system that is concerned with managing the risk. So, for instance if there is a disaster or there is a probability of a disaster; who is going to respond? Do we have a set of people who are trained in this response?

This is known as the risk management system; the set of elements of an organization's management system that are concerned with managing the risk. Then, we have risk source: the element which alone or in combination has the potential to give rise to others; an element which alone or in combination has the potential to give rise; to a risk. For instance, if there is a dam; that is made in an area that has been suffering from earthquakes.

So, this dam is now a source of risk because the dam would hold a very great volume of water which will have a very large amount of mass. Now this amount of mass will exert a downward force on the tectonic plates that are there in that area. Now, because of that the earthquake probability might go up or suppose an earthquake occurs.

And if the dam fails, in that case a huge area will get inundated; it will be flooded. So, this dam is now a source of risk in that area both because it can increase the occurrence of earthquakes and also because should an earthquake occur; it would lead to very great amounts of damage. This is a risk source, an element which alone or in combination has the potential to give rise to a risk. An event is defined as the occurrence or change of a particular set of circumstances, even if the occurrence of a circumstance or changes in a particular set of circumstances and consequence is the outcome of an event that affects the objectives. So, you can have an event of flood in which case there is a flood and the consequence could be things like loss of life or damage to property or damage to the agriculture of the area. So, it is impacting the normal management which is why it becomes a consequence; it is the outcome of the flood, so it is the outcome of an event.

Then, we have likelihood; likelihood is the chance of something happening. If you live in an area where you have a river, then there is a likelihood that there could be a flood. If you live in an area that is very dry and perhaps it rains say just a few millimeters in a year, then probably the likelihood of having a flood is much less.

So, likelihood is the chance or the probability of something happening; control is a measure that maintains or modifies the risk. When we have a risk and we try to control the risk, it is a measure that maintains or modifies the risk and in a number of cases it tries to reduce the risk.

A stakeholder is a person or organization that can affect, be affected by or perceive themselves to be affected by a decision or an activity. Stakeholder is a person or an organization; so you can have a person or you can have an organization and their role is; they can affect a decision.

They can be affected by a decision or they perceive themselves to be affected by a decision or by an activity. If the government is deciding to build a dam in your area; then the government is one of the stakeholders because they are doing something. If you live in that area and you can get affected by this dam; then you are also a stakeholder.

And if there is say an organization that caters to the well being of wild animals in your area; so and they think that because of this dam the wild animals will have a negative consequence, they will suffer a negative consequence and they perceive that they, that their activities will also get affected because of the construction of this dam, then all of these are stakeholders. If there are people who can tell the government that this should be the height of the dam or this should be the structure of the dam.

Then they are also the stakeholders. The experts are also the stakeholders, the media is a stakeholder. So, stakeholder is all those persons or organizations that can affect a decision or activity, that can be affected by a decision or activity or who perceive themselves to be affected by a decision or activity; they are all the stakeholders.

How do we manage risk? What are the principles of risk management? Well, the first principle is that risk management is integrated; it is an integral part of all organizational activities. It is not a

one of solution, it has to be there whenever you are doing any activity in your organization. So, whenever we are building a dam; we have to think about the kinds of risks that it might pose and we have to incorporate all these risks and the management of those risks in the construction of the dam.

Risk management always has to be integrated; it has to be structured and comprehensive. A structured and comprehensive approach to risk management contributes to consistent and comparable results. It is not that when you make one dam, you will have a different set of results; when you make another dam, you will have a very different approach to making this dam. It has to be structured; it has to be comprehensive so that it can be applied to different circumstances.

But at the same time you also need certain customized solutions. The risk management framework and process are customized and proportionate to the organization's external and internal context related to its objectives. So, risk management also has to be customized, it has to be inclusive, appropriate and timely involvement of stakeholders enables their knowledge, views and perceptions to be considered. This results in an improved awareness and informed risk management.

Whenever we are taking a decision; it is always prudent to include all the stakeholders. Whenever the government gives permission for a dam to be made, then before the construction ever begins; people have to go out and talk to all the different stakeholders that are there.

What are their perceptions, what are their fears and all those perceptions and fears, views; they have to be incorporated in the project document. So, risk management has to be inclusive; you cannot take decisions on behalf of others, you have to include them whenever you are making a decision.

Risk management is dynamic because the risk can emerge, change or disappear as an organization's external and internal context changes. So, risk management anticipates, detects, acknowledges and responds to those changes and events in an appropriate and timely manner.

What we are saying here is that the risks may change with time. When for instance, you set up an industry and the whole of its surroundings is a barren land; then the sort of risk is very different than at a later point of time, when suppose the town has extended itself, the town has expanded and it is now right on your doorstep.

Because in the earlier situation, when it was a barren land and people were not living there; in those circumstances, there was hardly any risk of loss of life or property should any industrial accident occur. But when the town has expanded and has come to you; then the risk would be very different because if any industrial accident occurs.

Then there will be a huge loss of life and property. Now, in this case the organization that is the industry is not doing anything to change the risk, but the external conditions have changed to such a level that the risk has changed. In certain other conditions, it may be a result of the organization's internal dynamics that the risk changes.

For instance, if there is an industry and currently it has all new equipment; everything is computerized, everything is working properly, but then because of bad management over time; it is possible that the equipment now does not work in that way. Now, in such a scenario; you even though the outside environment remains the same, because the equipment is now failing; so that

would increase the amount of risk that an accident could happen because of which the risk management needs to be dynamic.

So, it has to change; if the equipment becomes old, you will have to make changes to your risk management strategy. If the town expands and comes to your backdoor, you will have to make changes to the risk management strategy. Then risk management should always incorporate the best available information.

The inputs to risk management are based on historical and current information, as well as on future expectations. When you are setting up the industry; you should know if any similar industry elsewhere in the world has resulted in any industrial accidents. If so, what kinds of accidents, how many people were involved, what was the response of management and was the disaster contained in a set period of time or not? So, you have to look at the historical context.

You have to look at the present quantities which is the best available way of mitigating the risk that the industry can propose to the surroundings. We also have to incorporate the information about the future set of events. How fast is the town expanding, how soon will people be able to reach into this area, is there any other industrial facility that is supposed to be set up nearby? Because they will all change the total amount of risk that the industrial setup is posing to the surroundings.

It has to be based on the best available information. Risk management explicitly takes into account any limitations and uncertainties associated with such information and expectations. Information should be timely, clear and available to relevant stakeholders. So, when we say that it explicitly takes into account any limitations and uncertainties associated with such information; what are we saying? Is that if you do not know how fast the town is going to expand.

Or how soon are people going to come near your industry? Then, you have to acknowledge this risk and work on a precautionary principle approach which means that if there is say a 10 percent probability; that people would have reached to your industry, then the precautionary approach would say that let us assume that this 10 percentage or probabilities going to happen and let us make all the arrangements. So, if there is a limitation or uncertainty that is associated with this information.

Because risk management is based on the best available information; you have to incorporate any limitations that you are facing. Risk management is based on human and cultural factors. Human behaviour and culture significantly influence all aspects of risk management at each level and stage which means that in certain societies.

There people might be more risk averse, in certain societies people may be less risk averse. Now, whenever you are making any decision; you have to incorporate what is the level of risk aversion of the surroundings, of the people in the surroundings, what are the other risks that these people are already facing, and what are the cultural aspects?

All of these have also to be incorporated into risk management. And risk management is based on continual improvement through learning and experience which means that if there is say a new study about how a risk should be managed and if it is applicable; then probably it should be implemented in the current scenario.

So, it has to be continuously improved; it is not that once you have made a risk management doc-

ument and once you have implemented it, then there are going to be no further changes; there has to be a continuous process of improvement in the risk management strategies in any organization.

The process of risk management comprises communication and consultation, monitoring and review and establishing the context, risk assessment and risk treatment. What happens in the case of a good risk management strategy is that we begin by things such as communication with the stakeholders, consultation with the stakeholders and getting to know everything that can be known about this particular risk. Then, we establish the context.

What is the site of the place where the industry is going to be set up, what is the setting of this area? In this context, what is the assessment of the risk, what is the possibility that things may go wrong and what is the possibility that we will have certain consequences because of something going wrong; so that is risk assessment.

It includes identification of the risk, analysis of the risk and evaluation of the risk. And then we make a strategy for risk treatment; how are we going to reduce this risk? And in all these processes; there is a continuous communication and consultation with the stakeholders.

Because remember we cannot take decisions on behalf of others, we have to incorporate every stakeholder in all the steps of risk assessment and risk management. There is a continuous process of communication and consultation and in all these processes; there is also a continuous monitoring and review.

When we talked about risk identification; did the person who was doing the risk identification; did he or she include all different kinds of risks that he or she should have looked at or perhaps they missed out on certain risks. Now, who is going to tell this; if there was no monitoring and review mechanism.

A monitoring and review mechanism is there during the risk; identification stage, it is there during the risk assessment stage because it is possible that the person who is doing the risk assessment probably comes up with a very low assessment. It has to be there when the risk management strategy is being implemented.

Because they could be lacunas in the implementation of the risk management strategy. In all these steps; there is a continuous monitoring and review. Now, this is a theoretical framework on which risk management works and this is how it should be managed, but then this is not always how things are managed in practice.

Now let us have a look at what happens if the risk is not properly managed. What are the kinds of reasons because of which a risk is not managed properly and what are the consequences?

We will have a look at certain case studies; the first one is the Minamata disease. Now, the Minamata disease originates from a village that is known as Minamata in Japan and this village was traditionally a fishing village. It was full of fishermen whose main source of livelihood was fishing in the nearby sea.

In 1932, a local industry by the name of Chisso factory; it begins the production of acetaldehyde and it uses a compound of mercury as a catalyst for the reaction. Now, once the reaction is done; what happens to the spent mercury, the spent catalyst; it is now of no use to the industry. Now, the industry could have done 2 things; one process this catalyst because whenever you are throw-

ing something out as a waste, it might have a negative consequence on the environment.

The industry could for instance have spent money on the processing of this spent catalyst that was having mercury inside it. But it did not do that; what it did was it just dumped the spent catalyst into the sea. Now, here again it is important to note the importance of externalities.

If the industry had spent resources on the processing of the spent catalyst; then it would have reduced the contamination of the surroundings, but it would have cost the industry; whereas, if the industry just threw it out into the environment, then the industry could increase its profits.

It is in the short run when it does not have to pay for damages and the damage is felt by the people who are there in the surroundings. It is not experienced by people in the Chisso factory, but by people in the surroundings in whose area they are throwing this waste. So, the spent mercury catalyst is dumped into the sea.

Now, by 1950; so it is now 20 years or roughly 20 years to the time when they start dumping off the catalyst; the spent mercury catalyst. Now, by the 1950s it is known that in a number of locations, fish are found floating in the water. So, these triangles; these white colored triangles are all those locations in the surrounding where fish are dead and they start to come to the surface, they start to float on the surface. Now, this is a disease that nobody had seen before; another thing that happens is that the cats in the area.

So, this is the water body and all over the water bodies; we are finding that the fish are dying. Inland, what we are finding is that at all these locations we are finding strange symptoms in the cats. Symptoms such as this; by 1952, people are starting to report that the cats are committing suicide.

The cats have a large number of neurological deficiencies; a large number of neurological diseases. So, they go on repeating an activity again and again and again and these cats are so highly depressed and they are so diseased because of these neurological symptoms that at times they jump from a cliff or they die off.

So, there are a number of instances of cats committing suicide in this area. So, this is when people actually started to look at this particular phenomenon. What is so special about Minamata is that the cats have started to commit suicides. What is suspicious is that the fish are dying and floating on top of the water.

Then in a short time, we start observing symptoms in the human sense value. So, the humans also start to show very similar symptoms. So, their hands, their body parts are now showing symptoms such that their joints are getting affected; they are showing repeated movements and the number of the human victims is increasing.

And by the year 1959, the scientists and the doctors have discovered that mercury is one of the reasons. What are the kinds of symptoms that we observe in humans? Disturbance of sensation, superficial sensation and deep sensation; the people are not able to sense properly, showing that there is damage to the nerves.

There is a constriction of the visual field in 100 percent of the people that is they are not able to see properly. There is dysarthria; arthrosis joint, dysarthria is a deformation in the joints such as what we have seen here. So, there is this dysarthria in a large number of patients; there are disturbances of coordination; people are not able to walk properly, people are not able to do any activ-

ity properly. We have things like impairment of hearing, tremors, changes in salivation, mental disturbances.

These different kinds of symptoms are noted; it is observed that a number of these symptoms arise because of neurological problems and it is known now that mercury is one of the reasons or the primary reasons. We will start observing damages in the brain. If there is a postmortem, people would find that the brains are having holes and importantly cat number 400 dies; what is cat number 400? One of the scientists; what he did was he took cats and he started feeding them with the residue that was being thrown by the company into the sea water.

Once he started feeding the cat; he was able to develop all these symptoms very quickly in the cat and so it was proven that it is because of this waste material that is being dumped that we are seeing all these different kinds of neurological symptoms. And in 1959, this cat died because of all these neurological symptoms.

Then in 1959, demonstrations began against the company and what the company does now is that they install equipment that supposedly treats the waste. But, here again what the company did was that they did not actually install a machine that could process the waste efficiently.

It was more of an eye wash because there were demonstrations; so, the company said ok we have to do something. So, they did something, but that was the; that was not the most efficient thing. So, the company still carried on dumping the waste into the sea even after knowing from one of its scientists that this waste was causing the neurological symptoms in the animals, in the fishes, and in the humans in this area. And because the company did hardly anything to stop these wastes; ultimately in 1975.

This whole area had to be dressed which means that all the sediments in the sea had to be excavated, processed and thrown to some other location so that the level of contamination goes down. Now, just think of the amount of money that a company would have to spend to process its waste.

Well, when the company is throwing the waste; the waste is in a very concentrated form and it is easy to treat. Once we have dumped the waste into the sea; it has spread to such a large extent over such a large area that now you have to dredge the whole of the sea in that; in the surrounding areas; so the cost goes up like anything.

Then, if you look at the environmental damage that the company did; a payment of 12.63 billion yen per year; now billions of yen per year are projected for health damage compensation, sludge treatment and damages to the fishery. And if we look at the human cost.

By the year 2005, total number of officially certified patients around 3000, recipients of the medical task of the comprehensive measure of Minamata disease; since 1992, around 13000, patients manifesting health effects of methyl mercury that were recognized by the ruling of the supreme court in 2004; 58 and applicants for certification before the judgment greater than 3300. So, what we are observing here is a huge cost. In terms of human health, human life, animal health and environmental damage.

And all of these walls were preventable had the company just treated the waste before throwing it out into the sea. So, this is what happens, when risks are not properly managed. The kinds of tragedies that we can observe, when people just contaminate the environment because it is just an

externality, just a cost cutting measure.

Another example is the Aral sea. Now, this is an image from 1974; that is telling us how big this Aral sea was. It was formerly the fourth largest lake in the world with an area of 68000 square kilometers. In the 1960s, the Soviet government decided to divert waters of Syr Darya and Amu Darya, these are 2 rivers that were providing water to the Aral sea. And the soviet government decided that the water of these rivers can better be used for agriculture.

In the 1960s; the Soviet government decided to divert the waters of Syr Darya and Amu Darya into the desert to enable cotton production. So, the water that is getting into the lakes is now diverted. A large system of canals was created; due to lack of water flowing into the Aral Sea, it started to shrink.

The lake earlier was in a dynamic equilibrium; the amount of water that it was losing out because of evaporation was roughly equal to the amount of water that was flowing inside. So, it was losing out as much water because of evaporation say because of some amount of seepage into the soil and so on.

But the amount was largely balanced by the amount of water that the rivers were bringing in. Now, if you stop the flow of these rivers and if you divert the water; then the input to the lake stops, but the output because of evaporation or because of seepage continues as it has. So, now, you are not letting water enter into the lake and so the size of the lake starts to shrink and the salinity increases from around 10 grams per liter to above 300 grams per litre; killing off most of the fish.

Now, we have observed in one of the earlier lectures that every organism has a range of tolerance for different components of its environment. Now, fishes also have a range of tolerance for salinity. When it becomes too saline the fishes are going to die off because it is now no longer fresh water, it has now become very salty water.

The salinity increased from 10 grams per liter to above 300 grams per liter killing most fish. Pesticides and fertilizers from the cotton fields reached the Aral Sea; increasing pollution and killing off most of its natural life. Not only was the salinity increasing, but at the same time; the pesticides and the fertilizers were also reaching into the sea and that was also causing a lot of contamination to the sea. Then cancer rates, infant mortality and diseases in humans have gone up.

Now, because the humans that are living in the surrounding of the Aral sea; now remember that the Aral sea was one of the largest lakes and it was a very beautiful tourist location. There were a number of resorts, there were a number of people who were fishing in the Aral sea. Now, when the Aral sea starts to shrink and when it becomes more and more contaminated; then the surrounding water, the fresh water that people are using also starts to get more and more contaminated.

Because all those pesticides and fertilizers that are getting drained into the sea; they will also be into the groundwater level and so we start to observe that the humans in the surrounding that were a very substantial population; we start observing a number of health problems in those women as well. The rates of abortions go up, diseases go up, cancer rates go up, infant mortality goes up. All these different kinds of diseases and symptoms are now increasing in this area.

Dust storms and salt deposition impacts the local communities who have already lost employ-

ment. Now, when the sea starts to shrink; then more and more land becomes exposed and whenever there is any storm; then all of this all the dust of this land would get airborne and it would spread.

Similarly, this lake has now become very saline and so the shores where the salt is getting deposited; that salt will also become airborne whenever there is a storm and it will get into the houses, it will get into the equipment of the people who are living in the locality.

On the one hand the tourism industry is gone because it no longer is a pristine water area, the fishery industry is gone because all the fishes have died, the level of diseases have gone up because the water is contaminated. Then, we start observing environmental damages because of this contaminated water and highly saline water and exposure of the soil through the winds. So, we start observing dust storms in the area and we also start to observe climatic changes.

Since the moderating effect of the water body has been lost. So, near any water body; we have moderate temperatures, it does not become very hot in the summers; it does not become very cold in the winters because of the moderating impact of the water body now that the water body is gone.

We also start to observe a much changed climate with more and more extremes. So, if you look at the hydrology of this area; the annual water balance changes like this. 1911 to 1960 that is before the expansion of agriculture and before the diversion, the blue is showing us the river inflow, the yellow is showing us the net evaporation. So, roughly the river inflow is equal to the net evaporation. The area is also getting certain water from ground and there is a small surplus that we observe.

The surplus is very close to 0; so roughly the Aral sea is being maintained in the same size, but now after 1961, the inflow has gone down. So, the inflow from here becomes this, but the level of evaporation; it roughly remains the same. Why? Because of dimming of the river you are reducing the inflow, but because the lake is still of roughly the same size; so the evaporation is roughly the same. But then from this point onwards, we start to observe a change in the net evaporation as well.

What we are observing here is that over the years from the 1970s to 2005. What we are observing is that the level of evaporation is also going down which is telling us that the size of the lake is also going down and at the same time; the river inflow has also reduced substantially.

And so, earlier while we were having a net surplus through a small surplus, but a net surplus of water that was entering into the lake. Now we are starting to observe a huge deficit. So, in the 1980s and 90s, there was a deficit as large as 30 cubic kilometers per year which means that in 1 year. The amount of water that is being lost from the sea is 30 kilometers multiplied by 1 kilometer in height and 1 kilometer in width. So, that is the amount of water that the Aral sea is using every year and what does that loss look like?

This is the image that we saw in 1974; by the 1980s; so this is the image from 1984 and we can observe that, this was 74, this is 84; it has already shrunk by a large amount. But then, over the years; it goes on shrinking even further, this is the year 2000, this is 2008. So, all these areas that were earlier the Aral sea are now gone; this is 2016.

Something that was as big as this in 1974 is now as small as this. So, when people were begin-

ning to divert the waters of the Syr Darya and the Amu Darya river for agriculture, especially cotton cultivation; they did not foresee the kinds of impacts it would have on the nearby Aral sea. Because had they known that it is going to cause this greater damage to the Aral sea probably they would not have done this. Even though the cotton cultivation went up; for it for the time being, after a while it again went down and in that time period the tourism industry was gone, the fishing industry was gone.

The local people, quite a lot of them have migrated out. The people who remain are diseased and they are suffering from the vagaries of nature because of extreme climatic events and also because of a huge amount of salt and dust that is getting into their houses and into their equipment. This is what happens when risks are not managed properly and this all happened because people were looking at the short term benefits and not the long term environmental damages.

The third case study we will look at is the Bhopal gas tragedy in our country. So, the Bhopal gas tragedy begins with the plant of Union Carbide; so Union Carbide; an American corporation, had an Indian subsidiary and they set up a pesticide plant in the city of Bhopal.

And it was hailed as one of the shining examples of the new India because in the; in the newer India, in the modern India more and more amounts of pesticides would be used in the case of agriculture so that we have bumper harvest. Now, the area that was chosen for this company; it was very close to the city limits and in a very short period of time, the population had or the city had grown to such an extent that people were living right next door to an industry.

This is an industry that is dealing with toxic materials because it is making pesticides. Now, what happens if these toxic materials ever get out? It will observe a large size mortality. So, this is a risk that should have been perceived at that point of time, but sadly it was not. So, it began with this shining example of new India; so this is the Union Carbide factory. And these are the kinds of advertisements that the Union Carbide was putting in.

If we have a look at the location of the factory. So, this is the upper lake of Bhopal and this is the location of the Union Carbide plant. As you can observe, all this area is the area where people live; here you have small bits of forest and agricultural lands, but this is where people live.

It is said that when the plant was set up; the human population nearby was not at large, but then when the plant was set up it provided employment opportunities; so a number of slums were set up near the plant. As we saw, risk management changes with time.

And on the night of December 2 and 3, 1984; the methyl isocyanate gas was released from this plant, it led to a large number of deaths and blinding of people. It was heavily documented because it was the worst industrial disaster in the history of humankind; 2500 people would die, it would injure thousands.

And we find documentation in all major media. So, this is the BBC, this is The Hindustan Times; on that particular day, the death toll was 1200 and it was rising; this is The Indian Express. So, this is something that has been very well documented and very well studied and the impacts of the release of methyl isocyanate on that night, they still continued. People are still disabled, people are still sick; now the basic question is, why did we have such a tragedy?

The Union Carbide happened to be a very established name, a very respected name. So, how was it possible that we just could not foresee the risk and we could not manage the risk, how was that

possible even? So, after this documentation; there were a number of studies. What went wrong? And we are interested in knowing what went wrong economically; well the insecticide named Sevin that they were manufacturing was not selling as expected. Only around 20 percent of the plant capacity was being used. So, everything begins from an economic point of view; the cause of this disaster was that the insecticide was not being sold at that large a quantity at that larger volume that the industry was expecting. So, only 20 percent of the plant's resources were being utilized.

When that happens; the cost that the company had put up in setting up of the plant that was not getting recuperated fast enough. Well it was still showing a profit mind you, but it was not showing profit to that large in extent or that fast that the company had expected to see.

Now, when only 20 percent of the plant capacity is being used; the plant was shut down for maintenance. And because it was only 20 percent of the plant capacity being used, they also did a large number of cost cuttings to maintain the profit of the company; cost cutting such as the excess methyl isocyanate gas.

Now, methyl isocyanate was the gas that got released on that particular day. Now, this is such a toxic gas that it is never stored in the company. Generally, the standard procedure is that when you make the methyl isocyanate gas; you make it in very small quantities and then you use that quantity so that you do not have to store it in any large quantity.

But because the company was going through a cost cutting measure, what they did was that methyl isocyanate was made in larger batches and it was stored because they wanted to increase the profits, they wanted to reduce the cost; so what was done was that the MIC was manufactured in larger quantities and it was stored. So, why run the equipment again and again? Then, not only was it stored in the tanks; it was stored above the requisite capacity.

So, the tank from which the gas was leaked, it was 75 percent full when safety procedures required that half of it should be kept empty to serve as buffer for heat; that is when the when this gas has been stored in a tank, then it is being stored above the capacity because again why run the equipment again and again to manufacture the gas.

They were trying to maximize the storage of the tank of the gas, but when it was being stored; the refrigeration unit was also shut down which raised the temperature. Now, MIC had to be stored below 0 degrees Celsius and the; what we are observing here is that the refrigeration unit was shut down. Why was it shut down? Well, why waste electricity? It is all profits. So, to maximize profit, the refrigeration unit was also shut down.

Then, impurities were getting in because of lack of maintenance and leaky walls. So, if there was a leaky wall; then the company officials did not bother to get it changed. Why? Again, cost cutting; maximization of profit, if there is something that is not working; why spend money on fixing it?

So, impurities including water were known to cause runaway exothermic reactions and this is actually what had happened on that day. Sensors were either not installed or did not work; why? Cost cutting. There was a lack of computerization; why? Because if there is a plant that is only working at 20 percent of its capacity; why spend money to modernize the plant; so, no computerization here.

The gas scrubber that used caustic soda was shut down. Now, why do we need a gas scrubber? Because if there is any gas that gets leaked from the industry, then it should be neutralized; so there are different ways of neutralizing a gas. One is that you treat it with certain chemicals such as caustic soda, second is that you can burn the gas, third is that you can make it pass through certain other chemicals that will absorb the gas but in this case, the gas scrubber or shut down; why?

Well again to maximize profits, to bring the cost down. The decontamination towers and the flares were shut down. Now, these flares are something where there is a big tower on top of which a flame is always burning so that if any amount of gas gets leaked, then that gas will get burnt in that flame. But, then these flare towers were also down; why? Because, why waste money in lighting up a flare tower? Water spray to reduce the temperature and neutralize the gas did not reach far enough of the stack.

So, we are observing a large number of deficiencies; then we talked about keeping the stakeholders in the loop. Now, in this case there was a lack of emergency plans and training, the locals were not apprised and drilled about safety procedures when sirens sounded and the locals just thought; it was a shift change.

Now, when you are manufacturing something that is as toxic as MIC, the locals or the stakeholders; they should have been kept in the loop. And a good way of keeping these people in the loop is through regular communication. Now, if you will remember when we talked about risk management; we were talking about communication at all different points of time. So, in this case what we can observe is that there was hardly any communication with the locals.

There were hardly any drills on what to do if this gas gets leaked? What are the kinds of emergency precautions that we should be taking? There was no such training, there was no such planning and there were. So, many accidents occur regularly in the plant due to the faulty maintenance that sirens were sounded regularly reducing their impact.

So, what was happening was that because of these leaky walls because of equipment that was not being maintained properly; there were so many accidents regularly that now people had gotten accustomed to the siren blaring. So, they just thought that ok it is a routine affair, there is nothing to be worried about. Safety equipment such as gas masks, oxygen cylinders etcetera were lacking; again why waste money in buying these safety equipment in a plant that is not running to the full capacity.

Technical workers were laid off; again this is a cost cutting measure, why use technical workers whom you have to pay more when you are not earning that much amount of profit. So, the technical workers were laid off and in their place; non technical staff was handling the equipment. Now, these non technical staff would hardly know what to do in such a dire situation.

And no citizen watch group was groomed and none existed; again when we talk about stakeholders, this was the level of stakeholder participation. So, when there was the release of this gas - now, this release happened because in one of the tanks water got in because one of the walls was leaky and when the water gets in; there is an exothermic reaction. The tank is already above the stipulated level of capacity and it is kept much warmer than is desired.

It had to be kept refrigerated at 0 degrees so that if even water entered into it; then the then the

whole reaction would be cooled down, which is why you need to always keep the refrigerator on in this case, but the refrigerator was off; so there was no cooling that was happening.

So, there was an exothermic reaction; the pressures increased, and the tank failed. So, when the tank fails; the gas gets out, when it gets out; it could have been neutralized by the chemical scrubbers or it could have been neutralized by the flares in the flare tower; they were not working.

The sirens were not working, there were no sensors. So, people did not know about such a mishap that was happening. If the sensors were installed, especially things like temperature sensors, then we would have known much before that there was some exothermic reaction happening, but then there were no sensors.

There was no computerization and this gas when it was getting released out, then we did not have the equipment to even pour water then bring its temperature down or at least dissolve some of the gas before it gets away from leaking out. And when it gets out into the surroundings; the locals just do not know about it because the sirens are blaring every day because of the regular accidents and so everybody thinks that it is a normal affair.

And then when they are actually exposed to the gas; they do not know what to do. Now a very simple way to have to prevent the deaths would have been just to take a piece of cloth and dip it in water and place it on top of your mouth so that the amount of gas that you are getting exposed to it; gets diluted it, gets dissolved in the water and so you are exposed to less of the gas, but the locals did not even know that. So, what happened was when they got exposed to the gas.

There was such a huge choking sensation there was so much burning of the eyes that people actually tried to run away from the location. And when you try to run away; what happens is, you get outside of your home and you get exposed to even greater concentration of the gas.

Because it is not that you are getting gas inside your house, your house is much safer; outside the concentrations are much harder and all of these things can be linked down to bad management, bad planning and bad economics. So, around 500000 people; that is 500000 of people; they got exposed to the MIC class.

And we can end with this quote; the morality that pollution is criminal only after legal conviction is the morality that causes pollution. It means that the morality that pollution or spreading pollution itself is not wrong, you are only wrong when the court punishes you; that is the morality that permits the society to tolerate pollution.

To tolerate damage to the environment, to tolerate not taking proper risk management procedures and we as a society will have to suffer the consequences, if we let this morality prevail. If we do not teach ourselves and our children and our grandchildren that pollution is wrong in any way. If you do not do that only we have to suffer the consequences.

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

Conservation Economics
Dr. Ankur Awadhiya, IFS
Indian Forest Service
Department of Biotechnology and Bioengineering
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 drums 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 remem-

ber 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 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 sheep 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!

**THIS BOOK
IS NOT FOR
SALE**
NOR COMMERCIAL USE



 (044) 2257 5905/08
 nptel.ac.in
 swayam.gov.in